

Metrical Structure and Licensing: An Argument from Ukrainian

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It has been debated in phonological literature whether word stress should be modeled using metrical grids or feet and how its directionality is assigned. In this article, we discuss new data from Ukrainian, which has a hybrid metrical system with unpredictable lexical stress and grammatical iterative secondary stress. We demonstrate that Ukrainian poses a challenge for current metrical theories relying on gradient alignment and propose an analysis based on categorical alignment coupled with a rhythmic licensing constraint mandating that lapses are located near the main stress (LAPSE-AT-PEAK). We argue that LAPSE-AT-PEAK is required regardless of the stress representations (feet or grids) assumed.

Keywords: grammatical stress, lexical stress, bidirectional stress systems, metrical theory, Ukrainian

1 Introduction

This article discusses the mixed lexical-grammatical metrical system of Ukrainian, whose complexity poses an analytical challenge to current metrical theories. Two central issues are raised by interactions between free lexical stress and grammatically assigned rhythmic stresses in Ukrainian:

- The directionality of stress assignment, given that rhythmic stresses are attracted concurrently by the left and the right edge of the word
- Formal representation of stress, given that the system has no default trochaic or iambic foot parsing

According to standard descriptions as well as recent acoustic studies (Nakonečnyj 1969, Łukaszewicz and Mołczanow 2018a,b), Ukrainian represents a complex bidirectional stress system with internal lapses, with secondary stresses iterating from the edges of the word toward the syllable carrying lexical stress: for example, *muńiçypali'tet* 'municipality', *'lahodytymeže* 'repair, 2PL'. In bidirectional stress systems reported in the literature, primary stress is typically assigned at (or near) one edge of the word, and secondary stresses iterate from the opposite end toward the syllable carrying primary stress (e.g., Kager 2001, 2005, Gordon 2002, Hyde 2002, Hermans 2011). Classic examples of such systems are Piro (Matteson 1965) and Polish (Rubach

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and Booij 1985, Kraska-Szlenk 2003, Łukaszewicz 2015, 2018, Łukaszewicz, Zajbt, and Krawczyk 2018, Łukaszewicz, Zajbt, and Mołczanow 2020), exhibiting a rightward iteration of secondary stresses, and Garawa (Furby 1974), which has a leftward stress iteration pattern. Characteristically, odd-parity words in these languages have lapses (i.e., sequences of unstressed syllables) adjacent to the peak, as schematized in (1).

- (1) a. Rightward iteration of secondary stresses (Piro): ,σ σ ,σ σ σ 'σ σ
 b. Leftward iteration of secondary stresses (Garawa): 'σ σ σ ,σ σ ,σ σ

Unlike bidirectional stress systems described previously in the literature, Ukrainian has free lexical stress and exhibits both the rightward and leftward iteration of secondary stress. The location of secondary stress depends on the position of lexical stress and the number of syllables separating lexical stress from the edges of the word, which we discuss in more detail in section 2. The iterative and bidirectional character of secondary stress can be inferred from examples in which lexical stress is separated by at least five syllables from the left or right edge of the word, as illustrated in (2a) and (2b). σ_n is a shorthand for zero or more (maximally four) syllables (see also footnotes 1 and 2).

- (2) a. Rightward iteration: ,σ σ ,σ σ σ 'σ (σ_n)
 ,ame,rykani'zovanyj 'Americanized'
 b. Leftward iteration: (σ_n) 'σ σ σ ,σ σ ,σ
 'vyliku,vaty,sja 'heal, REFL'

The basic generalization is that secondary stresses in Ukrainian are “repelled” from the syllable carrying primary stress toward the word’s edges, as in the bidirectional systems in (1). Hence, the lapse is predicted to occur in the vicinity of primary stress and not between secondary stresses (e.g., [$\sigma\sigma,\sigma\sigma\sigma'\sigma(\sigma_n)$], not * $[\sigma\sigma\sigma,\sigma\sigma'\sigma(\sigma_n)]$). It is important to note that the hitherto described bidirectional systems have predictable main stress and *either* a rightward *or* a leftward stress iteration pattern. The point of interest of the Ukrainian data, which as yet has not been discussed in the generative literature, consists in the presence of unpredictable lexical stress that coexists with different patterns of grammatical stress.

Although practically all contemporary metrical theories provide tools for describing bidirectional stress systems with internal lapses—rooted in grid-based, foot-based, or parameter-based mechanisms (e.g., Rubach and Booij 1985, McCarthy and Prince 1993, van der Hulst 1996, 2012, 2014, Kager 2001, 2005, Gordon 2002, Hyde 2002, 2016, Alber 2005)—the coexistence of the two opposite-edge-based secondary stress patterns within a single system poses a challenge for most of the hitherto proposed accounts. Most of these accounts are couched in the constraint-based framework of Optimality Theory (OT), regulating the positioning of stress in terms of alignment constraints, which require that the designated edge (left or right) of some prosodic domain coincide with the corresponding edge of some other prosodic or morphological domain (McCarthy and Prince 1993). Alignment constraints have been formulated as either gradient (McCarthy and Prince 1993, Alber 2005) or categorical (Kager 2001, 2005) constraints. As gradient constraints, they can be multiply violated, depending on the distance (the number of syllable units) from the designated edge. As categorical constraints, they can cause only single violations,

as they operate on strictly local factors, such as immediate adjacency to the domain edge or peak. In crosslinguistic studies of metrical systems, the alignment mechanisms have proved notoriously insufficient to generate the asymmetries in the existing patterns and are supplemented by licensing, which admits rhythmically marked entities (lapses) in a limited set of prosodic positions (the peak and the right edge of the prosodic domain); see Kager 2001, 2005. This article demonstrates that the Ukrainian pattern is problematic from the point of view of OT accounts of rhythmic stress appealing to gradient alignment (McCarthy and Prince 1993, Alber 2005). Instead, we suggest an analysis that is based on categorical alignment, which is coupled with a rhythmic licensing constraint mandating that lapses are located near the main stress.

The Ukrainian system, which is weight-insensitive and does not have default trochaic or iambic foot parsing, also raises a number of issues concerning the formal representation of stress. Beginning with the seminal work of Liberman and Prince (1977), generative metrical phonology has assumed grid-based representations, with grids reflecting relative syllabic prominence, as in (3). Rather than referring to grids alone (3a), most models of metrical structure have also assumed metrical footing (e.g., Liberman and Prince 1977, Hayes 1980, 1995, Halle and Vergnaud 1987), grouping syllables into a hierarchy of headed binary constituents and aligning the heads of feet with prominence marks on the grid (3b).

(3) a. Grids only:	x .	Primary stress	line 2
	x . x .	Secondary stress	line 1
	$\sigma \sigma \sigma \sigma$		line 0
b. Grids <i>cum</i> feet:	(x .)	Primary stress	line 2
	(x .) (x .)	Secondary stress	line 1
	$\sigma \sigma \sigma \sigma$		line 0

The two aspects of metrical structure are largely redundant with respect to each other. Nevertheless, in most theoretical analyses of stress patterns, both feet and grids are used simultaneously as they are acknowledged to play a complementary role in accounting for various stress-related phenomena (e.g., Hayes 1995). While feet are mostly irrelevant from the point of view of stress distribution alone (see Hermans 2011), it has been argued that from the point of view of application of certain phonological processes, unstressed syllables embedded within feet are not structurally the same as unstressed syllables outside of foot structure. For example, vowel reduction in Dutch is more likely to occur in the weak syllable of a foot than in the weak syllable that remains unparsed (Booij 1995:133–134). Also, reference to foot structure remarkably clarifies and simplifies the description of certain otherwise complex and vague patterns; for example, the process of High Vowel Deletion in Old English (/hēafud+es/ – [hēafdes], /word+u/ – [word]) can be generalized to take place in the weak branch of the strong-weak Germanic foot (Dresher and Lahiri 1991: sec. 1). The structural differences captured straightforwardly in models assuming foot-sized constituents are left unexpressed in terms of grid-only models, which encode only the differences in degrees of stress. In the latter models, all unstressed syllables are structurally the same; for an insightful discussion of the role of feet *cum* grids and grid-only representations in generating grammatical stress systems, see Hermans 2011.

Although the evidence for foot structure is massively supported by crosslinguistic patterns, the role of feet seems to be much less pronounced in the case of Slavic metrical systems than in the case of other systems, for example, languages from the Germanic group. While foot-based representations have been commonly assumed in previous accounts of the grammatical stress in Polish (see, e.g., McCarthy and Prince 1993, Kraska-Szlenk 2003), some studies have argued that feet are superfluous (see Rubach and Booij 1985). Also, the role of the intermediary foot constituent has been called into question in some contemporary work on typologies of stress patterns, based on broad crosslinguistic considerations and not referring specifically to Polish or other Slavic languages. Gordon (2002) argues that certain notorious parsing asymmetries can be resolved if feet are abandoned and the grid is used as the sole mechanism in generating alternating stress patterns. This radical proposal that grid-only representations (1a) should be assumed is in line with some earlier research in the derivational (Prince 1983, Selkirk 1984, Rubach and Booij 1985) and constraint-based (Walker 1996) frameworks. In this article, we argue that models relying exclusively on foot structure cannot accommodate the Ukrainian data, and we demonstrate that the metrical grid allows for a straightforward account of the distribution of stress in Ukrainian.

The discussion proceeds as follows. In section 2, we provide descriptive facts concerning the metrical system of Ukrainian. In section 3, we discuss the implications that these data have for the contemporary metrical theory. We begin by considering approaches involving binary feet coupled with either gradient or categorical alignment (section 3.1). Next, we confront Ukrainian data with a model postulating internally layered ternary feet (section 3.2). In section 3.3, we discuss the grid-based approach utilizing gradient alignment, which also fails to account for the data, and in section 3.4, we suggest a licensing-based modification that can successfully account for the Ukrainian metrical pattern. In section 3.5, we discuss an alternative solution assuming moraic feet, and point to some undesirable consequences of this solution for the Ukrainian phonological system. Finally, in section 4 we present conclusions.

2 Ukrainian Stress: Descriptive Background

Ukrainian, together with Russian and Belarusian, belongs to the family of East Slavic languages. All three languages have weight-insensitive lexical stress, which can occur on any syllable of a word. The lexical nature of East Slavic stress is confirmed by the existence of minimal pairs, as illustrated in (4). Here and below, Ukrainian and Russian words are transliterated.

- (4) a. 'ruki 'hands, NOM PL' – ru'ki 'hand, GEN SG' (Russian)
 'ruky 'id.' – ru'ky 'id.' (Ukrainian)
 b. 'golovy 'heads, NOM PL' – golo'vy 'head, GEN SG' (Russian)
 'holovy 'id.' – holo'vy 'id.' (Ukrainian)

However, Ukrainian differs from Russian in that, in addition to lexical stress, it exhibits a secondary degree of prominence. So, while the Russian words *'golovy* and *golo'vy* shown above have only one prominent syllable, the corresponding Ukrainian words have secondary stress on the final and initial syllables, respectively: *holo'vy* and *'holo.vy*. The metrical pattern of Standard Russian is usually expressed by the formula 1-2-3-1 (3 standing for the strongest and 1 for the weakest syllable of the word), which is meant to reflect the fact that every word has a strong

“center,” consisting of a pretonic and a tonic syllable (2–3), and a weak “periphery,” comprising the remaining syllables (Kasatkina 1996). In contrast, Ukrainian rhythm is described, on the basis of impressionistic observations, by the formula 1-0.75-2-0.75-1.25 (see Toc’ka 2002:72), suggesting a wavelike pattern of alternating strong and weak syllables. Standard grammars of Ukrainian (e.g., Nakonečnyj 1969, Toc’ka 2002) explicitly state that secondary stresses are assigned at the word’s edges as well as on every other syllable, forming a predictable alternating pattern.

The existence of rhythmic prominence in Ukrainian has also been confirmed in a series of acoustic studies, which have demonstrated that rhythmic stress is cued by increased syllable duration (Łukaszewicz and Mołczanow 2018a,b,c). It is worthwhile pointing out that the phenomenon of rhythmic stress is not confined to one dialect or to a geographic region, because its presence has been reported both in the standard literary language (Nakonečnyj 1969), which is based on the southeastern dialectal group, and in the standard Ukrainian spoken in the west of the country (Łukaszewicz and Mołczanow 2018a,b,c).

Possible rhythmic configurations for words consisting of three to six syllables are shown in (5).¹ Illustrative data come from Nakonečnyj 1969 and Łukaszewicz and Mołczanow 2018a,b.

(5) a. *3-syllable words*

'σσ,σ	zoloto ‘gold’
σ'σσ	nadija ‘hope’
,σσ'σ	borot’ba ‘struggle’

b. *4-syllable words*

'σσσ,σ	lahodyty ‘repair’
σ'σσ,σ	horodyna ‘vegetables’
,σσ'σσ	robitnyctvo ‘working class’
,σσσ'σ	obvynuvač ‘prosecutor’

c. *5-syllable words*

'σσ,σσ,σ	vybuduvaty ‘build, PERF’
σ'σσσ,σ	vyxovuvaty ‘bring up, IMPERF’
,σσ'σσ,σ	kukurudzjanyj ‘corn, ADJ’
,σσσ'σσ	amerykanec’ ‘an American’
,σσ,σσ'σ	peredovyky ‘leaders’

d. *6-syllable words*

'σσσ,σσ,σ	vylikuvatysja ‘heal, REFL’
σ'σσ,σσ,σ	zapamoročennja ‘dizziness’
,σσ'σσσ,σ	obraxovuvaty ‘calculate’
,σσσ'σσ,σ	xarakterystyka ‘characteristics’
,σσ,σσ'σσ	kapitalistyčnyj ‘capitalist, ADJ’
,σσ,σσσ'σ	municypalitet ‘municipality’

¹ Words of seven and more syllables are rare in Ukrainian.

As can be observed in (5), lexical stress can appear on any syllable, and secondary stress is predictably located on the initial and final syllables, given that at least one syllable intervenes between lexical and rhythmic stress; compare $\sigma'\sigma\sigma\sigma$ *horodyna* ‘vegetables’ and $\sigma\sigma'\sigma\sigma$ *robotnyctvo* ‘working class’ in (5b). Additional rhythmic beats appear word-medially in words with lexical stress removed from the left or the right word edge by four or more syllables: for instance, $\sigma\sigma\sigma\sigma\sigma$ *peredovyky* ‘leaders’ and $\sigma\sigma\sigma\sigma\sigma$ *vybuduvaty* ‘build, PERF’ (5c).² The examples in (5d) show that whenever lexical stress is separated from the word edge by five syllables, there is a lapse close to lexical stress ($\sigma\sigma\sigma\sigma\sigma\sigma$ *municipalitet* ‘municipality’, $\sigma\sigma\sigma\sigma\sigma\sigma$ *vylikuvatysja* ‘heal, REFL’), with the additional beats iterating from word edges toward main stress. This characteristic (i.e., rightward assignment of secondary stress in $\sigma\sigma\sigma\sigma\sigma\sigma$ and leftward assignment in $\sigma\sigma\sigma\sigma\sigma\sigma$) renders the metrical system of Ukrainian bidirectional.

As Ukrainian is a highly inflectional language with complex morphology, most words in (5) contain affixes: for example, *zolat+o* ‘gold’, *borot'+b+a* ‘struggle’, *vy+bud+uva+ty* ‘build, PERF’. It is generally known that morphology can potentially interact with stress assignment. Well-documented examples of such interactions come from English, where secondary stress placement is cyclic and thus dependent on morphological structure (Chomsky and Halle 1968, Hayes 1980, Halle and Vergnaud 1987). For instance, secondary stress is placed on the first syllable of the word *amika'bility* because this syllable carries main stress in the base form *amicable*. In contrast, secondary stress on the second syllable of *Ameri'cana* is inherited from the stress pattern of the stem *Ameri'ca*. No effects of this kind occur in Ukrainian. The fact that the assignment of secondary stress in this language proceeds regardless of lexical stress in related words is confirmed by several pieces of evidence. First, there is no correspondence between lexical stress in the base form and the grammatical stress in the derived form in word pairs such as *a'meryka* ‘America’ – *amery'kanec* ‘an American, MASC SG’, *xa'rakter* ‘character’ – *charakte'rystyka* ‘characteristics’, and many others. If morphological structure modulated the assignment of rhythmic stress, both *amery'kanec* and *charakte'rystyka* would have secondary stress on the second syllable: **amery'kanec* and **charakte'rystyka*. The second piece of evidence demonstrating that secondary stress is not lexicalized in Ukrainian comes from stress patterns of unaccented stems.³ Such stems lack an underlying accent specification and do not carry primary stress in the surface representation, and yet they regularly receive secondary stress. For instance, words such as *bu'd+yn+ok* ‘building’,

² Theoretically, lexical stress could be removed by four syllables *both* from the left *and* from the right word edge ($\sigma\sigma\sigma\sigma\sigma\sigma\sigma\sigma$). While words of such length are extremely rare in Ukrainian, it is predicted that in such cases additional beats would appear on both sides of main stress.

³ Like the morphemes of the other East Slavic languages (Russian and Belarusian), Ukrainian morphemes can be classified as accented and unaccented. In cases where a word contains two unaccented stems, the Basic Accentuation Principle places stress on the initial syllable (Halle 1997). If there are two accented morphemes (e.g., when an accented stem is combined with an accented suffix), the location of stress is determined by whether the accented suffix is dominant or not. If it is dominant, then stress falls on the rightmost accented morpheme: for example, *syl+'ač* ‘strong man’. If it is nondominant, then stress falls on the leftmost accented morpheme: for example, *ryb+n+yctv+o* ‘fish farming’. The words *amery'kanec* ‘an American’ and *charakte'rystyka* ‘characteristics’ contain lexically accented dominant suffixes, *-anec* and *-ystyk-*, which attract stress regardless of whether the stem they attach to is accented or unaccented (see Melvold 1990:70ff. for discussion and analysis). There are no studies examining Ukrainian default stress; however, experimental studies on Russian have demonstrated that Russian has a final default, contrary to the prediction of the Basic Accentuation Principle (see, e.g., Crosswhite et al. 2003, Gouskova 2010, Mołczanow et al. 2019). The issue of default stress in Ukrainian cannot be resolved at present and thus it awaits future study.

bud+u'va+ty 'build', *bud+i'v+el'+nyk* 'builder' have an unaccented stem *bud-*, with primary stress realized on the suffix (cf. the accented stem *-rod-* in *na+'rodž+uva+ty* 'give birth', *na+'rod+nist'* 'ethnicity', *na+'rod+nyk* 'patriot'). Regardless of its lack of lexical accent, *bud-* receives rhythmic prominence in those words in which it is separated from primary stress by one syllable, which indicates that secondary stress assignment in Ukrainian is postlexical in nature. Finally, secondary stress is not marked in pronouncing dictionaries of Ukrainian (see Žovtobrjux 1973), and native speakers are unaware of its existence. In this regard, Ukrainian is similar to grammatical stress systems such as Polish, which show the same surface-true rhythmic stress pattern in simple and complex words.

As mentioned previously, acoustic correlates of rhythmic stress in Ukrainian have been the subject of several experimental studies (Łukaszewicz and Mołczanow 2018a,b,c, Mołczanow, Łukaszewicz, and Łukaszewicz 2018). These studies have detected a rhythmic pattern in words with lexical stress located both at the right word edge (e.g., *ˈvelo,sype'dyst* 'cyclist') and at the left word edge (e.g., *ˈvyzo,loty,ty* 'gild'). However, whereas secondary stress was obligatorily present at both word edges (i.e., initially in *ˈvelo,sype'dyst* and finally in *ˈvyzo,loty,ty*), an additional beat in word-medial position was optional in words with lexical stress at the left word edge (*ˈvyzo,loty,ty*).

Also, phonetic studies have reported an increased duration of the syllable immediately preceding the syllable carrying lexical stress (Łukaszewicz and Mołczanow 2018b). Other East Slavic languages for which the existence of pretonic lengthening has been well-documented include Standard Russian and some East Slavic dialects (Bethin 2006). In these systems, increased duration is unconnected with rhythm and is argued to be caused by a high tone that is spread from the lexically stressed syllable (Bethin 2006, Mołczanow 2015, 2017). As mentioned above, Standard Russian as well as pretonic-length dialects do not have secondary stress; their rhythmic pattern is traditionally described using the formula 1-2-3-1, pretonic lengthening being marked with 2, which is meant to reflect the fact that the duration of this syllable is intermediate between that of the tonic syllable (marked with 3) and that of the unstressed syllable (marked with 1). Ukrainian rhythm is usually described by the formula 1-0.75-2-0.75-1.25, suggesting that the pretonic syllable has the same status as other unstressed syllables. In this respect, the detection of increased duration of the pretonic syllable in Ukrainian reported in Łukaszewicz and Mołczanow 2018b is unexpected. However, note that the formula provided above was stated on the basis of impressionistic observations, and was primarily meant to highlight the differences between the rhythmic structures of Ukrainian and Russian. Pretonic lengthening, in turn, is unconnected with rhythm; rather, it is related to the domain of lexical stress, which appears to extend beyond one syllable in East Slavic (for further discussion, see Łukaszewicz and Mołczanow 2018b). It should also be noted that pretonic lengthening is not as robust in Ukrainian as it is in the Russian dialects with pretonic length, where pretonic vowels often have the same duration as the vowels in stressed syllables. In contrast, Ukrainian pretonic vowels do not exceed two-thirds of the tonic syllable's duration. For these reasons, the presence of pretonic lengthening may have gone unnoticed in traditional descriptions of the Ukrainian metrical structure. Needless to say, the presence of increased duration that is related to lexical stress and unrelated to rhythm contributes to the complex-

ity of the metrical system of Ukrainian. However, it also provides an argument that primary and secondary stresses have a different status within the metrical grammar, rather than representing two degrees of the same phenomenon.

To summarize, Ukrainian represents a hybrid system, combining primary lexical stress with secondary grammatical stress. The two types of stress are distinct phenomena; the former is lexically encoded and cumulative, whereas the latter is predictable and iterating. In what follows, we argue that the contemporary theories of rhythmic stress cannot adequately model the Ukrainian pattern.

3 Theoretical Implications

In sections 3.1–3.5, we demonstrate that the Ukrainian pattern is problematic from the point of view of OT accounts of rhythmic stress based on feet, regardless of whether the mechanism employed is gradient alignment (McCarthy and Prince 1993, Alber 2005) or categorical alignment combined with licensing (Kager 2001, 2005), and regardless of the type of feet assumed (e.g., Hayes 1980, 1995, Kager 2001, 2005, Hyde 2002, 2016, Pruitt 2010, Martínez-Paricio and Kager 2015).

3.1 Approaches Postulating Binary Feet

The gradient alignment approach fails to generate both the concurrent secondary stresses in initial and final positions and the internal lapses adjacent to the peak that occur on both sides of the peak. This is because, in essence, it requires that all feet (or stresses in the pure-grid approach) are pushed *either* toward the left *or* toward the right edge of the word. Depending on whether ALIGN-FT-L (“The left edge of every foot is aligned with the left edge of a prosodic word”; McCarthy and Prince 1993) or ALIGN-FT-R (“The right edge of every foot is aligned with the right edge of a prosodic word”; McCarthy and Prince 1993) is the dominating constraint in the hierarchy, the rightward or the leftward pattern can be generated, but never both. In the following analyses, we focus on two examples, *muni,çypali'tet* ‘municipality’ and *'lahody,tyme,te* ‘repair, 2PL’, representing the rightward and leftward pattern, respectively. As shown earlier in (5), the interactions between lexical and rhythmic stress result in a spectrum of possible stress patterns depending on the position of lexical stress. The patterns exemplified by *muni,çypali'tet* and *'lahody,tyme,te* are patently the best to look at because they represent the limits of this spectrum: with lexical stress positioned at one extreme point (the right word edge) in *muni,çypali'tet* and at the other extreme point (the left word edge) in *'lahody,tyme,te*, these examples pose the superset of problems with respect to those posed by the remaining lexical-rhythmic stress interactions exemplified in (5). This is so because they involve (a) placing rhythmic stress at the edge of the word, (b) iteration of rhythmic stress on the third syllable counting from the edge, and (c) a lapse in the vicinity of lexical stress. The evaluation of candidates is shown in (6). It is important to bear in mind that the position of lexical stress is determined at the underlying level and does not follow from output well-formedness conditions. Thus, in this and subsequent analyses, only candidates with correctly marked lexical stress are considered; the violation marks referring to the syllable carrying lexical stress are given in parentheses as irrelevant to the point of discussion.

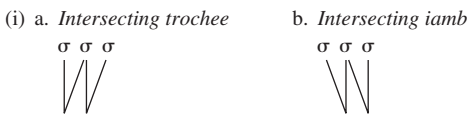
In (6a), the correct output (6ai) requires the ranking ALIGN-Ft-L >> ALIGN-Ft-R. The contradictory ranking is required for (6bi) to win: ALIGN-Ft-R >> ALIGN-Ft-L. However, this setting would produce an incorrect result for words with main stress on the final syllable: * $[\sigma(\sigma\sigma)][(\sigma\sigma)'\sigma]$.⁴

(6) Foot-based approach with gradient alignment: ALIGN-Ft-L >> ALIGN-Ft-R

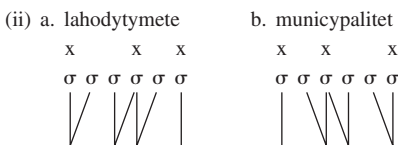
	ALIGN-Ft-L	ALIGN-Ft-R
a. Rightward iteration		
⇒ i. (,muni)(,cypa)li('tet)	** (2), (*****)	**, **** (6)
ii. (,muni)cy(,pali)('tet)	***! (3), (*****)	*, **** (5)
iii. mu(,nicy)(,pali)('tet)	*, ***! (4), (*****)	*, *** (4)
b. Leftward iteration		
☺ i. ('laho)dy(,tyme)(,te)	***, *****! (8)	* (1), (****)
ii. ('laho)(,dyty)me(,te)	** , *****! (7)	** (2), (****)
← iii. ('laho)(,dyty)(,mete)	** , **** (6)	** (2), (****)

Let us point out that we arbitrarily assume trochaic feet here because it is unclear whether any default foot parsing exists in Ukrainian. In this respect, Ukrainian is similar to Russian, where

⁴ A similar problem arises in the approach of Hyde (2002), who departs from the standard assumptions of proper bracketing and one-to-one correspondence between stresses and feet, instead proposing intersected feet. A detailed presentation of this approach would be beyond the scope of this article (see Martínez-Paricio and Kager 2020 for discussion and a critical assessment). However, let us point to the aspects of Hyde’s model that could potentially be employed in the analysis of Ukrainian. Hyde (2002:316) proposes the following intersected feet (vertical association lines indicate prosodic heads):



Both the foot type and the footing directionality are derived by the alignment constraints H_{DS}-L (“The left edge of every foot-head is aligned with the left edge of some prosodic word”) and H_{DS}-R (“The right edge of every foot-head is aligned with the right edge of some prosodic word”) (Hyde 2002:319). H_{DS}-L favors trochaic feet (ia), drawing them to the left word edge, while H_{DS}-R gives preference to iambs (ib) located as close as possible to the right word edge. As demonstrated in (ii), the mirror-image metrical patterns in *lahodytyme te* and *muni,cypali'tet* require both an intersecting trochee (iia) and an intersecting iamb (iib). The former can be generated by the ranking H_{DS}-L >> H_{DS}-R, whereas the latter requires the opposite ranking, H_{DS}-R >> H_{DS}-L. Hence, this model encounters the same problem as the approach assuming binary feet presented above, in that it cannot generate both patterns employing one constraint ranking.



no empirical evidence for foot parsing has been found and for which, as a result, both trochaic and iambic feet have been assumed on purely theoretical grounds.⁵ However, analyses assuming iambic feet would also yield contradictory results for the rightward and leftward patterns. That is, for the stresses in (6a), feet would have to be aligned with the left word edge in the pattern $(\sigma)(\sigma,\sigma)\sigma(\sigma'\sigma)$, so the ranking generating the rightward stress iteration would be ALIGN-FT-L \gg ALIGN-FT-R. The pattern with the leftward stress iteration, $(\sigma)\sigma(\sigma,\sigma)(\sigma,\sigma)$, mimicking the arrangement of prominences in (6b), would align feet with the right word edge; hence, the opposite ranking would be required: ALIGN-FT-R \gg ALIGN-FT-L. Aside from the contradictory direction effects and the iambic-trochaic controversy, lurking beneath these analyses is the question of how to ensure that candidate (6bi), where secondary stress resides in both binary and unary feet, can ever win in the competition with candidate (6biii), where secondary stress resides in uniform binary feet. (Candidates with both trochaic and iambic feet are excluded by GEN, so $*[(\sigma\sigma)(\sigma\sigma)(\sigma,\sigma)]$ is not a viable solution to this puzzle.) This question is also pertinent to the licensing-based account that we discuss below.

The Ukrainian pattern is also problematic from the perspective of the licensing approach proposed by Kager (2001, 2005). This approach accommodates a sequence of two unstressed syllables in the vicinity of main stress, both to the right and to the left, either via LAPSE-AT-PEAK ('Lapse must be adjacent to the peak'; Kager 2001) or via *LAPSE-IN-TROUGH ('No sequences of two unstressed syllables between secondary stresses'; Kager 2005), which must dominate the general *LAPSE constraint ('No two adjacent unstressed syllables'; Selkirk 1984). Yet it offers no mechanism for placing secondary stresses at the opposite word edges simultaneously; see (7). The point is that the nongradient ALIGN-WD-L and ALIGN-WD-R ('Every prosodic word starts/ends with a foot'; Kager 2001) operate in terms of foot units. While this solution is feasible for systems that exhibit clear iambic or trochaic patterns, it is problematic for Ukrainian, whose foot structure (iambic or trochaic) is far from obvious. In hexasyllabic words, this approach correctly generates initial secondary stress in words with main stress at the right edge of the word, such as *muni,cypali'tet* (7a). However, in words with main stress at the left edge of the word, such as *'lahody,tyme'te* (7b), the fully parsed and incorrect output $*[(\text{'laho})(\text{dyty})(\text{,mete})]$ (7biii) violates a subset of well-formedness conditions relative to the correct output with final stress $[(\text{'laho})\text{dy}(,tyme)(\text{,te})]$ (7bi).

⁵ In their analyses of Russian, Alderete (1995) and Crosswhite (2001) opt for iambs, whereas Mołczanow et al. (2013) and Lavitskaya and Kabak (2014) propose trochees; unbounded left-headed feet have been postulated by Idsardi (1992), Halle and Idsardi (1995), and Halle (1997), while Halle and Vergnaud (1987) and Melvold (1990) assume unbounded right-headed feet. Bethin (1998), in turn, concludes from her examination of Slavic languages with fixed stress (e.g., Czech, Polish, Macedonian) that 'the trochee is the fundamental metrical measure of Slavic' (Bethin 1998: 179–180).

(7) *Foot-based approach with categorical alignment and licensing*

	ALIGN-WD-L	ALIGN-WD-R	LAPSE-AT-PEAK	*LAPSE
a. Rightward iteration				
⇒ i. (,muni)(,cypa)li('tet)				*
ii. (,muni)cy(,pali)('tet)			*!	*
iii. mu(,nicy)(,pali)('tet)	*!			
b. Leftward iteration				
⊖ i. ('laho)dy(,tyme)(,te)				*!
ii. ('laho)(,dyty)me(,te)			*!	*
⇐ iii. ('laho)(,dyty)(,mete)				

Note also that while the lapse on the third syllable in the correct output ['lahody.tyme.te] can be modeled without reference to foot structure (in terms of LAPSE-AT-PEAK or *LAPSE-IN-TROUGH), the parsing of the word into feet raises several questions (as anticipated in the gradient alignment analysis above). Assuming that parsing is trochaic in Ukrainian, is there a unary foot at the end of the word, as in candidates (7bi) and (7bii)? If so, under what conditions are unary feet allowed in Ukrainian? Would the candidate [('laho)(dyty)(me)te] with leftward iambic parsing also be a viable output? What mechanisms would ensure unambiguous trochaic or iambic interpretation of the string, and on what grounds could they be posited? Further, putting aside the iambic/trochaic controversy, it seems that the incorrect parsing *[('laho)(,dyty)(,mete)] (7biii) would emerge as suboptimal only if one assumed priority of rhythmic beats over foot structure. Apparently, if foot parsing were imposed in such cases, it would have to be generated in accordance with the “optimal grid” requirements: a high-ranked constraint demanding that a stress mark be aligned with the edge of the word.

3.2 Internally Layered Feet

An attractive alternative seems to be offered by Martínez-Paricio and Kager's (2015) approach employing internally layered feet with minimal recursion. This model postulates both binary and ternary feet, which may coexist within one system. Systems with strictly binary or strictly ternary feet are at the end of the rhythmic continuum; the interior of the continuum is occupied by mixed systems, in which the coexistence of binary and ternary (and sometimes also unary) feet is determined by a restricted set of principles. Apart from regular trochees ($\sigma\sigma$), iambs ($\sigma'\sigma$), and unary feet (σ), four types of internally layered feet (ILF) are permitted by GEN: ($(\sigma\sigma)\sigma$), ($\sigma(\sigma\sigma)$), ($(\sigma'\sigma)\sigma$), ($\sigma(\sigma'\sigma)$). Alignment constraints refer to minimal/maximal foot projections as loci of violation, penalizing their separation (in terms of some prosodic category, such as the foot) from the left/right edge of some prosodic domain.

In the analysis of bidirectional stress systems such as Piro and Garawa, ternary feet combine with binary feet in odd-parity words, as shown in (8) (see Martínez-Paricio and Kager 2015:479).

- (8) a. *Piro*
 ($\sigma \sigma$) ($\sigma \sigma$) ($\sigma (\sigma \sigma)$)
 b. *Garawa*
 (($\sigma \sigma$) σ) ($\sigma \sigma$) ($\sigma \sigma$)

Both Piro and Garawa are classified as mixed binary/ternary systems. In these systems, binary parsing is the default option, but a single ternary foot emerges in odd-parity words (Martínez-Paricio and Kager 2015:472). Thus, allowing ILF makes it possible to replace the former mechanisms for generating unparsed syllables in odd-numbered words by exhaustive parsing.

The appearance of ternary feet is controlled by the constraint ALIGN-L/R_{nonmin} (“For every nonminimal foot Ft_{nonmin}, assign a violation mark if some foot intervenes between Ft_{nonmin} and the left/right edge of its containing ω ”). Apart from minimizing recursive (ternary) feet, ALIGN-L/R_{nonmin} ensures that the ternary foot—that is, the foot accommodating a lapse—is located at the left/right edge of the word. Ternarity, on the other hand, is promoted by the constraint ALIGN-L/R_{min}, which disfavors binary feet that are both maximal and minimal (“For every foot that is minimal and maximal ([Ft_{min}] _{ω}), assign a violation mark if some foot intervenes between [Ft_{min}] _{ω} and the left/right edge of its containing ω ”).

In Piro and Garawa, ALIGN-L/R_{nonmin} must be ranked above ALIGN-L/R_{min}, to ensure that the default foot parsing is binary; for a more exhaustive analysis, see Martínez-Paricio and Kager 2015:481. The directionality of stress iteration depends on the location of the ternary feet vis-à-vis the word edge (right-aligned in Piro and left-aligned in Garawa) and the structure of ternary feet (left-branching ($\sigma(\sigma\sigma)$) in Piro and right-branching (($\sigma\sigma$) σ) in Garawa). A consistent iambic or trochaic layout of recursive feet in a given metrical system is ensured by the constraints TROCHEE_{nonmin}/IAMB_{nonmin} (“For every minimal foot Ft_{min}, assign a violation mark if some footed syllable intervenes between Ft_{nonmin} and the left/right edge of its containing Ft”). Furthermore, exhaustive parsing in binary/ternary systems is generated by the high-ranked constraint CHAIN-L/R (“For every unfooted syllable (σ) _{ω} , assign a violation mark if some foot intervenes between (σ) _{ω} and the left/right edge of its containing ω ”). The constraint ranking of Garawa is provided in (9) (from Martínez-Paricio and Kager 2015:481).

- (9) *Garawa*
 CHAIN-L/R, ALIGN-L_{nonmin}, ALIGN-L/R_{unary}, TROCHEE, TROCHEE_{nonmin}
 >> ALIGN-L/R_{max}, ALIGN-R_{nonmin}, ALIGN-L/R_{min}, IAMB, IAMB_{nonmin}

The mirror-image system of Piro is derived by locating the ILF at the right word edge, through the reranking of ALIGN-L/R_{nonmin} as ALIGN-R_{nonmin} >> ALIGN-L_{nonmin}, and by changing the position of the foot head from the leftmost to the rightmost, which is achieved by the ranking IAMB, IAMB_{nonmin} >> TROCHEE, TROCHEE_{nonmin}.

As discussed previously, both rightward and leftward iteration of secondary stresses are found in Ukrainian in words with lexical stress separated from either the left or the right edge

of the word by at least five syllables, as in *muni,cypali'tet* and *'lahody,tyme,te*. From the point of view of the distribution of secondary stresses, Ukrainian meets the definition of a bidirectional system. Therefore, it is expected that the rightward iteration pattern could be generated using the ranking of constraints established for languages with rightward stress iteration (as in Piro), while the leftward iteration pattern would require the ranking generating systems with leftward stress iteration (as in Garawa). The two rankings are incompatible; therefore, as in other foot-based approaches discussed above, an approach assuming ILF is not capable of modeling both rightward and leftward stress iteration with one constraint ranking. This is illustrated in (10), where, on the basis of the ranking established for Garawa, the test items *muni,cypali'tet* and *'lahody,tyme,te* are evaluated. To simplify the presentation, we do not consider candidates with unfooted syllables (which are prohibited by the high-ranked CHAIN-L/R). Note also the presence of unary feet in (10). Martínez-Paricio and Kager (2015) exclude unary feet from bidirectional stress systems via the high-ranked constraint ALIGN-L/R_{unary}. We argue later in this section that Ukrainian must allow unary feet. Here, we note that eliminating unary feet from the candidate set in (10) would not lead to generating correct outputs.

(10) *Foot-based approach employing internally layered feet: Hexasyllabic words*

	ALIGN-L _{nonmin}	TROCHEE	TROCHEE _{nonmin}	ALIGN-L _{min}	ALIGN-R _{min}	ALIGN-R _{nonmin}	IAMB _{nonmin}	IAMB
a. Leftward iteration								
⇒ i. ('laho)dy)(,tyme)(,te)				*	*	*	*	**
ii. ('la)(ho(dy,ty))(me,te)	*!	**	*	*	*	*		
iii. ('laho)((,dyty)me)(,te)	*!			*	*	*	*	**
iv. ('la)(ho,dy)(ty(me,te))	*!	**	*	*	**			
b. Rightward iteration								
☺ i. (,muni)((,cypa)li)('tet)	*!			*	*	*	*	**
← ii. ((,muni)cy)(,pali)('tet)				*	*	*	*	**
iii. (,mu)(ni(cy,pa))(li'tet)	*!	**	*	*	*	*		
iv. (,mu)(ni,cy)(pa(li'tet))	*!	**	*	*	**			

In (10a), parsings (10ai) and (10aii) are consistent with the prosodic structure of hexasyllabic words with initial lexical stress. The former candidate wins because it locates the trochaic ternary foot at the left word edge, thus complying with the high-ranked ALIGN-L_{nonmin}. However, this constraint excludes the intended winner (10bi) in the rightward iteration pattern (10b), incorrectly

choosing candidate (10bii), where the lapse occurs between secondary stresses. For candidate (10bi) to win, ALIGN-R_{nonmin} must outrank ALIGN-L_{nonmin}. However, this ranking would not generate a correct output in (10a).

Besides the problem connected with the coexistence of leftward and rightward rhythmic stress iterations, a complication arises in the case of trisyllabic words. While the interweaving of binary and ternary feet ensures exhaustive parsing in classic bidirectional systems, such as Piro and Garawa, secondary stress in Ukrainian trisyllabic words such as *'zolo.to* 'gold' and *borot''ba* 'struggle' suggests that this system must also admit unary feet: (*'zolo*)(*to*) or (*'zo*)(*lo.to*), (*borot'*) (*ba*) or (*bo*)(*rot''ba*). These forms also indicate that the default foot parsing in Ukrainian is binary, not ternary. This would make Ukrainian analogous to the binary/unary systems analyzed by Martínez-Paricio and Kager (2015:478–479).

However, other examples are not in concert with assuming the primacy of binary parsing: *lahodyty* 'repair' is parsed [$\sigma\sigma\sigma$], not $*[\sigma\sigma\sigma]$. From the point of view of such examples, Ukrainian would have to be classified as a mixed ternary/binary/unary system. This is a contradiction in terms, because within the ILF theory, systems that have exhaustive parsing group three-syllable strings either into a single recursive foot (compare binary/ternary systems with ternary/binary/unary systems; Martínez-Paricio and Kager 2015:479, 481, respectively) or into a sequence of a binary and unary foot (binary/unary systems), never both.⁶ The theory does overgenerate in the case of three-syllable strings; however, the only inconsistent parsing of strings that cannot be parsed by a canonical foot is "three-syllable exceptionality"—a "pathological" scenario whereby three-syllable strings are parsed by a recursive foot, while longer odd-parity strings are parsed by a series of binary feet plus a single unary foot located at the edge; Martínez-Paricio and Kager 2015:488). Thus, the Ukrainian system does not fill the unattested gap; instead, it presents an unpredicted scenario.

It is also clear that the primacy of ternary over binary parsing, required for *lahodyty* in order to prevent the incorrect exhaustive binary parse $*[\sigma\sigma\sigma]$, would have an undesired effect in the case of the test items *¶muni.ɕypali'tet* and *lahodytyme.te*. Depending on the subpattern of a mixed ternary/binary/unary system that is assumed, either the ILF theory would generate incorrect exhaustive ternary parses (e.g., $*[(\sigma(\sigma\sigma))(\sigma(\sigma\sigma))]$ and $*[[((\sigma\sigma)\sigma)((\sigma\sigma)\sigma)]$, respectively; see the Unidirectional T*(B/U)/B patterns in Martínez-Paricio and Kager 2015, Supplementary materials, p. 8), or it would fall short of disentangling the contradictory iambic/trochaic demands and the contradictory unary/binary/ternary as opposed to ternary/binary/unary arrangements of feet within the Ukrainian word strings: $*[(\sigma)(\sigma\sigma)(\sigma(\sigma\sigma))]$ and $*[[((\sigma\sigma)\sigma)(\sigma\sigma)(\sigma)]$ (see the Unidirectional T/B*(U) patterns in Martínez-Paricio and Kager 2015, Supplementary materials, p. 7).

⁶ See also page 5 of Martínez-Paricio and Kager's (2015) supplementary materials (<https://www.cambridge.org/core/journals/phonology/article/binarytoternary-rhythmic-continuum-in-stress-typology-layered-feet-and-nonintervention-constraints/DA3D3F2841FFD87DD3B68A6E11CF4AFF#fndtn-supplementary-materials>).

The failed evaluation of trisyllabic words with primary stress on the final and initial syllables is shown in (11), where we employ the Garawa ranking (see (9) and tableau (10)). For reasons of space, we do not show ALIGN-L/R_{nonmin} because none of the candidates violates this constraint. Also, we do not consider candidates that exhibit reversal of lexical and rhythmic stress (e.g., *('borot')(ba), *(('borot')ba)), because they fatally violate a high-ranked constraint demanding preservation of lexical stress.

(11) *Foot-based approach employing internally layered feet: Trisyllabic words*

	ALIGN-L/R _{primary}	TROCHEE	TROCHEE _{nonmin}	ALIGN-L/R _{max}	ALIGN-L/R _{min}	IAMB _{nonmin}	IAMB
a. ,borot'ba 'struggle'							
⇒ i. (,borot')(ba)	*			**	**		*
ii. (,bo)(rot'ba)	*	*!		**	**		
iii. (bo)(rot'ba)		*	*!				
b. 'zolo ₁ to 'gold'							
i. ('zolo)(₁ to)	*!			**	**		*
ii. ('zo)(lo ₁ to)	*	*!		**	**		
⇐ iii. (('zolo)to)						*	*

3.3 Grid-Based Approach

Another way of modeling metrical bidirectionality is offered by approaches that do not appeal to the metrical foot but refer directly to the grid (Gordon 2002). In Gordon's (2002) approach, attraction of stress to word edges is straightforwardly ensured by ALIGN EDGES, which requires that the edges of level 0 of a prosodic word—that is, both the initial and the final syllable—be aligned with a grid mark on level 1, corresponding to secondary stress (p. 497). However, the family of *LAPSE constraints expanded along the lines that Gordon suggests does not include any equivalent of LAPSE-AT-PEAK or *LAPSE-IN-TROUGH. Iteration of rhythmic stress is modeled in terms of gradient alignment, reformulated in terms of the metrical grid: ALIGN (x₁, L) and ALIGN (x₁, R) require that every level 1 grid mark be aligned with the left/right edge of level 0 of grid marks in a prosodic word. As a result, as in (6)–(7) and (9)–(10), the predicted pattern is compatible with either the left or the right side of the rhythmic mirror attested in Ukrainian, but not with both. In (12), ALIGN EDGES needs to be ranked highest to ensure the occurrence of polar beats at the left/right edge of the prosodic word. The rightward iteration in (12a) is effected by the

ranking $\text{ALIGN}(x_1, L) \gg \text{ALIGN}(x_1, R)$; the leftward iteration in (12b) can only be modeled in terms of the opposite ranking of the two constraints. Note that positioning primary stresses at word edges in the two words cannot be enforced by the activity of ALIGN EDGES , as primary stress is lexical in Ukrainian.

(12) *Grid-based approach including gradient alignment*

	ALIGN EDGES	$\text{ALIGN}(x_1, L)$	$\text{ALIGN}(x_1, R)$
a. Rightward iteration			
\Rightarrow i. ,muni,cypali'tet		** (2)	***, ***** (8)
ii. ,municy,pali'tet		***! (3)	** , ***** (7)
iii. mu,nicy,pali'tet	*! (1)	*, *** (4)	** , ***** (6)
b. Leftward iteration			
\ominus i. 'lahody,tyme,te		***, *****! (8)	** (2)
\Leftarrow ii. 'laho,dytyme,te		** , ***** (7)	*** (3)
iii. 'laho,dyty,mete	*! (1)	** , ***** (6)	*, *** (4)

3.4 *Combining the Grid-Based Approach and Licensing*

In the light of the above discussion, it is clear that the Ukrainian mirror-image secondary stress pattern can be generated if and only if (a) foot-based constraints are replaced by grid-based constraints, and (b) gradient alignment pushing all secondary stresses toward the left or the right edge of the word is abandoned. In technical terms, this is achieved by the grid-based ALIGN EDGES accompanied by the licensing LAPSE-AT-PEAK .⁷ The two constraints are defined in (13).

(13) *LAPSE-AT-PEAK*

Lapse must be adjacent to the peak.

(Kager 2001:4)

ALIGN EDGES

The edges of level 0 of a prosodic word, i.e., both the initial and the final syllable, are aligned with a level 1 grid mark.

(Gordon 2002:497)

⁷ The ranking $\text{ALIGN EDGES} \gg \text{LAPSE-AT-PEAK}$ will also generate the bidirectional systems illustrated in (8). However, in order to generate penultimate stress in languages such as Piro, ALIGN EDGES would have to be outranked by NONFINALITY (Prince and Smolensky 2004, Walker 1996), formulated by Gordon (2002:501) as "A final syllable does not have a grid mark on level 1." In Gordon's proposal, the placement of primary stress on the penult is regulated not in terms of ALIGN EDGES but by a gradient alignment constraint referring to level 2 of the metrical grid, $\text{ALIGN}(x_2, R)$. In the account we propose here, we could instead use a grid-based version of the familiar End Rule-R (McCarthy 2003: 111). Note that this issue is not relevant to Ukrainian, where primary stress is lexically marked.

LAPSE-AT-PEAK ensures that rhythmic stress iterates from word edges so that the lapse is located in the vicinity of the lexical stress in even-parity words such as *muni,cypali'tet* and *'lahody,tyme,te*. ALIGN EDGES, in turn, derives edge-based secondary stress. This constraint is needed to account for edge-based stress patterns in a number of languages, including Canadian French, Armenian, and Udihe (see Gordon 2002:500 for discussion and references). These systems are different from Ukrainian in that they involve primary stress at one word edge and secondary stress at the opposite word edge. Thus, the point of interest of the Ukrainian pattern lies in the fact that ALIGN EDGES enforces secondary stresses at both word edges in this language. The analysis is shown in (14).

(14) *A combination of the grid-based approach and the licensing approach*

	ALIGN EDGES	LAPSE-AT-PEAK
a. Rightward iteration		
⇒ i. ,muni,cypali'tet		
ii. ,municy,pali'tet		*!
iii. mu,nicy,pali'tet	*!	
b. Leftward iteration		
⇒ i. 'lahody,tyme,te		
ii. 'laho,dytyme,te		*!
iii. 'laho,dyty,mete	*!	

The Ukrainian data are also consistent with the parameter-based approach developed by van der Hulst (1996, 2012, 2014), who assumes that rhythmic stress is derived without reference to foot structure by two independent mechanisms. First, a polar beat is placed at the edge opposite to the primary stress (on the initial and/or final syllable), shown in (15a). Next, rhythmic beats are added in between the two stresses (15b).

- (15) a. Polar beats: $\underline{\sigma} \sigma \sigma \sigma ' \sigma, ' \sigma \sigma \sigma \underline{\sigma}, \underline{\sigma} \sigma ' \sigma \sigma \underline{\sigma}$
 b. Rhythmic beats: $\sigma \sigma \underline{\sigma} \sigma ' \sigma, ' \sigma \sigma \underline{\sigma} \sigma \sigma$

Rhythmic beats can “ripple away” either from the primary stress (echo rhythm) or from the polar beats (polar rhythm), resulting in two different lapse systems.

- (16) a. Echo rhythm: $\sigma \sigma \sigma \sigma \sigma \sigma ' \sigma, ' \sigma \sigma \sigma \sigma \sigma \sigma$
 b. Polar rhythm: $\sigma \sigma \sigma \sigma \sigma \sigma ' \sigma, ' \sigma \sigma \sigma \sigma \sigma \sigma$

In this approach, Ukrainian can be analyzed as having obligatory polar beats (15a) and optional rhythmic beats (15b). When rhythmic beats are present, they spread from the polar beats (16b), producing a bidirectional stress system with internal lapses near the primary stress.

There are obvious parallels between this approach and the OT analysis suggested in (14). Polar beats correspond to ALIGN EDGES and polar rhythm achieves the same result as LAPSE-AT-

PEAK: the former attracts rhythmic stress to word edges while the latter repels it from the primary stress. The difference between van der Hulst's approach and the analysis suggested in (14) is that the latter does not predict the existence of patterns such as (16a). In our approach, only polar rhythm is possible in systems with polar beats. Thus, lapses are possible only at the peak, as in (16b). This prediction is consistent with the fact that bidirectional systems with secondary stress at word edges and a lapse not adjacent to main stress are unattested among the languages of the world (Kager 2001).

Further research is needed to predict the consequences of the hybrid approach that we propose here for the factorial typology of stress patterns. Also, the role of LAPSE-AT-PEAK needs to be further investigated. Intuitively, however, LAPSE-AT-PEAK offers a direct expression of the symmetrical distribution of secondary stress around main stress in Ukrainian.

3.5 Licensing Approach Based on Moraic Feet

An alternative foot-based analysis has been suggested by an anonymous *LI* reviewer, who points out that the increased duration of stressed syllables, reported in experimental research, may be encoded phonologically. Assuming that feet are maximally binary at the level of the mora, and that all heads of feet are heavy, moraic feet can be constructed at both word edges. As in the grid-based licensing model proposed above, the iterative stresses can be derived using LAPSE-AT-PEAK. The derivation of the two test items, *muničypali'tet* and *'lahody.tyme.ʃe*, is shown in (18). The constraint enforcing bimoraic foot heads, which we provisionally call STRESS-TO-WEIGHT ("If stressed, then heavy"), is the reversal of the familiar Weight-to-Stress principle ("If heavy, then stressed").⁸ As in the grid-based approach laid out in section 3.4, the position of iterative stresses is derived by the rhythmic licensing constraint LAPSE-AT-PEAK, defined in (13), repeated here for convenience.

- (17) *LAPSE-AT-PEAK*
Lapse must be adjacent to the peak.
(Kager 2001:4)

⁸ A similar constraint ("Stressed vowels should be bimoraic") has been employed by Crosswhite (2001:81) in her analysis of dissimilative vowel reduction in Russian dialects.

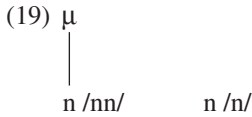
(18) *Approach employing moraic feet*

	ALIGN- WD-L	STRESS-TO- WEIGHT	CLASH	LAPSE-AT- PEAK	PARSE- SYL
a. Rightward iteration					
μμ μ μμ μμ μμ ⇒ i. (,mu)ni(,cy)pali('tet)					***
μμ μ μ μμ μ μμ ii. (,mu)nicy(,pa)li('tet)				*!	***
μ μμ μ μμ μ μμ iii. mu(,ni)cy(,pa)li('tet)	*!				***
μ μ μ μ μ μμ iv. (,muni)(,cypa)li('tet)		*!*			*
μμ μμ μ μμ μ μμ v. (,mu)(,ni)cy(,pa)li('tet)			*!		**
b. Leftward iteration					
μμ μ μ μμ μ μμ ⇒ i. ('la)hody(,ty)me(,te)					***
μμ μ μμ μ μ μμ ii. ('la)ho(,dy)tyme(,te)				*!	***
μμ μ μ μ μ μ μ iii. ('la)ho(,dyty)(,mete)		*!	*!		*

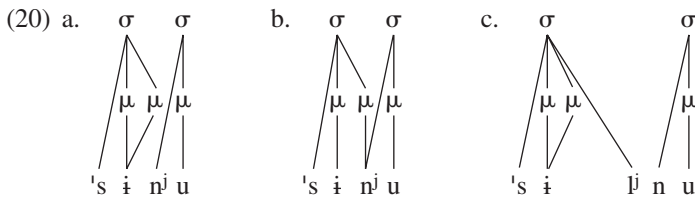
As demonstrated by the tableau above, the foot-based model combined with licensing constraints can successfully derive the Ukrainian pattern. The assumption that foot heads are bimoraic allows for the correct placement of secondary stresses at word edges, which is technically achieved by means of the constraints ALIGN-WD-L and ALIGN-WD-R. LAPSE-AT-PEAK, in turn, accounts for the bidirectional iteration of stresses, locating them in positions removed by two syllables from lexical stress.

As we have shown, both the grid-based and the foot-based licensing models are able to account for the distribution of stress in Ukrainian. Unlike the grid-based analysis, the foot-based analysis retains the foot constituent, which demonstrably plays an important role in many phonological systems. However, though the foot-based model can account for the distribution of secondary prominence in Ukrainian, it is based on a theoretical assumption that does not dovetail with the rest of the Ukrainian phonological system. In particular, the bimoraicity of foot heads makes wrong predictions concerning the behavior of geminates and glides in Ukrainian, as demonstrated in the remainder of this section.

Ukrainian has true geminates, which contrast with single consonants in various contexts, including morpheme-medial positions: for instance, *‘synju* ‘blue, FEM ACC SG ADJ’ – *‘synnju* ‘blue, INSTR SG NOUN’, *su‘di* ‘court, LOC SG’ – *su‘ddi* ‘judge, GEN SG’ (Toc’ka 1969, Bethin 1992, Loboda 2009).⁹ It has been standardly assumed in the literature that single consonants are distinguished from geminates by the presence of a mora in the latter (Hayes 1989:257).



If we assume that stressed syllables are bimoraic in Ukrainian, then the words *‘synju* [‘sɪnʲu] ‘blue, FEM ACC SG ADJ’ and *‘synnju* [‘sɪnnʲu] ‘blue, INSTR SG NOUN’ have the structure in (20a) and (20b).¹⁰ The stressed vowel [i] in (20a) is bimoraic due to STRESS-TO-WEIGHT. It remains monomoraic in (20b), because the stressed syllable contains two moras (the second of which comes from the consonant) and thus fulfills the bimoraicity requirement. The representation of the word *‘sylv’nu* [‘sɪlʲnu] ‘strong, ACC SG ADJ’, with a stressed syllable closed by a coda consonant, is shown in (20c). Since the stressed syllable is followed by a nonmoraic consonant in *‘sylv’nu* (Weight-by-Position does not apply in Ukrainian), the stressed vowel [i] is bimoraic, as in (20a).



This model predicts increased duration of the bimoraic vowels in (20a) and (20c), but not of the initial monomoraic vowel in (20b).¹¹ While the vowel in a closed syllable, as in (20c) and (20b), is expected to be phonetically shorter than a vowel in an open syllable, as in (20a), to the best

⁹ Ukrainian true geminates arose historically at morpheme boundaries where coronals were followed by a sequence of a short vowel and a glide (*mazz’u* ‘ointment, INSTR SG’ < **maz+ĭju*). True geminates are different from sequences of identical consonants that are present at morpheme boundaries—for example, *vid+dil* ‘department’, *son+n+yj* ‘sleepy’—in that they do not allow epenthesis. Though there exist minimal pairs, there is no agreement in the literature about whether Ukrainian geminates are phonemic (see Bethin 1992, 1998 for detailed discussion).

¹⁰ For an alternative interpretation, see Bethin 1998:232. Bethin suggests that geminates share the mora with the preceding vowel. As a result, geminates are moraic, but they do not add to the syllabic mora count.

¹¹ It has been noted in the literature that Hayes’s (1989) theory of geminates predicts the existence of systems in which syllables closed by geminates act as heavy (similarly to syllables with long vowels), and syllables closed by nonmoraic consonants act as light (on a par with syllables containing short vowels); for a detailed discussion, see Davis 2011. Such a system is in fact found in Seto (Southeastern Estonian), where vowel lengthening occurs in syllables closed by coda consonants but not in syllables closed by geminates (Kiparsky 2008, discussed in Davis 2011:121).

of our knowledge the vowels in the stressed syllables of (20b) and (20c) do not exhibit durational differences.¹²

Another problem with the moraic-feet analysis arises when we consider the alternation of high vowels with their nonsyllabic counterparts, which is attested both at morpheme and at word boundaries in Ukrainian (Toc'ka 2002). The vowels [i] and [u] occur after consonants, while the glides [j] and [w] are found after vowels, as exemplified in (21).¹³

(21) /i/ – /j/

vin ide ['vʲin i'de] 'he goes' – vona jde [vɔ'na 'jde] 'she goes'; naš Ivan ['naš i'van] 'our Ivan' – naša Jvanka ['naša 'jvanka] 'our Ivanka'; lycar ide ['liŋsar i'de] 'knight goes' – lycari jdut' ['liŋsarʲi j'dutʲ] 'knights go'

/u/ – /w/

zustriv učytelja [zu'strʲiw u'čitɛ,ʲa] 'he met a teacher' – zustrity učytelja [zu'strʲiti w'čitɛ,ʲa] 'to meet a teacher'; rostut' u lisi [rɔ'stutʲ u 'lʲisʲi] 'they grow in the forest' – žyve v lisi [žy'vɛ w 'lʲisʲi] 'she/he lives in a forest'; idut' učytysja [i'dutʲ u'čitʲi,sʲa] 'they go to study' – idu včytysja [i'du w'čitʲi,sʲa] 'I go to study'

It is a generally accepted view that in languages such as Ukrainian, high vowels and the corresponding glides are derived from one underlying source. Gliding, which consists in the deletion of a mora, is employed as a strategy to avoid vowel hiatus. Underlyingly, then, the sequence [i j] in *lycari jdut'* ['liŋsarʲi j'dutʲ] 'knights go' contains two moras. Assuming that stressed vowels are bimoraic on the surface, the vowel /i/ in the rhythmically stressed final syllable of the word *'lyca,ri* could acquire the second mora from the gliding of the word-initial /i/ of the word *idut'*, producing the output *[liŋsarʲi: 'dutʲ]. The evaluation of the relevant sequence is presented in (22).

¹² Toc'ka (1969:82–83), who provides measurements of vowel duration in different consonantal contexts, does not mention any differences in vocalic duration before clusters and before geminates. An anonymous *LI* reviewer rightly points out that the fact that Toc'ka does not mention the relevant difference may as well indicate that no measurements were conducted that would systematically compare vocalic duration in the two contexts. At present, we are not in a position to resolve this issue, and thus it must await future instrumental study.

¹³ In some contexts, the process applies optionally; for a detailed discussion, see Toc'ka 2002:60. Another caveat is that gliding occurs across word boundaries, while in word-medial positions hiatus is resolved by glide insertion, as in *stojik* ['stɔjɪk] 'Stoic', *kokajin* [kɔka'jin] 'cocaine' (Rubach 2002).

(22) *Gliding*

$\begin{array}{c} \mu \quad \mu \\ \quad \\ /i \quad i/ \end{array}$	STRESS- TO- WEIGHT	ONSET	NoCODA	IDENT μ	*LONG
$\begin{array}{c} \mu \quad \mu \\ \diagdown \quad / \\ \ominus \quad i. \quad (i \quad j) \end{array}$			*	*!	*
$\begin{array}{c} \mu \quad \mu \\ \diagdown \quad / \\ \leftarrow \quad ii. \quad (i) \end{array}$					*
$\begin{array}{c} \mu \quad \mu \\ \quad \\ iii. \quad (i. \quad i) \end{array}$	*!	*			
$\begin{array}{c} \mu \\ \\ iv. \quad (i \quad j) \end{array}$	*!				

The intended winner (22i) attaches the second mora to the initial vowel, fatally violating IDENT μ , which mandates that the mora of the input should be preserved on the same output vowel. Candidate (22ii) wins because it violates a subset of constraints violated by candidate (22i). Thus, the model assuming bimoraicity makes the wrong prediction that the underlying sequence /i i/ could be realized as a long vowel.¹⁴

In sum, though the foot-based model presented in this section can account for the distribution of secondary prominence in Ukrainian, it is based on a theoretical assumption that has certain undesirable consequences for the rest of the Ukrainian phonological system. In particular, the bimoraicity of foot heads makes wrong predictions concerning the behavior of geminates and glides in Ukrainian.

¹⁴ An *LJ* reviewer points out that this argument may not be strong, as it hinges on the assumption that moras are encoded in the underlying representation. If moras are added in the process of syllabification in response to a syllable structure constraint, then the argument against bimoraic feet loses its force. However, as we highlighted in footnote 13, the Ukrainian alternations involving high vowels are not limited to the gliding pattern that occurs across word boundaries. Thus, it is not clear whether all facts relating to the distribution of glides in Ukrainian may be amenable to such an analysis. This issue is secondary from the perspective of the present study, whose main objective is to argue for LAPSE-AT-PEAK, which is required whether a grid-only or a grid-*cum*-feet approach is taken.

4 Conclusions

In this article, we have discussed new data from Ukrainian, which has a hybrid metrical system with unpredictable lexical stress and grammatical iterative secondary stress. We have argued that the Ukrainian metrical system poses a challenge for current theories relying on foot structure construction and/or employing the mechanism of gradient alignment. We have suggested an alternative account based on licensing theories that appeal directly to the grid. However, it is important to point out that we do not posit that feet can be entirely dispensed with in phonological analysis. The considerable body of evidence for foot structure amassed by research on metrical phonology allows us to predict that that would be an undesirable move. Rather, the Ukrainian data suggest that languages differ in which aspects of metrical structure—feet or grids—they highlight as primary, and which they mark off as redundant. From a typological perspective, there is abundant evidence for the interaction between metrical and segmental phenomena in Germanic languages (vowel reduction in Dutch (Booij 1995), flapping in English (Kiparsky 1979), and glottal stop insertion in German (Wiese 1996), to mention just a few), but there is no stress-independent evidence for foot structure in Slavic languages. Regardless of whether stress is lexical (as in Russian) or grammatical (as in Polish), feet have been posited as theoretical artifacts, rather than independently motivated structures (see also footnote 5).

The metrical system of Ukrainian sheds new light on the nature of bidirectional stress systems and the relationship between primary and secondary stress. Although the initial intuition was that lapses in such systems are adjacent to the peak (Kager 2001), the technical apparatus evolved to regulate this characteristic by fixing feet with respect to word edges, rather than with respect to the peak. This resulted in making the distinction between primary stress (the peak) and the rhythmic beats irrelevant (see, e.g., the analyses in Hyde 2002, 2016 and Martínez-Paricio and Kager 2015). In our analysis, we restore the view that the window in which secondary stresses apply is delimited by primary stress at one end and the word edge at the other end. In grammatical systems, primary stress is necessarily fixed with respect to one of the word's edges, which invites technical solutions aimed at orienting all metrical structure left or right—that is, with respect to edges of the word. In such systems, it is impossible to disentangle the potential demarcating effect of primary stress from that of the corresponding word edge because they coincide. The confound does not exist in Ukrainian, which has free lexical stress. Directionality paradoxes in Ukrainian reveal that it is the primary stress that acts as the landmark toward which secondary stresses radiate from both edges (as in polar rhythm systems predicted in van der Hulst 1996, 2012, 2014); the exclusively left- or exclusively right-orientation of secondary stress alternation is not borne out.

Including LAPSE-AT-PEAK among the licensing mechanisms correctly predicts that secondary stresses are repelled from primary stress, rather than being pushed to the left edge or to the right edge. This mechanism has been criticized (Alber 2005, referred to in Kager 2005) for its potential to generate the unattested metrical pattern whereby the peak stays in initial position in even-parity words, [$(\sigma)(\sigma)(\sigma)$], while shifting toward the end of the word in order to license a lapse in odd-parity words: *[(σ)(σ)(σ)]. The assumed ranking for such a purported system was ALIGN-L \gg LAPSE-AT-END \gg LAPSE-AT-PEAK \gg LEFTMOST (Alber 2005:533); LEFTMOST/

RIGHTMOST derive from the EDGEMOST constraint family of Prince and Smolensky (2004) imposing the requirement that the head foot of the prosodic word be placed in initial/final position. The above criticism works on the premise that a language with default primary stress on the initial syllable is generated with LEFTMOST ranked at the bottom of the constraint hierarchy. One solution to the problem would be to posit that either LEFTMOST or RIGHTMOST must be ranked at the top of the constraint hierarchy in default stress systems (see Kager 2004, 2005). Another solution would be to use End Rule-L/R (“The head foot is not preceded/followed by another foot within the same prosodic word”; McCarthy 2003:111).

Though it is technically possible to prevent generating an unattested pattern in which primary and secondary stress swap positions, it is important to bear in mind that the problem arises because main stress is treated on a par with rhythmic stress and the model lacks a mechanism that would give priority to main stress assignment. In the light of our analysis, by referring to the peak as the licenser, LAPSE-AT-PEAK correctly brings to the fore the issue of the difference in status between the primary stress and secondary stresses. Notably, this difference is also highlighted in the parameter-based approach of van der Hulst (1996, 2012, 2014).

In Ukrainian, it is self-evident that lexical stress and rhythmic stress must be different phenomena, as they are located in different components, lexical as opposed to grammatical. But also in grammatical stress systems such as Polish, the status of the two phenomena is different: primary stress is insensitive to the presence of rhythmic stress, and hence to its position, while the application of secondary stress is restricted within a domain demarcated by the primary stress and the edge of the word. Two- and three-syllable words have primary stress, but no secondary stresses; obviously, there are no words with secondary but not primary stress in Polish to reify the hypothetically reversed scenario of primary stress assignment conditioned by the distribution of rhythmic beats. This makes the situation in Polish and Ukrainian fully comparable: secondary stresses apply only when the distance between the primary stress and the edge of the word is sufficiently big to accommodate these stresses.

Finally, it should be pointed out that theories of lexical stress (see, e.g., Alderete 1999, Revithiadou 1999) do not provide tools to model a possible interaction of lexical stress with rhythmic stress. At the same time, lexical stress systems fall outside the purview of the models of bidirectional stress systems, which have been designed to account exclusively for grammatical stress systems (see, e.g., Martínez-Paricio and Kager 2015:487). The question then arises whether grammatical stress theories should be capable of modeling grammatical stress in systems with primary lexical stress or whether these theories can only provide technical apparatus to describe systems in which both primary and secondary stress are predictable. If the latter is the case, then we need another model, which would target grammatical stress in languages with primary lexical stress. This, however, would be an undesirable move, as introducing two technical devices to account for what is essentially the same phenomenon (rhythmic stress) would amount to restating descriptive generalizations and, in effect, call into question the basic rationale of metrical theory. We hope that the complexity of the Ukrainian metrical system, which has not been previously discussed in the theoretical literature, will point to new research directions and contribute to advancing the theory of stress.

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