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Vowel Alternations in Ukrainian: From the Perspectives of Phonological Universality

【Invited Article】

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Abstract: This paper focuses on Ukrainian vowel alternations: mid vowel raising in closed syllables, mid vowel deletion in open syllables and the epenthesis of [i] between prepositions/prefixes and roots. The analysis is based on cross-linguistic phonological universality proposed in previous theoretical research. The first two are generalized as the avoidance of mid vowels, which have been documented as marked across languages, and accounted for by positional faithfulness depending on syllable structure. As for lexical exceptionality, it is formalized by assuming faithfulness constraints referring to lexical properties, which have been affirmed, especially in research on loanword phonology. In contrast, neutralization into [i] in the raising is problematic, given that such a backness alternation is generally unattested in Ukrainian. The current study suggests that the emergence of this vowel results from the default status of [i], which is confirmed by the observation that this vowel behaves as an epenthetic vowel.*

Key words: Ukrainian, Slavic languages, phonology, vowel alternations, markedness

1. Introduction

Ukrainian is classified as an East Slavic language, along with Belarusian and Russian. Although this language preserves commonalities with other Slavic languages, it has undergone several changes throughout its history. Consequently, its sound patterns differ considerably from those of other East Slavic languages. This study investigates Ukrainian synchronic phonology from the viewpoints of general principles proposed in theoretical studies.

This paper focused on three phonological phenomena in Ukrainian. The first is mid vowel raising, wherein mid vowels [e, o] in open syllables alternate with [i] in closed syllables (e.g., r**o**ki ‘year.NOM.PL.’ ➔ r**i**k ‘year.NOM.SG.’: see Section 3.2), which differentiates this language from other Slavic languages. The second topic is vowel–zero alternation, which is widely observed among Slavic languages and has been called *yer* or “ghost” vowels in Slavic linguistics. In Ukrainian, the mid vowels

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undergo this process (e.g., d**e**nʲ 'day.NOM.SG.' ➔ dnʲ**i** 'day.NOM.PL.': see Section 3.3), and this, along with raising, can be generalized as the avoidance of mid vowels, which have been regarded as *marked* in phonological theory. The third is vowel epenthesis motivated by the breaking of complex consonant clusters between prepositions or prefixes and roots (e.g., z**i**-znakom 'with a sign' cf. z-druɦom 'with a friend': see Section 3.4). The last two phenomena seem similar and can be regarded as a uniform process in other Slavic languages. In Ukrainian, however, these processes should be distinguished: while the mid vowels [e, o] participate in vowel–zero alternation, the epenthetic vowel is [i]. This signifies its default status in this language, and the current research suggests that the emergence of [i] (and not [u]) in the raising is motivated by the phonological unmarkedness of this vowel.

The structure of this paper is organized as follows. Section 2 reviews the theoretical background, focusing on the formal analysis of phonological markedness. Section 3 introduces vowel-related phonological processes in Ukrainian. Section 4 presents an analysis of these phenomena, mainly within the framework of Optimality Theory (hereafter, OT). Section 5 concludes the discussion.

2. Theoretical background

This section reviews formal approaches to vowel alternations. First, Section 2.1 discusses the cross-linguistic *markedness* of mid vowels. Section 2.2, in contrast, considers a language-specific unmarkedness or *default*, focusing especially on vowel epenthesis. Finally, Section 2.3 briefly discusses phonological exceptionality in which sound patterns cannot be generalized exclusively based on phonological factors.

2.1. Universal markedness of mid vowels

While typological studies have documented that a five-vowel system such as /a, i, u, e, o/ is widespread across languages, they have also confirmed that high and low vowels are more common than mid vowels (Gordon 2016: 49; see also Hyman 2008: 96). Furthermore, the universal tendency that the presence of mid vowels implies the presence of high and low vowels has been documented (Crothers 1978; see also Beckman 1997: 14). Thus, formal linguistic theory generalizes this situation by assuming that mid vowels are more *marked* than other vowels (Rice 2007: 85).

Within the OT framework, Beckman (1997) formalized this observation as a universal markedness scale as schematized in (1): the constraint on mid vowels (*Mid) is ranked higher than (i.e., prior to) those on high and low vowels (*High and *Low, respectively).

(1) Universal markdness scale of vowels (Beckman 1997: 14)
*Mid » *High, *Low

If a certain faithfulness constraint is ranked between *Mid and *High/*Low, only high and/or low vowels can emerge, with mid vowels eliminated by raising, lower-

ing or deletion. A simplified analysis of a nonce word is presented in (2).

(2) Elimination of mid vowels: OT analysis

a. Raising/lowering e.g. /pape/ ➔ [papi], [papa]

/pape/	*Mid	Ident	*High	*Low
pape	*!			*
☞ papi		*	*	*
☞ papa		*		**
pipi		**!	**	

b. Deletion e.g. /pape/ ➔ [pap]

/pape/	*Mid	Max	*High	*Low
pape	*!			*
☞ pap		*		*

In (2a), the candidate including a mid vowel [pape] is eliminated by *Mid, which is ranked higher than the faithfulness constraint on segmental change, Ident. In (2b), by contrast, *Mid is ranked higher than the faithfulness constraint on deletion, Max, resulting in the deletion of the mid vowel.

The markedness of mid vowels has also been considered in formal analyses of Slavic languages. For instance, Gouskova (2012) analyzed Russian vowel–zero alternation (e.g., s**o**n 'sleep.nom.sg' ~ sna 'sleep.gen.sg': see Section 3.3) by the constraint on mid vowels (*Mid). Simply put, stem-final mid vowels are deleted if the consequent syllable structure is acceptable. In addition to this general markedness, Crosswhite (2001) assumed a constraint on unstressed mid (non-peripheral) vowels (e.g., *Mid/Unstressed), accounting for vowel reduction in Russian (e.g., k**ó**t 'cat.nom.sg' ~ k**a**tá 'cat.gen.sg') and Belarusian.

Further, sound processes occurring exclusively under certain phonological conditions can be formalized by *positional faithfulness*. Beckman (1997) argues that faithfulness constraints are likely to be ranked higher in certain contexts such as word-initial positions across languages. For instance, the aforementioned mid vowel reduction can be accounted for by assuming that the faithfulness constraint on vowel height in unstressed syllables (e.g., Ident/Unstressed) is ranked lower than the general markedness constraint on mid vowels (i.e., *Mid). To determine the appropriate approach, the characteristics of each type of constraint should be considered.

In general, markedness constraints, which restrict the emergence of surface (output) sound patterns, are motivated by phonetic properties such as articulatory difficulty and/or perceptual ambiguity. For instance, Kochetov (2002) accounted for the positional effects of Russian palatalized consonants by assuming relevant positional markedness constraints (e.g., *$C_{[+pal]}$/_C) based on the accuracy of production and perception. Vowel reduction as mentioned above should also be regarded as this type of process, as it is difficult for vowel contrast to be realized in unstressed syllables because of weak articulation.

In contrast, faithfulness constraints impose restrictions on sound patterns compared to their inputs. In other words, these constraints focus on processes (i.e., phonological changes) rather than on results (i.e., surface sound patterns). For example, Lombardi (1999) accounted for regressive voicing assimilation by assuming that the relevant positional faithfulness constraint on onset consonants (i.e., Ident/Onset) was generally higher than that on consonants (i.e., Ident). Consonants are perceived more clearly before vowels than in other contexts. Therefore, their change should have a more critical effect on speech perception in the former. In short, this analysis focused on positional voicing assimilation (i.e., a process) rather than consonantal voicing on a certain position (i.e., a result).

Positional faithfulness can also be extended to factors related to sound patterns that are neither phonetic nor phonological. Beckman (1998: 194) assumed faithfulness constraints on roots (i.e., Ident/Root) to account for the observation that phonological processes are more likely to be blocked in roots than in affixes. Furthermore, sound patterns specific to lexical properties, such as loanwords (e.g., Ito and Mester 1999), should also be regarded as positional faithfulness. As noted later, the aforementioned vowel–zero alternation in Slavic languages is avoided in certain morphemes, which can be accounted for by a lexically specific faithfulness constraint on deletions.

Before concluding this section, it must be noted that, while the markedness of mid vowels has been formalized by phonological grammar, as discussed so far, it has also been attributed to phonological structures or *representation*. In Element Theory in particular, while low and high vowels are represented by a single element |A, I, U|, mid vowels are represented by a combination or syntax-like merge of multiple elements: /e, o/, for instance, are formalized by |A, I| and |A, U|, respectively (Harris and Lindsey 1995; Backley and Nasukawa 2020, among others). This framework regards the avoidance of and/or restriction on mid vowels (e.g., reduction of unstressed vowels) as a structural simplification: a complex phonological structure consisting of multiple elements is reduced to a simpler structure. Notably, grammatical and representational approaches do not necessarily contradict one another. We return to this issue at the end of the next section.

2.2. Language-specific default and vowel epenthesis

In addition to the cross-linguistic tendency discussed in the last section, researchers have proposed language-specific markedness hierarchies. Central to this issue is unmarkedness or phonological *default*.[1] Theoretical research suggests that default vowels are used as epenthetic segments (Lombardi 2003; de Lacy 2006; Uffmann 2007: 4–6; Backley and Nasukawa 2020, among others). Lombardi (2003) documented the cross-linguistically widespread epenthetic vowels as [ə], [i], [ɨ] and [a].

[1] One reviewer pointed out that unmarkedness is also reflected by emergence frequency. However, it can be affected by lexical specification rather than a grammatical principle. As this paper focuses primarily on phonological grammar, the overall frequency of vowel emergence is not considered in the following discussions.

Vowel epenthesis can also be affected by phonological factors such as adjacent segments (Uffmann 2007). If these phonological principles are not involved, however, default vowels are epenthesized; this has been generalized as the emergence of the unmarked (Rice 2007: 83–84; see also McCarthy and Prince 2004).

As discussed in the previous section, markedness is formalized by constraint hierarchies within the OT framework. Lombardi (2003) accounted for the typology of default epenthetic vowels by assuming a ranking variation of markedness constraints on vowel features, such as [+low]. For example, if the constraint on [+low] (i.e., *Low) is ranked lower than the constraints on other vowel features (e.g., *High, *Mid), then the epenthesis of a low vowel [a] is selected. A simplified analysis of [a]-epenthesis in five-vowel systems is demonstrated in (3). Note that *Mid is ranked higher than the other two constraints, as discussed in the previous section.

(3) Epenthesis of [a] in a five-vowel system: OT analysis
e.g. /pig/ ➔ [pig**a**] (cf. Lombardi 2003[2])

/pig/	*Mid	*High	*Low
pigi		*!	
pigu		*!	
pige	*!		
pigo	*!		
☞ piga			*

By contrast, Pulleyblank (1998) focused on the sonority of epenthetic vowels, arguing for a universality that the epenthesis of vowels with higher sonority incurs more serious violations than the epenthesis of vowels with lower sonority. Although his analysis is based on a perceptional study, it fails to explain why sonorous vowels, such as [a], are epenthesized in many languages. It should thus be assumed that epenthetic vowels cannot be determined by a universal principle, but by language-specific constraint hierarchies.

Inter-language variation in vowel epenthesis has also been attributed to phonological representations. Backley and Nasukawa (2020) assumed default vowel structures within a framework of Element Theory: for example, if an element |A| constructs a core structure, the default vowel is [ə] (or presumably [a]). One remarkable advantage of this approach is that the elimination of marked vowels, such as the reduction in unstressed syllables, is formalized as a structural simplification; vowels with complex elemental structures are avoided in *weak* positions.

Notably, the representational approaches reviewed above do not contradict the aforementioned grammatical approaches, such as constraint-based OT analysis. One possible formalization is that constraints on *marked* segments in terms of

[2] Lombardi (2003) assumed the constraint on non-low vowels *NonLow. She also focused on the markedness of rounded and front vowels observed across languages, which is beyond the topic of this paper.

representation are likely to be active in phonological grammar. Meanwhile, the assumption that phonological structure determines sound patterns raises the problem of exceptionality. Some phonological processes do not necessarily occur under the phonological conditions concerned and are difficult to explain using representational approaches. The next section explores this issue.

2.3. Grammatical approach to exceptionality

Although various phonological principles have been proposed by researchers, as discussed thus far, it has also been documented that some sound patterns cannot be generalized exclusively by certain mechanisms. Although this topic is not central to the focus of this paper, this section briefly reviews previous studies discussing this issue, as the phonological processes discussed in the following sections also show such exceptionality.

One factor related to exceptionality is lexical and morphological properties, as noted in Section 2.1. In particular, the sound patterns in loanwords tend to differ from those in native words (e.g., Ito and Mester 1995, 1999, 2001). In addition, affixes are more likely to undergo phonological processes than roots or stems (Beckman 1998). Another factor is the frequency of language usage. Bybee (2002) argued that the more frequently words are used, the earlier they undergo sound changes.

What is important in theoretical analysis is how these non-phonological factors are considered in phonological grammar. One possible approach involves the interface between phonology and other components, the latter of which is referred to by phonological grammar. For instance, Ito and Mester (1995, 1999) accounted for Japanese loanword phonology, in which some of the patterns prohibited among native words are observed, by assuming that faithfulness constraints on loanwords are ranked higher than those on native words. It should be noted that it was not etymology (i.e., native words vs. foreign words) that their analysis was based on, but phonologically-determined lexical *strata*. Ito and Mester (1995, 1999) pointed out that some loanwords show native-like phonological patterns, implying a shift in lexical status. According to this approach, the lexicon forms a *core–periphery* structure: native items are placed at the core, while loanwords and neologisms are placed at the periphery. Therefore, constraints *indexed* to such lexical strata can also be applied to other properties, such as morphological status (roots/stems vs. affixes) and language usage (especially frequency or familiarity) (see also Beckman 1998).

The exceptionality of sound patterns can also be formalized by representational variations; a phonetically identical segment is structured in multiple ways, leading to variations in the occurrence of a phonological process. Morén (2006), for instance, analyzed two types of velar consonant alternations in Serbian by assuming different featural structures for the triggering vowel /i/. Backley and Nasukawa (2020) formalized inter-language variation in vowel reduction by assuming different elemental structures for a phonetically identical vowel. However, such a representational distinction is *phonological* and is not directly motivated by lexical

or morphological properties. For instance, it cannot be argued that the underlying representation of a phonetically identical [e] is specified as /e/ for native words and as /ɛ/ for loanwords. Moreover, the occurrence of *exceptional* patterns is not static; for example, some loanwords may exhibit phonological behavior similar to that of native words (Ito and Mester 1995, 1999). In summary, *non-phonological* properties conditioning the exceptionality of sound patterns are formalized by assuming a grammatical interface and not a representational distinction.[3]

There have also been disputes regarding the constraint indexation related to non-phonological properties. The most important question is whether markedness constraints can be indexed to these factors. Ito and Mester (1999) argued that the markedness hierarchy in a given language should be constant, even though the surface pattern may vary depending on lexical properties (e.g., native words or loanwords). As discussed in Section 2.1, there are universal markedness scales across languages, but they are collapsed if relevant markedness constraints can be indexed to non-phonological properties. As long as the current analyses of Ukrainian phonological phenomena are grounded in the fixed ranking introduced in (1), the following discussion assumes indexation exclusively for faithfulness constraints.

3. Vowel alternations in Ukrainian

This section introduces vowel-related phonological phenomena in Ukrainian. Before considering each process, Section 3.1 briefly presents the vowel system of the language. The following sections take up three vowel alternations: raising (Section 3.2), deletion (Section 3.3) and epenthesis (Section 3.4), respectively.

3.1. Vowel system

Researchers have documented that standard Ukrainian has six vowels /a, i, ɪ, u, e, o/, as shown in Table 1 (cf. Shevelov 1993: 948–949; Tots'ka 2002: 35). Several points should be noted in this regard. First, /ɪ/ cannot be distinguished from /e/ when unstressed. Second, while unstressed vowels do not undergo notable reduction in standard Ukrainian, as observed in Belarusian or Russian, there are considerable dialectal variations that are not discussed in this paper. Finally, the mid vowels are often pronounced as more open [ɛ, ɔ] (cf. Rubach 2005), but can become

Table 1 Vowels in Ukrainian

	front	central	back
high	i		u
	ɪ		
mid	e		o
low		a	

[3] One reviewer pointed out that the exceptionality of phonological processes can be generally attributed to lexically-specific representation. Such an approach is logically possible, but the current study asserts that representation is primarily phonological and not directly linked to lexical properties.

closer primarily by coarticulation with neighboring high vowels (Tots'ka 2002: 53–54). A precise phonetic description is beyond the scope of this study. Therefore, in the following discussion, these vowels are regarded as *mid* in a broad sense and transcribed as [e, o] for simplicity.

3.2. Raising

Vowel raising is one of the most striking features that differentiates Ukrainian from other Slavic languages. As exemplified in (4), the mid vowels [e, o] in open syllables alternate with the high front vowel [i] in closed syllables (Tots'ka 2002: 63). Note that the syllable structure varies due to suffixation in these examples.

(4) Vowel raising in Ukrainian

r**e**.ʧi	(NOM.PL.)	r**i**ʧ	(NOM.SG.)	'thing'
n**e**.sla	(PAST.FEM.SG.)	n**i**s	(PAST.MASC.SG.)	'carry'
o.s**o**.ba	(NOM.SG.)	o.s**i**b	(GEN.PL.)	'person'
r**o**.ku	(GEN.SG.)	r**i**k	(NOM.SG.)	'year'

This alternation is often observed in nominal declension: the zero ending creates word-final closed syllables, whereas the other endings make stem-final vowels emerge in open syllables with stem-final consonants embedded into the following syllables.

As mentioned earlier, exceptional cases are observed, as shown in (5): the mid vowels remain unchanged in closed syllables.

(5) Vowel raising in Ukrainian: exceptions

m**e**.du	(GEN.SG.)	m**e**d	(NOM.SG.)	'honey'
mja.k**o**.ti	(GEN.SG.)	mja.k**o**tʲ	(NOM.SG.)	'pulp'

While some lexical and morphological factors that block raising have been documented (Tots'ka 2002: 63), many exceptional cases cannot be generalized based on linguistic properties (Shevelov 1993: 955). The current study conducted a survey of nouns with monosyllabic and disyllabic stems whose citation forms end in consonants (i.e., closed syllables). Data were collected from an online dictionary (slovnyk.ua) and classified based on the vowels emerging in open syllables. Words ending with frequently used suffixes[4] and loanwords[5] were excluded. In addition, a frequency dictionary based on the corpus of Ukrainian by the laboratory of computer linguistics at Kyiv University was consulted to consider frequency effects: the top 10,000 words in the section "Publication" (http://www.mova.info/cfq1.aspx?fdid=publ2018) were picked up. The results are summarized in Table 2. Note that words undergoing vowel deletion mentioned in the next section were

[4] The words ending in the following suffixes were excluded: *-ist'*, *-iv* (wherein the raising is always attested); *-ets'*, *-ok* (wherein the deletion rather than the raising is attested); *-er*, *-izm*, *-ing*, *-ist*, *-ich* (wherein no alternations are attested).

[5] Mel'nychuk's (1974) dictionary was consulted, but it is possible that recent loanwords were not excluded.

excluded here. As seen in Table 2a, raising generally occurred with a small number of nouns, whereas this process was observed at a relatively high rate among frequently used words, as seen in Table 2b (cf. Watabe 2022).

Table 2 a. Raising in nouns with mono- and disyllabic stems (total)

Vowels	[e]	[o]
Raising	88 (7.4%)	513 (30.1%)
No raising	1007 (92.6%)	1191 (69.9%)
Sum	1195	1704

b. Raising in nouns with mono- and disyllabic stems (10,000 frequent words)

Vowels	[e]	[o]
Raising	24 (25.8%)	153 (56.9%)
No raising	69 (74.2%)	116 (43.1%)
Sum	93	269

Significant difference was confirmed for both [e]-raising (χ^2 = 47.393; df = 1; p < .001) and [o]-raising (χ^2 = 107.3; df = 1; p < .001) between the frequent words and the others. A detailed analysis is presented in the next section.

3.3. Deletion

In Slavic languages, certain stem-final vowels can be deleted when they would emerge in open syllables otherwise (Scheer 2011). The vowel undergoing the deletion or vowel–zero alternation is called *yer*, which was originally denoted as a super-short vowel in Old Slavic, the loss of which resulted in this alternation. Note that some cases appeared in the subsequent development of contemporary languages (e.g., vo.g**o**nʲ 'fire' < Old Church Slavic *ognĭ*); as a result, the occurrence of this process cannot be fully explained by etymology (see Gouskova 2012: 91–93 for examples from Russian). In Ukrainian, as seen in (6), mid vowels [e, o] undergo this process. Because the current study focuses on synchronic phonology, the origins of these vowels are not considered in the following data presentations. In these cases of word inflection, while [e, o] are attested in closed syllables, the vowels are lost in open syllables.

(6) Vowel–zero alternation in Ukrainian

d**e**nʲ	(NOM.SG.)	dnʲi / *d**e**.nʲi	(NOM.PL.)	'day'
ki.n**e**tsʲ	(NOM.SG.)	kin.tsʲa / *ki.n**e**.tsʲa	(GEN.SG.)	'end'
j.ʂ**o**w	(PAST.MASC.SG.)	j.ʂla / *j.ʂ**o**.la	(PAST.FEM.SG.)	'go'
vo.g**o**nʲ	(NOM.SG.)	vo.gnʲa / *vo.g**o**.nʲa	(GEN.SG.)	'fire'

It should be noted that these examples are exceptions to the raising discussed in the previous section; the mid vowels remain unchanged in closed syllables. In addition, Watabe (2023) demonstrated that raising and deletion avoid co-occurring because of the opacity of phonological motivation; [i] in closed syllables

would not be regarded as underlying mid vowels and would avoid deletion. These observations suggest that, while mid vowel raising can be blocked by a certain non-phonological factor in general, it is avoided because of a phonological restriction when deletion occurs. Note that the deletion cases were excluded from the data in Table 2, where mid vowels appear in stem-final open syllables. The results for the deletion from the survey mentioned in the last section are summarized in Table 3.

Table 3 a. Deletion in nouns with mono- and disyllabic stems (total)

Vowels	[e]	[o]	[i]	Sum
Deletion	163 (13.9%)	30 (2.5%)	5	198
No deletion	1007 (86.1%)	1191 (97.5%)	1646	3844
Sum	1170	1221	1651	4042

b. Deletion in nouns with mono- and disyllabic stems (10,000 frequent words)

Vowels	[e]	[o]	[i]	Sum
Deletion	44 (38.9%)	9 (7.2%)	0	53
No deletion	69 (61.1%)	116 (92.8%)	330	515
Sum	113	125	330	568

These data lead to the following observations. First, both raising and deletion were more likely to occur among the frequently used words than among the others: significant difference was confirmed also for deletion ([e]-deletion: $\chi^2 = 62.942$; df = 1; $p < .001$; [o]-deletion: $\chi^2 = 10.96$; df = 1; $p < .001$). Second, the co-occurrence of both processes, which results in the deletion of [i], was rarely observed; only five cases were confirmed in total and none were among the frequent words. Finally, while [e] tended to undergo deletion rather than raising, the tendency was reversed for [o].

One may suspect that this process is epenthesis rather than deletion. First, vowel emergence is generally motivated by the repair of syllable structures (cf. Gouskova 2012). For example, vowel epenthesis occurs in English-origin loanwords in many languages such as Japanese (Ito and Mester 1995, 1999), Shona (Uffmann 2006) and Samoan (Uffmann 2006) to avoid coda consonants and/or consonant clusters. Meanwhile, the mid vowels emerge regardless of the syllable structure in many cases, suggesting that vowel deletion in Ukrainian is not phonologically motivated: see (7) for the exceptional cases.

(7) Vowel–zero alternation in Ukrainian: exceptions

be.r**e**ʂ	(NONPAST.2SG.)	be.r**e**.mo	(NONPAST.1PL.)	‘take (impf.)’
ʲu.b**o**w	(NOM.SG.)	ʲu.b**o**.vi	(GEN.SG.)	‘love’

However, most researchers agree that certain vowels are specified in the underlying forms and are deleted in open syllables (for a detailed discussion, see Gouskova 2012). First, vowel emergence can occur even if consonant clusters need not be

broken. In (6), for instance, *[kintsʲ] 'end.NOM.SG.' is phonotactically accepted; there are several words ending in a similar cluster such as [prints] 'prince.' Another important reason is that it cannot be predicted which vowel (i.e., [e] or [o]) emerges in Ukrainian. Moreover, as briefly noted earlier, the deletion has been extended within Ukrainian phonology (cf. Gouskova 2012; Scheer 2011). With regard to exceptional cases, Gouskova (2012) argued that a certain lexical property determines the occurrence of the deletion, as discussed in Section 2.3. According to her analysis of a similar alternation in Russian, this process is triggered by an *indexed* constraint on mid vowels, exclusively among morphemes specified to a certain lexical *index* L. Note that the constraint on mid vowels has been proposed, given the cross-linguistic tendency discussed in Section 2.1. In contrast, as Scheer (2011) summarized, some researchers have proposed special phonological representations for vowels undergoing the deletion, independent of etymologically weak vowels. The current observations suggest that the variability of the vowel–zero alternation should be conditioned both phonologically and non-phonologically. While the fact that the occurrence rate is generally low should be attributed to a specific phonological representation undergoing this process, the alternation is also affected by lexical properties such as usage frequency. Although this exceptionality is beyond the scope of this work, a simplified theoretical analysis is presented in Section 4.1. Put it shortly, the deletion occurs exclusively on underlyingly *weak* vowels due to the low-ranked faithfulness constraint on these vowels. As for low-frequency or *periphery* items, by contrast, this constraint is ranked high and blocks the deletion.

3.4. Epenthesis

In the last section, it was argued that vowel–zero alternation, as exemplified in (6), should be regarded as a deletion rather than an epenthesis. However, in Ukrainian, alternation cases that seem to be epentheses are also observed: several examples are presented in (8).

(8) Vowel epenthesis in Ukrainian

z-druɦom	'with a friend'	z**i**-znakom	'with a sign'	
roz-berusʲa	(NONPAST.1SG.)	roz**i**-bratɪsʲa	(INF.)	'understand (PF.)'
pid-rɪvatɪ	(IMPF.INF.)	pid**i**-rvatɪ	(PF.INF.)	'explode'
nad-sɪlatɪ	(IMPF.INF.)	nad**i**-slatɪ	(PF.INF.)	'send out'

In these cases, [i] is inserted between the prepositions/prefixes[6] and the roots (the boundaries are denoted by hyphens) probably to avoid complex consonant clusters.[7] As mentioned in Section 2.2, epenthesis of this vowel is widely observed

[6] In Ukrainian (and other Slavic languages), most verbs have perfect and imperfect forms. There are several ways of aspect alternation, and the patterns are lexically determined. Some imperfect verbs are derived by insertion of [ɪ] as seen in the last two examples in (8).

[7] Some of the consonant clusters broken by the epenthesis are not unattested in this language (e.g., zbroja 'weapon' cf. *rozbratɪsʲa / rozibratɪsʲa 'understand.PF.INF.'). It can be as-

across languages. Note that the acceptable complexity of consonant clusters is relatively high in Ukrainian from cross-linguistic perspectives (e.g., [zgnɪtɪtɪ] 'press. PF.INF.'); thus, vowel epenthesis is generally unattested in loanwords.

The sound patterns in (8) should be regarded as epentheses because, as mentioned in the previous section, [i] generally does not undergo deletion (see Table 3). In other words, it cannot be assumed that this vowel, unlike [e] or [o], underlies the endings of prepositions or prefixes. This point strikingly differentiates Ukrainian from other Slavic languages, in which the *epenthetic* vowel is identical to (one of) the vowel(s) that undergo deletion. Some examples are shown in (9): the first examples from each language are stem-final alternations, as discussed in the previous section, whereas the second examples occur between prepositions/prefixes and roots, as in (8).

(9) Vowel–zero alternation in Slavic languages

a. Russian (when unaccented[8]: cf. Gouskova 2012)

pa.da.rək	(NOM.SG.)	pa.da.rkʲi	(NOM.PL.)	'gift'
kə-mnʲe	'toward me'	k-nʲim	'toward him'	

b. Polish (cf. Gussmann 2007)

s**e**n	(NOM.SG.)	snu	(GEN.SG.)	'sleep'
v**e**-fɕi	'in (a) village'	v-mʲje.ɕtɕe	'in (a) city'	

c. Serbian

do.b**a**r	(MASC.SG.)	do.bra	(FEM.SG.)	'good'
i.z**a**-tɕi	(PF.INF.)	i.z-la.zi.ti	(IMPF.INF.)	'go out'
ko.mu.ni.z**a**m	(NOM.SG.)	ko.mu.ni.zma	(GEN.SG.)	'communism'

In South Slavic languages such as Serbian, vowel epenthesis is also attested in some loanwords, as seen in the last example of (9c). These cases suggest that which vowel emerges is determined by the same mechanism as in the deletion (this paper does not discuss whether vowel emergence after prepositions or prefixes is an epenthesis in these languages). In contrast, in Ukrainian, the epenthetic vowel is clearly distinguished from vowels that undergo deletion and must be determined by an independent phonological principle. As discussed in Section 2.2, this epenthetic vowel should be unmarked or the default, which leads to the emergence of [i] in the raising, as argued in Section 4.2.

4. Theoretical analysis

This section presents a formal analysis of the vowel alternations introduced in Section 3. The current analysis is based primarily on the OT framework reviewed in Section 2. These phenomena can generally be formalized using the universal phonological principles introduced in Sections 2.1 and 2.2. In contrast, as dis-

sumed that the acceptability of these clusters depends on morphological positions, though this issue is not discussed in this paper.

[8] [e, o] undergo the deletion when the vowels are stressed. Note that the epenthesized vowels are generally unstressed.

cussed in Section 2.3, the exceptionality related to non-phonological factors, which is also observed in the Ukrainian sound patterns concerned, should be accounted for primarily by grammatical interfaces between phonology and other parts. The remainder of this section is organized as follows. First, Section 4.1 discusses the avoidance of mid vowels in raising and deletion in Ukrainian, arguing that these processes are motivated by the general markedness of mid vowels, as noted in Section 2.1, and lexically specific faithfulness. Next, Section 4.2 deals with the most problematic issue in the raising, neutralization of backness, demonstrating that this process can be formalized by assuming the default status of [i], which is affirmed by the vowel epenthesis. Finally, Section 4.3 mentions several remaining issues to be addressed.

4.1. Markedness of mid vowels and positional faithfulness

As discussed in Section 2.1, mid vowels are regarded as more marked than other vowels; therefore, vowel raising and deletion should be motivated by markedness avoidance. Notably, these processes occur exclusively under certain conditions: raising occurs in closed syllables, whereas deletion occurs in open syllables. One approach to this observation is positional faithfulness, as introduced in Section 2.1: the raising can be formalized by assuming that the markedness constraint on mid vowels is ranked higher than the relevant faithfulness constraint on closed syllables and lower than the faithfulness constraint on open syllables. The constraints and rankings are summarized in (10). Note that raising is preferred to lowering (i.e., the emergence of [a]), which should be blocked by a context-free faithfulness constraint on [low] (Ident (low)) ranked higher than *Mid. For simplicity, this point is omitted from the following analysis.

(10) Positional faithfulness for the raising
  a. Ident/Open (high): [high] must not be changed in open syllables.
  b. Ident/Closed (high): [high] must not be changed in closed syllables.
  c. Ranking with the markedness constraint on mid vowels:
    Ident/Open (high) » *Mid » Ident/Closed (high)

In addition to the phonologically driven positional effects, lexical exceptionality is also related to the raising. The current survey mentioned in Section 3.2 suggested that this process is more likely to occur among frequently used words. This situation should be apt for the *core–periphery* model of the phonological lexicon discussed in Section 2.3, wherein a given sound process tends to be observed at the *core*. Thus, we assume that an indexed constraint as in (11)[9] is ranked higher than *Mid in Ukrainian.

[9] The reviewers pointed out that the lexical status should be defined more concretely (e.g., native vs. foreign as in Ito and Mester (1999)). While this issue is a question for future research, I tentatively state that the phonological lexicon of Ukrainian forms a core–periphery structure regardless of etymology.

(11) Faithfulness indexed to lexical properties
Ident$_{periphery}$ (high): [high] must not be changed in lexical items positioned at the *periphery*.

A tentative OT analysis of the raising is demonstrated in (12): the underlying mid vowel /o/ emerges as [i] only in a closed syllable.

(12) Elimination of mid vowels: OT analysis
a. /rok/ ➔ [rik] 'year.nom.sg.'
b. /rok-u/ ➔ [ro.ku] 'year.gen.sg.'
c. /mjakoti$_{periphery}$/ ➔ [mja.koti] 'pulp.nom.sg.'

		Ident$_{periphery}$ (high)	Ident/Open (high)	*Mid	Ident/Closed (high)
a. /rok/	rok			*W	L
	☞ rik				*
b. /rok-u/	☞ ro.ku			*	
	ri.ku		*W	L	
c. /mjak**o**ti$_{periphery}$/	☞ mja.koti			*	
	mja.kiti	*W		L	*

In (12a), the candidate including [o] in the closed syllable ([rok]) is eliminated by *Mid because this constraint is ranked higher than Ident/Closed (high), which is violated by the candidate in which the vowel is raised to [i] ([rik]). By contrast, in (12b), the raising candidate ([ri.ku]) is eliminated by Ident/Open (high), which is ranked higher than *Mid. Finally, (12c) exemplifies a lexical exception, where the raising is eliminated by Ident$_{periphery}$ (high) regardless of the syllable structure. However, in this analysis, it remains unclear why the front vowel [i] emerges instead of [u], which preserves backness. This issue is discussed in the following section.

The markedness of mid vowels should also be related to their deletion; however, there are several points to consider. First, as noted above, while raising occurs in closed syllables, deletion is conditioned by open syllables. Second, the relevant faithfulness constraint for the deletion is also different from that for the raising: Max blocks the former. Finally, the current survey (see Section 3.3) indicated that the number of items undergoing the deletion was considerably smaller than the number of items undergoing the raising. As noted in Section 3.3, this point suggests that it is possible for the occurrence of the deletion to be phonologically conditioned to some extent. As discussed in Section 2.3, such patterns can be accounted for by representational distinctions. Based on these observations, the current analysis proposes faithfulness constraints, as shown in (13).

(13) Positional faithfulness for the deletion
a. Max-WV/Open: *Weak vowels* must not be deleted in open syllables.
b. Max-WV/Closed: *Weak vowels* must not be deleted in closed syllables.

c. Max-V: Non-weak vowels must not be deleted.
d. Ranking with the markedness constraint on mid vowels:
Max-V, Max-WV/Closed » *Mid » Max-WV/Open

Note that the concrete underlying representation for vowels undergoing the deletion is not pursued in this study and is tentatively assumed as *weak vowels* (WV: denoted by the capital letters E or O) in the following OT analysis. While the faithfulness constraint on *weak vowels* in open syllables (13a) is ranked lower than the markedness constraint on mid vowels, the faithfulness constraint on normal vowels (13c) dominates *Mid regardless of syllable structure.

A summary of the OT analysis is presented in (14). In (14a), the candidate undergoing deletion in the closed syllable is eliminated by Max-WV/Closed, which is ranked higher than *Mid. By contrast, in (14b), the candidate avoiding deletion is eliminated by *Mid because this constraint is ranked higher than Max-WV/Open. When the underlying vowel is not *weak*, as seen in (14c), deletion is blocked by Max-V.

(14) Deletion of mid vowels: OT analysis
a. /kinEʦʲ/ ➔ [ki.neʦʲ] 'end.nom.sg.'
b. /kinEʦʲ-a/ ➔ [kin.ʦʲa] 'end.gen.sg.'
c. /reʧ-i/ ➔ [re.ʧi] 'matter.gen.sg.'

			Max-V	Max-WV /Closed	*Mid	Max-WV /Open
a.	/kinEʦʲ/	☞ ki.neʦʲ			*	
		kinʦʲ		*W	L	
b.	/kinEʦʲ-a/	ki.ne.ʦʲa			*W	L
		☞ kin.ʦʲa[10]				*
c.	/reʧ-i/	☞ re.ʧi			*	
		r.ʧi	*W		L	

Several points need to be considered here. First, the deletion cases, wherein the mid vowels emerge in closed syllables, are regarded as exceptions to the raising. The results shown in Section 3.3 indicate that the deletion is likely to avoid co-occurring with the raising, which suggests that the absence of raising in items undergoing the deletion should be conditioned phonologically rather than by a certain lexical property. Another point is that the deletion is also affected by usage frequency, which leads us to assume that this process, similar to the raising, is blocked by a lexically indexed faithfulness constraint, as shown in (15).

[10] Even though the nasal consonant [n] is embedded into the preceding syllable due to vowel deletion, the deleted [e], which would be between the [n] and the following [ʦ], is regarded as syllable-final.

(15) Faithfulness indexed to lexical properties
MAX$_{periphery}$-WV: *Weak vowels* must not be deleted in lexical items positioned at the *periphery*.

However, it remains unclear whether weak vowels can be spread to the periphery of the lexicon. This study does not pursue this topic and tentatively proposes that the vowel–zero alternation primarily occurs on *weak vowels*.

In summary, vowel raising and deletion in Ukrainian are generalized as the avoidance of mid vowels, which have been documented as marked across languages. With regard to positional effects and lexical exceptionality, faithfulness constraints specific to the relevant conditions block the phonological processes. The next section discusses the unresolved issue: neutralization into [i] in the raising.

4.2. Backness neutralization and the emergence of the unmarked

Another issue in Ukrainian vowel raising is backness neutralization: both /e/ and /o/ alternate with [i]. Especially problematic is the fronting of /o/ because the high back vowel [u] freely emerges without fronting (e.g., r**u**ka 'hand'; k**u**ʧa 'a lot of' etc.). This suggests that the faithfulness constraint on [back] (i.e., IDENT (back)) seems to be active in general, although backness is not preserved exclusively in the raising. As this process occurs in closed syllables, the following positional faithfulness constraint is assumed:

(16) Constraint on fronting
IDENT/OPEN (back): [back] must not be changed in open syllables.

However, this constraint cannot block fronting in closed syllables when the raising does not occur. The main point is that phonological processes are generally avoided unless they are required: in principle, lexically specified sound forms emerge without change, even if the given words are inflected. Phonological *uniformity* through morphological paradigm has been mentioned in the literature (see McCarthy 2005 for an OT analysis) and the constraint as shown in (17) is assumed.

(17) Constraint on *paradigm uniformity*
PARADIGMUNIFORMITY (PU): Sound forms on a morpheme must not alternate within a morphological paradigm.

Specifically, this constraint is not violated when the raising (or deletion) does not occur, whereas it is violated in the raising cases because the relevant constraint on mid vowels (i.e., *MID) is ranked higher than this one.

Now, let us return to the main question: why are mid vowels neutralized into [i]? The key to the current analysis is the default status of [i], which is confirmed by the vowel epenthesis discussed in Section 3.4. This is formalized by assuming that the constraint on this vowel (i.e., *i) is ranked lower than that on the other vowels. Such patterns have been generalized as the emergence of the unmarked in the OT framework, as noted in Section 2.2.

A full analysis based on (12) in the previous section is demonstrated in (18).

(18) Elimination of mid vowels and neutralization into [i]: OT analysis
a. /rok/ 'year.NOM.SG.' ~ /rok-ɪ/ 'year.NOM.PL.' ➔ [rik] ~ [rokɪ]
b. /retʃ/ 'thing.NOM.SG.' ~ /retʃ-i/ 'thing.NOM.PL.' ➔ [ritʃ] ~ [retʃi]
c. /ruk/ 'hand.GEN.PL.' ~ /ruk-ɪ/ 'hand.NOM.PL.' ➔ [ruk] ~ [rukɪ]

		IDENT/OP (high)	*MID	IDENT/OP (back)	PU	IDENT/CL (high)	*u	*i
a. /rok/ ~ /rok-ɪ/	rok ~ rokɪ		**W		L	L		L
	ruk ~ rokɪ		*		*	*	*W	L
	☞ rik ~ rokɪ		*		*	*		*
	rik ~ rikɪ	*W	L	*		*		**
b. /retʃ/ ~ /retʃ-i/	retʃ ~ retʃi		**W		L	L		*L
	rutʃ ~ retʃi		*		*	*	*W	*L
	☞ ritʃ ~ retʃi		*		*	*		**
	ritʃ ~ ritʃi	*W	L		L	*		***
c. /ruk/ ~ /ruk-ɪ/	☞ ruk ~ rukɪ						**	
	rik ~ rukɪ				*W		*L	*
	rik ~ rikɪ			*W			L	**

As seen in (18a, b), the mid vowels are eliminated by *MID in closed syllables because this constraint is ranked higher than IDENT/CLOSED (high), which is violated by the candidates undergoing the raising. In contrast, the raising is blocked in open syllables by IDENT/OPEN (high), which is ranked higher than the constraint on mid vowels. As a result, the paradigm candidates wherein high vowels emerge in closed syllables, whereas mid vowels emerge in open syllables, are preferred to the others. Since *i is ranked lower than *u, [i] is predicted in the raising wordforms. Finally, (18c) exemplifies non-alternation of /u/. Fronting in all the wordforms is eliminated by IDENT/OPEN (back) and fronting exclusively in the closed syllable is eliminated by PARADIGMUNIFORMITY because these constraints are ranked higher than *u.

4.3. Residual issues

Thus far, it has been argued that vowel alternations in Ukrainian are motivated by cross-linguistically affirmed phonological principles such as the markedness of mid vowels and the default status of epenthetic vowels. However, several issues remain to be resolved.

First, the default status of [i] must be verified precisely. In particular, the epenthesis of this vowel is observed exclusively in prefixes and prepositions. Therefore, it remains questionable whether [i] is generally unmarked in Ukrainian phonology. In addition, although the raising and deletion should be conditioned by the universal markedness of mid vowels, the difference between /e/ and /o/ in the likelihood of these processes should be discussed. Finally, lexical variations in the raising and deletion should be investigated in more detail. Previous research (Ito

and Mester 1995, 1999, among others) has suggested that such variable patterns can be *extended* in the lexicon, and it is predicted that some of the words that originally avoid a given phonological process come to undergo the same. In future studies, for instance, production and perception experiments with native speakers are expected to resolve these issues.

5. Conclusion

This study investigated the phonological mechanisms underlying vowel alternations in Ukrainian, and the discussion is summarized as follows. First, the raising and deletion of mid vowels are generalized as the avoidance of mid vowels, which are documented as marked compared to high and low vowels. Second, lexical exceptionality is attributed to specific faithfulness constraints that block given processes among *periphery* items, which are not used frequently. As for the deletion, however, a specific underlying representation (i.e., *weak* vowel) primarily triggers this process. Finally, the emergence of and neutralization into [i] in the raising is motivated by its default status, which is confirmed by the observation that this vowel can be epenthesized to avoid complex consonant clusters. This phonological pattern differentiates Ukrainian from other Slavic languages. In summary, the seemingly complicated sound alternations in this language are primarily grounded in universal phonological grammar.

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【要　旨】

ウクライナ語における母音交替―音韻的普遍性の観点から―

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本論文では，ウクライナ語で観察される中段母音の閉音節における高段化，中段母音の開音節における削除，および前置詞および接頭辞の直後における [i] の挿入について，これまでの理論研究において提唱されてきた普遍的な音韻原理に基づいて分析を行った。高段化および削除については，通言語的に有標とされる中段母音の回避が関連していると考えられ，音節構造に応じた局所的忠実性との競合によって交替が生じる。語彙的な例外性についても，使用頻度の低い語で交替が生じにくいことから，特に借用語音韻論において仮定されてきた，語彙的な性質によって優先度が異なる忠実性制約によって定式化される。一方で高段化における [i] への中和については，同言語では概して前後の交替が生じないため問題となるが，母音挿入によって裏付けられる [i] の無標性によって引き起こされると主張した。