Morea Linearity in Compensatory Lengthening*

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1 Theoretical Background

1.1 *Mora Theory* In Mora Theory (Hyman 1984, Hyman 1985, McCarthy and Prince 1986), phonological length distinctions are encoded in abstract suprasegmentals known as *moras* (μ), which are associated with segments below them and syllables above them via *association lines* (Goldsmith 1979). Accordingly, a vowel is short if associated with a single mora (1a), and long if two (1b). Meanwhile, onsets are assumed to be non-moraic, being instead associated directly with the syllables above them.

(1) Phonological weight in Mora Theory

a. Short vowel b. Long vowel

1.2 *Compensatory Lengthening* In many languages, the deletion, shortening, or desyllabification of one segment causes another segment to lengthen—a phenomenon known as *compensatory lengthening* (CL). For example, coda /s/ was deleted from Pre-Latin to Latin, lengthening the preceding vowel as shown in (2) (from Hayes 1989, taken from Ingria 1980). Although this example represents a historical change, CL also occurs as a synchronic phenomenon in languages like Slovak, as we will see below.

(2) Compensatory Lengthening in Pre-Latin

	Pre-Latin	Latin	Gloss
a.	*kasnus	kaːnus	"gray"
b.	*kosmis	koːmis	"courteous"
c.	*fideslia	fideːlia	"pot"

In moraic phonology, CL is analyzed as the transfer of a mora from one segment to another (Hayes 1989). For example, Pre-Latin **kasnus* underwent the changes illustrated in (3): after /s/ was deleted, its mora was preserved and transferred onto the preceding /a/, making it bimoraic, i.e. long. (Henceforth, dashed gray lines will indicate association lines that have been deleted, and solid black lines those that have been preserved or added. Additionally, nodes will be indicated in their surface positions using solid black labels, while their underlying/original positions will be given in gray. Finally, X will indicate a deleted segment/node.)

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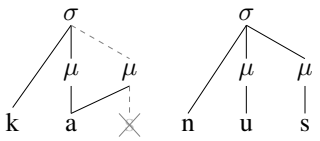
(3) CL in Pre-Latin: prosodic hierarchy



1.3 *Long-distance Compensatory Lengthening* The segment that is deleted or shortened is referred to as the *trigger* of CL, and the one that ultimately gains a new mora as the *target*. In some languages, trigger and target may originate in non-adjacent syllables. I term this *long-distance* CL (LDCL). In the following Estonian words, for example, the deletion of a vowel from the third syllable lengthens the final segment of the first (see Borgeson 2022 for analysis). Trigger and target have been underlined for ease of reference.

(4) LDCL in Estonian

	UR	SR	GLOSS
a.	/kyl̲.ma.ta̲/	[kyl̲ː.ma]	"cold.PART.SG"
b.	/ka̲ː.lu.ta̲/	[ka̲ː.lu]	"weight.PART.SG"
c.	/kas̲.si.ta̲/	[kas̲ː.si]	"cat.PART.SG"
d.	/koe̲.ra.ta̲/	[koe̲ː.ra]	"dog.PART.SG"

Nevertheless, there is a cross-linguistic preference for CL to be as local as possible (which is operative even within Estonian). This is captured in Borgeson (2022) by positing an expanded definition of LIN (below) that punishes the inversion of precedence relations among all nodes in the prosodic hierarchy.

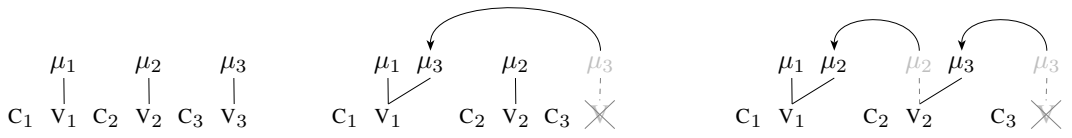
(5) LIN: Assign one violation if node X precedes node Y in the input, and is preceded by it in the output. This constraint evaluates all nodes in the prosodic hierarchy. (Paraphrased from Borgeson 2022:76).

Moving a mora over a single consonant and onto the preceding vowel will incur one violation of LIN, since the consonant preceded the mora in the input but the mora preceded the consonant in the output. Every additional such movement will incur another violation of LIN. As such, this constraint serves to favor local CL over more long-distance forms. Of course, languages can still display LDCL, but only if LIN is dominated in them by some markedness constraint that forces additional mora movements.

1.4 *Mechanisms of LDCL* There are two ways in which LDCL could in theory transpire, which I will refer to as "Swooping" and "Looping."[1] Although they result in phonetically identical outputs, they are nevertheless structurally distinct form one another.

To illustrate, let us consider the hypothetical input /CV.CV.CV/, shown in (6a). Let us suppose that it loses its final vowel, triggering CL and lengthening the first vowel (for unspecified reasons). There are two ways this could happen. First, the mora of the deleted vowel could be relocated directly onto its ultimate landing site, as in (6b); I term this "Swooping" LDCL because the mora moves in "one fell swoop." Second, the mora of the deleted vowel could be moved just one syllable leftwards, displacing the mora of that syllable and causing it to move one syllable leftwards as well, onto the ultimate target vowel. The result of this would be a chain reaction of local mora movements that add up to produce a long-distance effect, much like the balls of a Newton's Cradle. This possibility is illustrated in (6c); I will refer to it as "Looping LDCL."

(6) a. Input b. Output: Swooping c. Output: Looping



Swooping and Looping result in outputs that are phonetically identical (a long vowel in the first syllable), but structurally distinct: while Looping LDCL preserves the linear of moras, Swooping LDCL upsets it by

[1] The terms are obviously borrowed from the discussion surrounding successive cyclicity in syntax.

inverting the order of $\mu_2 \prec \mu_3$. But does this ever make a difference? After all, the identity of a mora does not matter – /vː/ is a long vowel whether it is associated with μ_1 and μ_2, or alternatively with μ_1 and μ_3.

Below, I will present evidence that the difference between the two mechanisms does indeed matter. Specifically, I will show that Swooping LDCL must be completely prohibited in Slovak, lest we predict LDCL in cases where it is not found. At the same time, Looping LDCL must be allowed, but constrained so that it does not apply in some cases. (The constraint responsible for reining it in is not able to prevent Swooping LDCL in the same manner—hence the need for the total ban.) Since the two strategies result in phonetically identical outputs, no markedness constraint can realistically distinguish between them. Instead, we must posit a constraint (LIN-μ) that forbids the inversion of moras, and hence rules out Swooping LDCL.

2 Slovak

2.1 *Yers in Slovak* Let us begin by establishing some basic facts about Slovak phonology. Slovak, like all Slavic languages, contrasts a set of *full vowels* (e o) with corresponding *yer vowels* (ĕ ŏ). Yer vowels are deleted in certain phonological contexts,[2] but full vowels are never deleted even in the same contexts. For example, the stem-final vowels of the words in (7) are all yers, and are deleted in the GEN.SG once a suffix has been added; by contrast, the vowels in (8) are all full vowels, and hence are not deleted even in the same environments. (Data from Rubach 1993:139.)

(7) Slovak: yer vowels

	NOM.SG	GEN.SG	GLOSS
a.	semest̲e̲r	semestra	“semester”
b.	še̲v	švu	“seam”
c.	kot̲o̲l	kotla	“cauldron”
d.	bah̲o̲r	bahra	“felly”

(8) Slovak: full vowels

	NOM.SG	GEN.SG	GLOSS
a.	jeseter	jesetera	“sturgeon”
b.	lev	leva	“lion”
c.	atol	atolu	“atoll”
d.	baxor	baxora	“belly”

2.2 *Compensatory lengthening in Slovak* When yers are deleted, they trigger compensatory lengthening. This may result in the lengthening of a preceding root vowel, as in (9), or a preceding suffix vowel, as in (10). (Trigger/target are underlined below. Note that /e o/ diphthongize to [ie uo] when lengthened.)

(9) Slovak: CL from suffix to root

a.	/r̲u̲k-ŏ̲/	[ru̲ː̲k]	“hand-GEN.PL”
b.	/mr̲a̲z-ŏ̲/	[mr̲a̲ː̲z]	“frost-NOM.SG”
c.	/s̲u̲d-ŏ̲k-a/	[s̲u̲ː̲dka	“cup-DIM-GEN.SG”
d.	/hl̲a̲v-ŏ̲k-a/	[hl̲a̲ː̲vka]	“head-DIMIN-NOM.SG”
e.	/dr̲e̲v-ĕ̲c-e/	[dri̲e̲vce]	“wood-DIMIN-NOM.SG”
f.	/č̲e̲l-ĕ̲c-e/	[či̲e̲lce]	“forehead-DIM-NOM.SG”
g.	/izĕ̲b-ŏ̲/	[izi̲e̲b]	“room-GEN.PL”
h.	/hĕ̲r-ŏ̲/	[hi̲e̲r]	“game-GEN.PL”

(10) Slovak: CL from suffix to suffix

a.	/mal-ĕ̲b-ŏ̲/	[mali̲e̲b]	“painting-NZ-GEN.PL”
b.	/pros-ĕ̲b-ŏ̲/	[prosi̲e̲b]	“request-NZ-GEN.PL”
c.	/tajom-stĕ̲v-ŏ̲/	[tajomsti̲e̲v]	“secret-NZ-GEN.PL”
d.	/viːtʲaz-stĕ̲v-ŏ̲/	[viːtʲazsti̲e̲v]	“victor-NZ-GEN.PL”

Based on this, I argue that yers are moraic underlyingly. If they were not, there would be no way for them to trigger CL upon their deletion. Further evidence for this position comes from the fact that yers are themselves able to be lengthened—exactly this occurs in (9g-h) and (10a-d)—and when they do, the result is bimoraic. If lengthening amounts to the addition of a single mora via CL, and if yers surface as bimoraic when lengthened in this way, then they must have been monomoraic to begin with.[3]

[2] A full description of where exactly they are deleted is outside of the scope of the present work. Here, we will simply assume that they are deleted where they must be deleted, and provide no further comment on the matter.

[3] Rubach (1993) instead argues that yers are non-moraic underlyingly, and that this is what distinguishes them from full

2.3 *CL in Slovak is blocked within stems* CL took place in the words above because the yers that were deleted there belonged to suffixes. By contrast, the deletion of a yer within the stem *never* results in compensatory lengthening. For example, deleting yers in (7) above and (11) below does not cause any other vowels to lengthen. (Unattested forms that incorrectly display lengthening are given in gray to the right.)

(11) Slovak: CL is blocked within roots

a.	/semestĕr-a/	[semestra]	*semiestra	"semester-GEN.SG"
b.	/kotŏl-a/	[kotla]	*kuotla	"cauldron-GEN.SG"
c.	/bobŏr-a/	[bobra]	*buobra	"beaver-GEN.SG"
d.	/svetĕr-a/	[svetra]	*svietra	"sweater-GEN.SG"

The term "stem" here includes bare roots (as above), as well as the combination of root + certain suffixes, which includes the nominalizers /-ĕb/ and /-stĕv/. As such, even though the following words contain yers that are deleted, this too fails to trigger CL because those yers originate within the stem (as defined above).

(12) Slovak: CL is blocked within the stem

a.	/mal-ĕb-a/	[malʲba]	*ma:lʲba	"painting-NZ-NOM.SG"
b.	/pros-ĕb-a/	[prosba]	*pruosba	"request-NZ-NOM.SG"
c.	/tajom-stĕv-o/	[tajomstvo]	*tajuomstvo	"secret-NZ-NOM.SG"
d.	/husit-stĕv-o/	[husitstvo]	*husi:tstvo	"hussitism-NZ-NOM.SG"

The failure of CL to apply within stems can be captured easily enough: all we need is a constraint that punishes the movement of moras within stems specifically (Hermans 1999:77).[4] For example:

(13) LIN(STEM): For two stem-internal nodes (including segments and moras), X and Y, assign one violation if node X precedes node Y in the input, and is preceded by it in the output.

If this constraint is undominated, it will allow CL to take place, but *only* if the mora being moved does not originate within the stem. This allows for CL to take place in (9-10), but not in (11-12).

2.4 *LDCL in Slovak* CL in Slovak can also be long-distance: in the following words, the deletion of a yer from the final syllable lengthens not the penult, but the antepenult.

(14) LDCL in Slovak

a.	/sud-ŏk-ŏ/	[su:dok]	"cup-DIM-NOM.SG"
b.	/kvet-ŏk-ŏ/	[kvietok]	"flower-DIM-NOM.SG"
c.	/hlav-ŏk-ŏ/	[hla:vok]	"head-DIM-GEN.PL"
d.	/hor-ŏk-ŏ/	[huorok]	"mountain-DIM-GEN.PL"
e.	/drev-ĕc-ŏ/	[drievec]	"wood-DIM-GEN.PL"
f.	/čel-ĕc-ŏ/	[čielec]	"forehead-DIM-GEN.PL"

This can be analyzed as follows. Mellander (2002, 2003) argues that Slovak displays a preference for feet of the shape (HL), and uses this to explain the famous Rhythmic Law (the shortening of two consecutive long vowels). I argue that this is what drives LDCL in the words above: outputs like [su:dok] are preferred over alternatives like *[suduok] because the foot structure (HL) is preferred over (LH) (Borgeson 2022). If the constraint enforcing this preference is promoted above LIN, then additional mora movements will be forced to take place in order to maximize the number of (HL) feet and minimize the number of (LH).

vowels. This faces two problems. First, why do vowels lengthen before an underlying yer? Rubach posits a rule that lengthens them there (example 62 on pg 187), but this seems phonologically arbitrary–why should vowels gain an extra mora (or, in Rubach's analysis, an extra X-slot) just because they happen to precede other vowels that lack them? By contrast, I argue that such vowels are lengthened as a result of compensatory lengthening, which is a robustly attested phenomenon. Second, if yers are underlyingly non-moraic, then they should surface as *mono*moraic when lengthened. As argued above, they in fact surface as *bi*moraic, indicating that they were monomoraic to begin with.

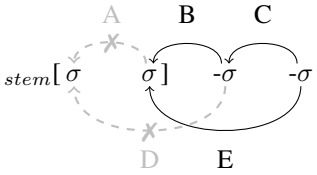
[4] Hermans' constraint targets the root rather than the stem, but serves fundamentally the same function.

2.5 *LDCL in Slovak is blocked by stem boundaries* Words of the shape $[\sigma]_{stem}\sigma\sigma$, such as those given in (14), display obligatory LDCL. But the following words have the shape $[\sigma\sigma]_{stem}\sigma$, and here LDCL is impossible. Instead, local CL takes place: when the final yer deletes, it is the penult that lengthens rather than the antepenult.

(15)	a.	/koryt-ŏ/	[kory:t]	*[kuoryt]	"trough"
	b.	/pokut-ŏ/	[poku:t]	*[puokut]	"penalty"
	c.	/sirot-ŏ/	[siruot]	*[si:rot]	"orphan"
	d.	/malěb-ŏ/	[malieb]	*[ma:leb]	"painting"
	e.	/prosěb-ŏ/	[prosieb]	*[pruoseb]	"request"

2.6 *Interim summary of CL in Slovak* To summarize, then, the deletion of a suffix yer CAN lengthen another suffix vowel (10) as well as a stem vowel (9), but the deletion of a *stem* yer CANNOT lengthen anything (11-12). Moreover, the trigger and target of CL in Slovak can be non-adjacent, but only if the intervening syllable is part of a suffix (14); if it instead belongs to the stem, LDCL is blocked and local CL takes place instead (15). All this is schematized below. Licit operations of CL are indicated using solid black arrows, and illicit ones with dashed, gray ones. The stem boundary is indicated using brackets.

(16)



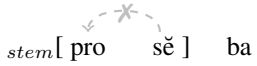
The upper arrows (A-C) correspond to local operations of CL. The facts here have successfully been explained: all such movements are licit except those that move moras around within the stem (i.e., arrow A), which is specifically prohibited by LIN(STEM). The lower arrows (D-E), meanwhile, indicate long-distance operations of CL. These are licit as long as the syllable separating the trigger and target is stem-*ex*ternal; if the trigger is preceded by a stem-*in*ternal syllable, then its mora may not skip past that syllable and land on the preceding one. Explaining this divergence will be the primary goal of the analysis given below. In short, I will argue for banning Swooping LDCL entirely, thereby reducing all instances of LDCL to Looping. Accordingly, the process of LDCL schematized using Arrow E will in fact necessarily amount to the combination of Arrows B + C, while Arrow D will necessarily amount to A + B. The illegality of Arrow D, then, can be attributed to the illegality of its constituent Arrow A.

3 Analysis

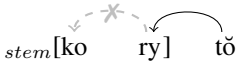
The key question raised by the Slovak data is this: how do we explain why LDCL is possible in words of the shape $[\sigma]_{stem}\sigma\sigma$ (14), but *not* in words of the shape $[\sigma\sigma]_{stem}\sigma$ (15)? In fact, the latter is a two-part question: how do we prohibit Swooping *and* Looping LDCL in such words? If we prohibit only one type of LDCL, we still predict that LDCL should take place via the other type, contrary to fact. We will examine each in turn below, starting with Looping.

3.1 *Constraining Looping LDCL* In fact, we have already explained why Looping LDCL is sometimes not possible: it amounts to a chain reaction of local mora movements, any step of which can be prohibited by LIN(STEM). The sum behavior of this constraint, then, is as follows. First, as we have already established, it will prohibit any and all forms of CL in words where a yer is deleted from within the stem, as in (17a). Second, in words of the shape $[\sigma\sigma]_{stem}\sigma$ (shown in 17b), it will allow a mora to travel from the third vowel to the second, but not from the second syllable to the first, since the latter would represent a stem-internal mora movement. This has the effect of prohibiting LDCL, but not local CL. Finally, in words of the shape $[\sigma]_{stem}\sigma\sigma$ (shown in 17c), the constraint will have nothing to say at all, because neither mora movement will be stem-internal. As a result, both will be permissible—in other words, LDCL will occur.

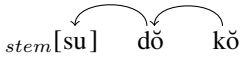
(17) a.



b.



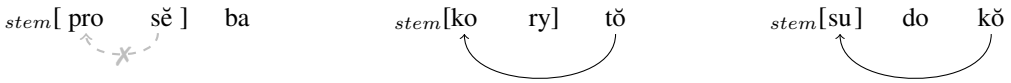
c.



Thus, we have successfully explained the distribution of LDCL—both why it takes place where it does, and why it does not take place elsewhere—but *only* as far as Looping LDCL is concerned.

3.2 *Swooping LDCL sidesteps this prohibition* When we consider Swooping LDCL as a possibility, the analysis fails. This is because it sidesteps the above prohibition entirely, and thus if we allow it at all, we predict that LDCL should take place in cases like (17b), contrary to fact. This is illustrated below using the same words as above. (Arrows indicate mora movements that should be possible according to the theory, rather than those that are actually attested.)

(18) a. $_{stem}$[pro sě] ba b. $_{stem}$[ko ry] tŏ c. $_{stem}$[su] do kŏ



LIN(STEM) can still correctly rule out (18a), but now fails to rule out (18b), precisely because the mora that is being moved belongs to the suffix /-ŏ/ rather than to the stem, and hence moving it into the stem does not violate LIN(STEM) any more than the mora movement seen in (18c) does. As a result, we predict that LDCL should be possible in both words, when in reality it only occurs in the latter.

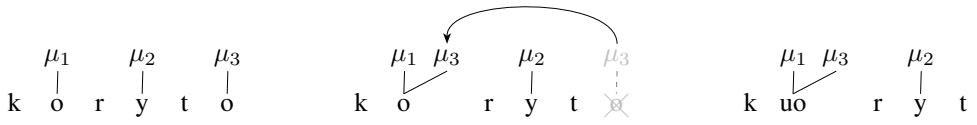
I argue that no constraint can successfully eliminate Swooping LDCL in (18b) without also eliminating it in (18c). If it takes place in one of them, it should be able to take place in both, as there is no structural difference between the two words other than the identity of the intervening syllable, which should not matter as it is not involved in the process. Since we cannot allow Swooping LDCL in one without allowing it in both, the only solution is to allow it in neither, and instead ascribe all instances of LDCL in Slovak to Looping, which is much more easily constrained.

3.3 *Banning Swooping LDCL entirely* Looping LDCL can be constrained by LIN(STEM) so that it applies exactly where it is attested, and is blocked where it does not occur. Swooping LDCL, by contrast, is not so easily tamed. It must therefore be banned entirely in Slovak, lest we predict LDCL where it does not occur. The question now becomes how to accomplish this. Since the two produce phonetically identical outputs, there is no markedness constraint that will realistically be able to distinguish them. Instead, we need a constraint that punishes the structural difference between them, namely the inversion of moras found in Swooping LDCL that was discussed above. For this, I propose the following.

(19) LIN-μ: For every pair of moras, μ_x and μ_y, assign one violation if μ_x precedes μ_y in the input but is preceded by it in the output.

The prosodic hierarchies in (20) illustrate how Swooping LDCL as it occurs in (18b) violates LIN-μ: in the input, μ_2 precedes μ_3, but in the output, the reverse is true. (The actual attested output for this word is [kory:t] = 15a.)

(20) a. Input = /koryt-ŏ/ b. Swooping LDCL c. Output = *[kuoryt]



If LIN-μ is undominated in Slovak, then Swooping LDCL will be prohibited entirely. Looping can still be admitted, but with the caveat that it may not violate LIN(STEM), as noted above. In short, then, we obtain the following behavior. In words of the shape $[\sigma\sigma]_{stem}\sigma$, LDCL is prohibited in both its forms: Looping is prohibited by LIN(STEM), and Swooping by LIN-μ. In words of the shape $[\sigma]_{stem}\sigma\sigma$, Swooping is still prohibited, but now Looping is possible because it no longer violates LIN(STEM). Thus, LDCL can only take place in the latter case, and only via Looping. This is summarized below.

(21) Slovak: summary of LDCL behaviors

	Swooping LDCL	Looping LDCL
$[\sigma\sigma]_{stem}\sigma$	Prohibited by LIN-μ	Prohibited by LIN(STEM)
$[\sigma]_{stem}\sigma\sigma$	Prohibited by LIN-μ	Permitted

3.4 LIN-μ *and* LIN *are different constraints* Now admittedly, every time LIN-μ is violated, it will necessarily incur a large number of violations of LIN as well, since any mora that moves to the left of another mora must move to the left of its host segment as well, in addition to any intervening segments. As such, one might be tempted to say that any candidate that displays Swooping LDCL will automatically be harmonically bounded by another candidate that instead displays Looping. If this were the case, then there would be no reason to posit LIN-μ at all. But this harmonic bounding does not exist—although it is true Swooping will always do worse with respect to LIN than Looping, it can also avoid violations of LIN(STEM) that Looping incurs. Thus, separate constraints are indeed needed. Furthermore, the two constraints cannot be conflated for the additional reason that they must be ranked separately in Slovak: LIN-μ must be undominated, as argued above, but LIN must be ranked fairly low—if it were undominated too, it would prohibit *any* movement of a mora over an intervening consonant, and hence prohibit CL in the language altogether.

4 Conclusion

In short, I have argued that LDCL can take place in one of two ways: Swooping and Looping. Thus, if LDCL can take place in a given language, but not in words of a given shape, we must explain why *both* types of LDCL fail. In Slovak, Looping LDCL takes place, but stops as soon as it hits the stem boundary, as otherwise it would run afoul of the constraint LIN(STEM) (which also prohibits single mora movements not involved in such chain reactions). By contrast, Swooping cannot be so easily contained: if we allow it at all, we predict that LDCL will occur in words where it does not. Thus, it must be banned entirely, and all LDCL that occurs in the language must be attributed to Looping. Since the two strategies result in phonetically identical outputs, the only way to ban Swooping but not Looping is via the mora linearity constraint LIN-μ.

Stepping back for a moment, some broad takeaways from these findings are as follows. First, moras are not interchangeable: they must be individually labeled and tracked in the phonological derivation in the same way that individual segments are. In other words, μ_2 and μ_3 are as distinct from one another as /o/ and /a/ are. If this were not the case, we would have no way of knowing whether a particular output mora in Slovak corresponded to an input *stem* mora, or alternatively an input *suffix* mora, and hence whether it should be permitted to move over a stem-internal consonant or not. Second, the ordering of moras with respect to one another matters as well. Reordering moras does not have any discernible phonetic effects, but the phonology of Slovak tells us that it must be made illegal outright in that language. Finally, the traditional constraint LIN(EARITY) must be broken into a stringency hierarchy composed of numerous constraints, including at least the general constraint LIN (which governs the linear ordering of all segments in the prosodic hierarchy) as well as the mora-specific LIN-μ, and likely also a segment-specific LIN-SEG (which would thus take over the function of the constraint traditionally labeled LIN). Other constraints in the hierarchy may exist as well, e.g. LIN-σ or LIN-ϕ, but their existence would undoubtedly be more difficult to establish, since any reordering of syllables or feet would naturally entail the reordering of their segments as well.

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