Layered feet and syllable-integrity violations: The case of Copperbelt Bemba bounded tone spread

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Abstract

We identify evidence supporting two amendments to standard metrical theory: the inclusion of layered feet, and the allowance of syllable-integrity violations, where a foot parses some, but not all, of a syllable's constituents. The evidence comes from a High tone spreading process attested in Copperbelt Bemba (CB), which as reported by Bickmore and Kula (2013) et seq., occurs over a ternary domain. In quintessentially metrical fashion, the domain is sensitive to the presence and position of heavy syllables. Thus, we argue that metrical theory should take the CB data into account.

CB ternary spreading can occur in contexts with an abundance of unparsed syllables on either side of the domain. We argue that this property is problematic for 'Weak Layering' accounts using binary feet (McCarthy and Prince 1986; Hayes 1995), which revolve around the minimal presence of unparsed syllables. We propose an alternative account using layered feet (Martínez-Paricio and Kager 2015), specifying an inner quantity-sensitive iamb and a strictly monomoraic adjunct. We show that a principled characterization of the spreading domain is that tone associates to all and only footed moras. We argue that a metrical analysis provides a more principled account of the data than can be achieved by Bickmore and Kula's purely autosegmental analysis.

Finally, we show that foot-based accounts of CB ternary spreading predict syllable-integrity violations (SIVs), where parsing consumes only the first of two tautosyllabic moras. Contrary to the common view that SIVs are universally disallowed, we embrace this result and put it in a typological context. We adopt an Optimality Theory constraint set to model SIVs (Kager and Martínez-Paricio 2018b), and extend it, paving the way for a typological investigation of SIVs.

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1 Introduction

1.1 Successes and a challenge for binary feet

Arguably the most common conception of a metrical foot is that it is a syllable-parsing constituent that is by default binary, and exceptionally unary (McCarthy and Prince 1986, 1993b; Hayes 1995).[1] Languages differ in whether they parse heavy syllables into unary feet or not, and in whether the binary foot is left or right-headed. Feet with heads on the initial member are called trochees, and those with heads on the final member are called iambs. Headedness asserts itself not only through a crosslinguistic variety of phonetic correlates, but also through the quantity asymmetries that the foot allows; only iambic feet can parse a sequence of a light and a heavy syllable (denoted as $\sigma_\mu \sigma_{\mu\mu}$), while only trochaic feet accept the parsing of a sequence $\sigma_{\mu\mu} \sigma_\mu$.

The original development of these representations was mainly driven by considerations from stress typology. However, feet also found use in accounting for prosodic morphology, prosodic minimality, reduplication, locus of infixation, truncation, and templatic and root-and-pattern morphology (Broselow 1982; McCarthy and Prince 1986, 1993b; Itô 1990; Mester 1990, 1994; Poser 1990; Spring 1990; Crowhurst 1991, 1994; Wiese 2001; Bat-El 2005; Alderete and MacMillan 2015). In addition, binary feet have been invoked to describe the domain for a variety of phonological processes (Nespor and Vogel 1986; Dresher and Lahiri 1991; Halle and Kenstowicz 1991; Rice 1992; Kenstowicz 1993; Mester 1994; Hayes 1995; Bennett 2012).

Binary foot theory has had to grapple with phenomena that operate over what we will loosely call a "ternary" domain, whose size exceeds a binary foot by an additional mora or syllable. Several ways of dealing with ternary phenomena using binary feet have been developed, which together account for previously considered cases of ternarity. In this paper, we will identify a type of ternarity that has received insufficient attention in the literature on metrical theory. We will develop this claim using data from Copperbelt Bemba (CB), which shows quantity-sensitive, ternary tone spreading (Bickmore and Kula 2013; Kula and Bickmore 2015). We will show that this ternarity cannot be captured by traditional, binary means. Consequently, we will argue for a revision of foot theory to include larger and more flexible constituents. In the course of making this argument, we will also develop a foot-based analysis of CB bounded tone spreading, and argue that it is preferable to Bickmore and Kula's purely autosegmental analysis, in which the domain shape was directly stipulated. In order to explain the relevance of the CB data to metrical theory, we will first give an overview of the way that ternarity has previously been handled in binary foot theory.

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[1] An earlier version of this paper was published in the proceedings of the 2016 Annual Meeting on Phonology (Breteler and Kager 2017).

1.2 Analyzing ternarity with binary feet

At least three types of ternarity have previously been identified. Firstly, some languages target the third position from an edge. For example, in Macedonian strings of three or more syllables, stress falls on the third syllable from the right (Beasley and Crosswhite 2003), as in (1). We mark syllable boundaries with full stops.

(1)   a.   ˈtat.kov.tsi   'fathers'
        b.   tat.ˈkov.tsi.te   'the fathers'
        c.   ˈri.do.vi   'hills'
        d.   ri.ˈdo.vi.te   'the hills'

Secondly, in Japanese, a process of word clipping can lead to tripartite forms, such as the trisyllabic loanwords in (2) (Itô and Mester 1992, forms shown here with accent marking). Crucially, these loanwords come from longer source forms, suggesting that a clipping process is at work that has favored the tripartite outcome over other options.

(2)   a.   ˈa.ni.me   'animation'
        b.   ˈte.re.bi   'television'

Finally, some languages display iterative stress occurring every three syllables. A classic case is Cayuvava, which stresses every third syllable counting from the right, as shown with the example in (3) (Key 1961, 1967; Levin 1985).

(3)   ˈca.a.di.ˈro.bo.βu.ˈru.ru.ce   'ninety'

The binary feet solutions to the types of ternarity presented above all make use of unparsed syllables. We will refer to these approaches collectively as "Weak Layering."

For third-from-the-edge patterns, binary feet accounts invoke extrametricality of the edgemost syllable (Liberman and Prince 1977; Hayes 1982). For the example in (1), this means that the final syllable is not available for metrical parsing. The penultimate and antepenultimate positions are then effectively rightmost, and by that status they can be the exclusive targets of foot parsing, leading to representations such as [tat.(ˈkov.tsi).<te>].

For the clipping patterns in Japanese, Itô and Mester (1992) suggest that a ternary structure can emerge from parsing preferences. They suggest Japanese ternary forms are instances of a structure they term the "loose minimal word," containing a binary foot and, optionally, an unparsed light syllable.[2] Thus, for the case of 'animation' they propose the structure [$_{Wd}$ (a.ni)me].

Finally, Hayes (1995:308) proposes that ternary iterative stress languages such as Cayuvava have a parsing parameter set to Weak Local Parsing (WLP), which positions feet so that they are non-adjacent, but only minimally so (see also Kager 1993, 1994; Elenbaas and Kager 1999). This leads to forms where binary feet are interleaved with stray light syllables. Hence, under the assumption of WLP, and with the application of extrametricality, the structure of the form in (3) comes out as [(ˌca.a).di.(ˌro.bo).βu.(ˈru.ru).<ce>].

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[2]Itô and Mester credit unpublished work by McCarthy and Prince (1991a,b) for the concept of the loose minimal word.

1.3 Ternarity in Bantu tonology

In summary, the Weak Layering approaches above account for ternary patterns in a binary foot theory by *minimally* allowing the presence of unparsed syllables. The nature of this approach also suggests its limitation: The success of Weak Layering, and by extension binary foot theory, might not extend to cases where a ternary target is embedded in a context with *abundant* unparsed syllables (e.g. a case where a ternary domain is flanked by multiple unparsed syllables on either side). In previous literature on metrical theory, such contexts have not been identified. However, previous literature on *tonology* has long discussed phenomena that might be argued to show exactly this type of ternarity, particularly in the context of Bantu tonal reassociation. Bickmore and Kula (2013:Sect. 6) present a survey of previous literature on ternary tone phenomena, showing that this literature goes back at least as far as Myers (1987), who reported a trisyllabic tone spreading pattern for the "North-Central" dialects (Zezuru, Korekore, and Northern Karanga) of Shona. In this paper, we will consider bounded, ternary tone spreading data from Copperbelt Bemba (Bickmore and Kula 2013; Kula and Bickmore 2015), and argue for a metrical account of the CB tone spreading domain. In pursuing such an account, we accept the premise of earlier work that metrical structure can be an organizing factor for tonal distributions, even when no claims about accompanying stress are involved (Goldsmith 1987; Sietsema 1989; Downing 1990; Kenstowicz and Kisseberth 1990; Cassimjee and Kisseberth 1992; Bickmore 1995; Zec 1999; De Lacy 2002; Pearce 2006; Weidman and Rose 2006; Shimoji 2009; Green 2015; Breteler 2017).

We believe that among the various reported cases, Copperbelt Bemba presents the clearest case of a need for a metrical account of ternary tone phenomena. Firstly, this is because, unlike other reported cases, CB ternary tone spread is quantity-sensitive, meaning that the realization of tone depends on the sequencing of light and heavy syllables. Running ahead of our data discussion in the next section, we demonstrate the point briefly here with the pair of forms in (4); we mark tone with acute accent and syllable boundaries with periods. We indicate the lexical origin of the tone with underlining.

(4) | | *Tone domain shape* | *Example and gloss* |
|---|---|---|
| a. | $\underline{\acute{\sigma}_{\mu}}\acute{\sigma}_{\mu\mu}\acute{\sigma}_{\mu}$ | **bá.kéé.mbí**.la.kó |
| | | 'they will dig for' |
| b. | $\underline{\acute{\sigma}_{\mu\mu}}\acute{\sigma}_{\mu}$ | tu.**léé.mú**.ʃii.ki.la bwii.no |
| | | 'we are burying well for him' |

In both forms above, a rightward tone spreading process has applied; we show the resulting tone spans in boldface. Compared to (4b), the tone span in (4a) is larger both in mora and syllable count, despite the presence of further anchors for tone to spread to in (4b). As we will detail in this paper, the surface tonal difference between these forms can be traced back to a difference in the sequencing of heavy and light syllables that tones encounter on their spreading paths. Quantity sensitivity is a property that is classically associated with foot structure. Two other cases of ternary tone spans mentioned by Bickmore and Kula (2013:Sect. 6) are Shona (Myers 1987) and Ikalanga (Hyman and Mathangwane 1998). In these cases, different spreading

rules apply within e.g. the stem, the prosodic word, and the phrase. Consequently, any ternarity found in the surface tonal spans of these languages is interpretable as an epiphenomenon, the sum of multiple tone spreading effects occurring in the course of morphophonological composition. In CB, there is no indication of such domains being involved in bounded ternary spreading (but see Kula and Bickmore 2015 for another phrasal tonal phenomenon in CB). In general, Bickmore and Kula (2013:127) state that ternary spreading is "a widespread and across the board phenomenon" in the language.

A second reason to single out CB over other ternary tone patterns is that CB shows a spreading pattern, rather than a shifting pattern. Bickmore and Kula (2013:Sect. 6) mention some cases of ternary shift, i.e. cases where tone disassociates from its lexical origin and associates to a position that is two tone-bearing units away from this origin. This type of phenomenon is attested in Sukuma, which, generally, maps /µ́µµ/ to [µµµ́] (Richardson 1971; Goldsmith 1985; Sietsema 1989; Batibo 1991; Kang 1997), and Saghala, which maps /σ́σσ/ to [σσσ́] (Patin 2009; Breteler 2017). While the tonal phenomena in these languages cross ternary distances, there is no ternary tonal span at the surface, since tone has delinked from its lexical origin. Consequently, we believe the spreading case of CB is clearer than these tone shift cases in the sense that CB presents not just ternary-sized reassociation, but also demonstrates that the grammar requires surface ternarity. In conclusion, we select the example of CB ternary tone spreading to demonstrate that ternarity in natural language can come in a shape that exceeds the generative capabilities of Weak Layering approaches.

1.4 Layered feet and syllable integrity violations in CB

To formally describe the CB spreading domain, we will adopt layered feet (Bennett 2012; Kager 2012; Martínez-Paricio 2013). These representations allow for a second foot layer, which parses a typical binary foot along with an adjunct element. This allows for nested, ternary constituents, such as $((\sigma\sigma)\sigma)$. As we will show, with the correct specification of parsing behavior for both foot layers, we can reduce the various shapes of the CB tone spreading domain to a single foot type. The layered feet framework retains the binary foot as a representational element, extending the representational schema rather than overthrowing it. Hence, we retain the fruits of research performed in the context of binary feet frameworks.

The CB data motivate another revision of traditional foot theory, namely the assumption of syllable integrity. That is, our account of the CB data contains instances where a foot parses one mora of a heavy syllable, but not the other. This analysis is driven by the observation that under specific circumstances, CB tone spread stops in the middle of a heavy syllable. For example, we will argue for the layered, syllable-integrity violating foot structure over the initial tone span in the form: ((bá.ká).ʃí)i.ka.kó 'they will bury.'

Although foot theory has traditionally assumed strict syllable integrity (Prince 1976; Hayes 1995), some work has questioned this assumption (Halle and Vergnaud 1987; Buller et al. 1993; Everett 1996; Blevins and Harrison 1999; Martínez-Paricio 2013; Kager and Martínez-Paricio 2018b). In this paper, we will situate CB tone spread in this discussion. We suggest that on a continuum of strictly moraic to strictly

syllabic footing, CB can be seen as taking up an intermediate position since it has "blended" footing, which is partly syllable-parsing, and partly mora-parsing. We will also extend the Optimality Theory (OT, Prince and Smolensky 1993) constraint set for syllable-integrity violations proposed in Kager and Martínez-Paricio (2018b).

In the next section we describe the Copperbelt Bemba data and argue in favor of a foot-based generalization. Then, we show in Sect. 3 that none of the Weak Layering approaches are suitable for an account of CB ternary tone spreading. In Sect. 4, we introduce the layered feet framework and offer a layered feet analysis of the CB data. In Sect. 5, we consider and reject an alternative analysis with binary feet. Based on further CB data involving (near-)contact between multiple tonal autosegments, we argue that it does not avoid the use of syllable-integrity violations. In Sect. 6, we consider a more detailed model of syllable-integrity violations in our account of CB, using an OT approach. In the discussion in Sect. 7, we discuss previously raised objections against syllable-integrity violations, briefly consider alternative theoretical approaches, and point to peculiarities of the data with regard to prenasalized consonants. After that, the paper concludes.

2 Ternarity in CB bounded tone spreading

All data in this section are taken from Bickmore and Kula (2013) and Kula and Bickmore (2015), which we will collectively refer to as B&K. They use the term "Copperbelt Bemba" to refer to a variety of Bemba spoken in the Copperbelt province of Zambia. Their reports also provide a comparison between CB and "Northern Bemba," the variety of Bemba predominantly discussed in previous literature on Bemba. See Hamann and Kula (2015) for a study of the phonetics of a Copperbelt Bemba speaker.

Our focus is on the facts of CB bounded high tone spreading, a process where a tone spreads across a bounded domain that is calculated relative to that tone's starting position. We call the tone-bearing unit (TBU) at this starting position the "sponsor" (following Cassimjee and Kisseberth 1998); this is the TBU that the tone is underlyingly associated to. The tone spreading domain is bounded, in the sense that spreading does not iterate indefinitely to the edge of the phrase. However, the domain is larger than can be covered by any binary foot. In the following, we will go through the data to show the various ways in which the domain spans different sequences of heavy and light syllables. Then, we will discuss B&K's purely autosegmental analysis of the data, arguing that their account misses an opportunity to tie together the various weight groupings of the spreading domain in a principled way. We will go on to demonstrate the plausibility of a foot-based generalization, which will serve as the basis for the theoretical accounts considered in later sections.

We start with a discussion of some general tone facts of CB, and basic theoretical assumptions. In all respects, our choices match those of B&K. There are two level tones, which we will refer to as high and low, respectively. The contrastive nature of these tones follows from the observation of tonal minimal pairs, such as [luká] 'weave!' vs. [lúká] 'vomit!' (Bickmore and Kula 2013:104). We follow B&K in assuming that only high tones are active in the phonology, represented as tonal autosegments. We think this is a non-problematic assumption from a phonological

perspective; we have not seen processes that suggest the imposition of low tone on lexically high positions, or the blocking of high tone spreading by the presence of low tone (but see Myers 1998 for options for further phonetic investigation into such matters). Low tones could be inserted either "late" in the phonology (i.e. in a way that does not interfere with other phonological processes), or as the phonetic implementation of phonologically toneless TBUs; we have no reason to prefer one of these analyses over the other. On long vowels, CB can display falling tones in addition to level tones. Rising tones are absent from the data (Yip 2002:27–30). Because falling tones appear only on bimoraic syllables, we take the mora to be the TBU in CB, and we analyze a falling-toned syllable as one where only the first of two moras is associated with a high tone. Both light and heavy syllables can contain sponsor moras, but sponsor moras are generally leftmost in heavy syllables.[3]

We focus our discussion on surface forms, because this is sufficient for discussing foot and tone structure in the language. Notably, the application of some processes is obscured by our simplified presentation of the data. Firstly, sequences of short vowels trigger coalescence and glide formation (Hamann and Kula 2015). Second, like many Bantu languages, CB displays imbrication, where the perfective suffix fuses with preceding material, again applying vowel coalescence, as well as loss of a consonant. For example, a verbal base ending in the reciprocal morpheme /an/ and followed by the perfective suffix /ilé/ will surface as [eené] (Kula 2013 and refs therein). For a more detailed presentation of underlying forms, we refer the reader to B&K's more comprehensive coverage.

In addition to bounded tone spread, an unbounded spreading process is also active in CB, and it is relevant to the interpretation of the data. If a tone is the rightmost tone in a phrase-final word, it spreads unboundedly to the final syllable, masking any potential ternary spreading. For this reason, many of the data have two tones, so that we can study ternarity on the leftmost tone; we will ignore rightmost tones in those cases.[4] For example, (5a) shows unbounded rightward tone spreading from /bá/; the bounded spread becomes visible in (5b) through the addition of a second lexical High on /kó/. In these and following data presentations, we list the data source, with page and example numbering; BK13 stands for Bickmore and Kula (2013) and KB15 stands for Kula and Bickmore (2015). We write hyphens to indicate morpheme boundaries in the verb phrase, and use underlining for the suggested lexical origins of high tones.

(5) $\acute{\sigma}_\mu \acute{\sigma}_\mu \acute{\sigma}_\mu$

    a. <u>bá</u>-lá-mú-lúk-íl-á   'they weave for him/her'   BK13:111, (17c)

    b. <u>bá</u>-mú-lúk-il-a=<u>kó</u>   'they plait a bit for him'   KB15:149, (2d)

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[3] It is possible to position sponsor moras as the second mora in a heavy syllable by combining a vowel-final and vowel-initial morpheme, which leads to a derived vowel (Lee Bickmore, p.c. 2015), but to our knowledge, there are no tautomorphemic cases where tone is on the second mora of a heavy syllable. In any case, we do not have sufficient data with second-mora heavy syllable sponsors, so we will restrict our discussion to data where sponsoring moras are syllable-initial.

[4] The source of the rightmost tone is sometimes a melodic tone pattern, where tone is a reflection of tense–aspect–mood morphology that targets specific positions, instead of being underlyingly linked to the TBU marked as sponsor (Odden and Bickmore 2014). This does not impact the generalizations we make; in either case, tone behaves as if it originated in the marked position.

The unbounded spreading occurs at the phrasal level (Kula and Bickmore 2015), while the bounded pattern occurs at the word level. Consequently, the unbounded pattern cannot block or otherwise hinder the application of the bounded pattern. In addition, the unbounded spreading pattern simply targets the right edge of the phrase, without seeming to place any requirements on the footing or span shape of the spreading tone, so unbounded spreading does not place extra demands on our analysis of the bounded spreading. We conclude that bounded spreading can be fruitfully studied separately from unbounded spreading, because the two patterns operate orthogonally from one another.

Another tonal phenomenon of CB is its sensitivity to the contact or near-contact of tonal autosegments; tone spreading sometimes stops short of its expected target because of the presence of another tone. In other words, the Obligatory Contour Principle (OCP) plays a role in CB tone spreading. For this section, where possible, we have selected only data where the OCP is not relevant. We take up OCP cases in Sect. 5.1.

2.1 Ternarity and quantity sensitivity

Firstly, in strings of only light syllables, tone spreads twice, covering the sponsor and the two syllables that follow, as shown in (6). As before, we underline suggested tone sponsors and write hyphens between morphemes. In addition, we separate words with whitespaces. We follow Kula and Bickmore's (2015:149) assessment of word status, particularly their inclusion of the post-verbal enclitic /kó/ into the prosodic word. We denote the clitic boundary with =. We denote syllable weight by subscripting the mora count: Light syllables come out as σ_μ and heavy syllables as $\sigma_{\mu\mu}$. Syllables with a High tone are accented, showing as $\acute{\sigma}$.

(6) $\underline{\acute{\sigma}_\mu}\acute{\sigma}_\mu\acute{\sigma}_\mu$

a.	<u>bá</u>-ká-pá-ta=<u>kó</u>	'they will hate a bit'	KB15:149, (2c)
b.	<u>bá</u>-mú-lúk-il-a=<u>kó</u>	'they plait a bit for him'	KB15:149, (2d)
c.	ta-tú-lúk-íl-ee<u>né</u>	'we didn't plait for each other'	KB15:149, (2a)
d.	<u>bá</u>-ká-sálul-a bwiino	'they will fry well'	KB15:150, (3b)

The contrast between (6b,c) shows how the same morpheme sequence /luk-il/ 'plait-APPLICATIVE' is realized with High tone on different syllables depending on the distance of this morpheme from the preceding sponsor. Consequently, alternations like these support the interpretation of the data as a productive, left-to-right spreading process.

The spreading domain shows itself to be more complicated when heavy syllables are involved. All and only long vowels constitute heavy syllables in Copperbelt Bemba. The position of heavy syllables in the string matters to the outcome of tone spreading. Surface tone in cases where the sponsor itself is heavy are shown in (7). Tone spreading when the sponsor is light but the following syllable is heavy are shown in (8).[5]

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[5]We follow the transcription style of Kula and Bickmore (2015). That is, for data taken from Bickmore and Kula (2013), we have changed "sh" to "ʃ" and "ng" to "ŋg."

(7) $\acute{\sigma}_{\mu\mu}\acute{\sigma}_{\mu}$
     a. tu-ka-<u>léét</u>-él-an-a=<u>kó</u>   'we will bring for each other' BK13:112, (19a)
     b. tu-<u>léé</u>-mú-ʃiik-il-a bwiino 'we are burying well for him' KB15:158, (20b)

(8) $\acute{\sigma}_{\mu}\acute{\sigma}_{\mu\mu}\acute{\sigma}_{\mu}$
     a. <u>bá</u>-ké-émb-íl-a=<u>kó</u>   'they will dig for'   BK13:111, (18e)
     b. <u>bá</u>-lóóndólol-é   'that they introduce'   BK13:111, (18f)
     c. tu-ka-<u>bé</u>lééŋg-él-an-a=<u>kó</u> 'we will read for each other' BK13:111, (18h)

With the data so far, we already have enough grounds to conclude that the term "ternary" will have to entail more than simply a rule counting to three. As the table in (9) shows, the tone spreading domain is neither strictly trisyllabic, nor strictly trimoraic; in specific cases, it is disyllabic or quadrimoraic.

(9)

	syllable count	*mora count*
$\acute{\sigma}_{\mu}\acute{\sigma}_{\mu}\acute{\sigma}_{\mu}$	3	3
$\acute{\sigma}_{\mu\mu}\acute{\sigma}_{\mu}$	**2**	3
$\acute{\sigma}_{\mu}\acute{\sigma}_{\mu\mu}\acute{\sigma}_{\mu}$	3	**4**

Before considering alternative generalizations, we complete our survey of the data with cases where the spreading domain ends in a heavy syllable.

2.2 Falling tones

In the data so far, all syllables affected by tone spreading had level high tones. However, this is not the case when the spreading domain ends in a heavy syllable. Rather, domain-final heavy syllables surface with a falling tone. Thus, for each of the cases we described above, there is an analogous case where the domain-final syllable is heavy instead of light, and where tone on that syllable is falling instead of level; we show these cases in (10-12).[6] Falling tones are marked with a circumflex accent, showing as $\hat{\sigma}$.

(10) $\underline{\acute{\sigma}_{\mu}}\acute{\sigma}_{\mu}\hat{\sigma}_{\mu\mu}$
     a. <u>bá</u>-ká-ʃíik-a=<u>kó</u>   'they will bury'   BK13:111, (18c)
     b. <u>bá</u>-ká-lóondolol-a=<u>kó</u> 'they will introduce'   BK13:111, (18d)
     c. <u>bá</u>-ká-ʃíik-il-a tʃituundu tʃaaŋga bwii.no
       'They will bury the bushbaby well for Chituundu.' KB15:164, (25)

(11) $\underline{\acute{\sigma}_{\mu\mu}}\hat{\sigma}_{\mu\mu}$
     a. tu-<u>léé</u>-lóondolol-a=<u>kó</u>   'we are introducing'   BK13:112, (19b)
     b. tw-aa-<u>léé</u>-mw-íimb-il-a=<u>kó</u> 'we used to dig for him' BK13:112, (19c)

B&K provide one datum showing tone spreading for the sequence $\sigma_{\mu}\sigma_{\mu\mu}\sigma_{\mu\mu}$. It is shown in (12). This datum has three sponsors, with tone contact occurring through spreading between the first and second sponsors. A downstep, indicated with the symbol "!", indicates the transition between the two spans. We offer a discussion of tone

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[6]In (10b), we added a nasal consonant to the verb root *loondolol* that was absent in Bickmore and Kula's (2013) original datum, but present in all their other presented instances of this stem.

Table 1 The various shapes of the ternary CB tone spreading domain

Seen in..	Domain shape	Example form and gloss
(6)	$\acute{\sigma}_\mu\acute{\sigma}_\mu\acute{\sigma}_\mu$	bá.ká.pá.ta.kó 'they will hate'
(7)	$\acute{\sigma}_{\mu\mu}\acute{\sigma}_\mu$	tu.lée.mú.ʃii.ki.la bwii.no 'we are burying well for him'
(8)	$\acute{\sigma}_\mu\acute{\sigma}_{\mu\mu}\acute{\sigma}_\mu$	bá.kéé.mbí.la.kó 'they will dig for'
(10)	$\acute{\sigma}_\mu\acute{\sigma}_\mu\hat{\sigma}_{\mu\mu}$	bá.ká.ʃíi.ka.kó 'they will bury'
(11)	$\acute{\sigma}_{\mu\mu}\hat{\sigma}_{\mu\mu}$	tu.lée.lóo.ndo.lo.la.kó 'we are introducing'
(12)	$\acute{\sigma}_\mu\acute{\sigma}_{\mu\mu}\hat{\sigma}_{\mu\mu}$	ú.kú.ˈtá.láá.ntáa.nta ku.kú.lú 'the big stumbling'

contact in Sect. 5.1. For now, we are concerned only with the tone spreading starting from /tá/, which follows the generalization mentioned above that tone spreading is analogous to spreading for the sequence $\sigma_\mu\sigma_{\mu\mu}\sigma_\mu$, except that the domain-final syllable shows a falling tone.

(12) $\underline{\acute{\sigma}_\mu}\acute{\sigma}_{\mu\mu}\hat{\sigma}_{\mu\mu}$
     a. ú-kú-ˈtáláántáanta ku-kúlú   'the big stumbling'   KB15:158, (20c)

With (12), we have presented the core data set we need to argue for a metrical analysis of CB and the concomitant adjustments to metrical theory. Later in the paper, in Sect. 5.1, we will add data relating to the OCP in order to compare our metrical analysis with an alternative one. For now, the relevant data is summarized, with syllabification, in Table 1.

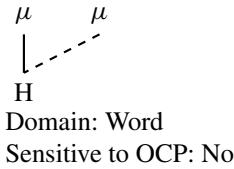## 2.3 Analysis: Autosegmental vs. metrical

Bickmore and Kula (2013:120) present a purely autosegmental, rule-based formalization of CB bounded spreading.[7] Their account consists of two parts—an initial rule of "High Doubling" that creates a bimoraic tone span, followed by a rule called "Secondary High Doubling" (SHD) that performs the remainder of the ternary spreading. The rules are presented in (13).[8] The formulation of these rules, and especially the division of the spreading process into two parts, is motivated by data whose in-depth discussion we postpone to Sect. 5.1. For now, the crucial aspect about this data is that

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[7]In Kula and Bickmore (2015), B&K present an OT analysis that also touches on bounded spreading, although its focus is on another phenomenon in CB, namely unbounded spreading. We do not discuss this analysis here because for the bounded spreading phenomena, it is incomplete. B&K apply it only to cases with exclusively light syllables; the analysis does not cover the quantity-sensitive nature of the bounded spreading domain.
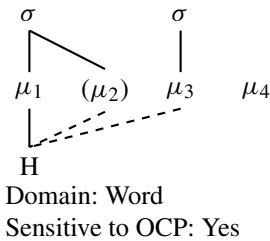
[8]Our presentation of (13b) has a slight graphical deviation from Bickmore and Kula (2013). We enclose μ_2 itself in parentheses, whereas in the original presentation, the domination line between the mora and its parent syllable was parenthesized. The intended meaning, to our understanding, is unchanged; the rule accepts both light and heavy initial syllables for its context, and associates tone to all moras in that initial syllable.

it shows that not all parts of the spreading are enforced equally strictly by the grammar. Spreading from the sponsor to the next mora occurs whenever space permits; but any and all further (ternary) spreading occurs only under the condition that spreading does not cause contact with other tonal autosegments or association to a word-final position.

(13) a. High Doubling (B&K)

$$\mu \qquad \mu$$

H
Domain: Word
Sensitive to OCP: No

b. Secondary High Doubling (B&K)

$$\sigma \qquad \sigma$$

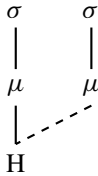$$\mu_1 \quad (\mu_2) \quad \mu_3 \quad \mu_4$$

H
Domain: Word
Sensitive to OCP: Yes

The quantity-sensitive nature of the tone spreading pattern is expressed by the SHD rule in (13b). Specifically, it is the optional status of μ_2 that allows the rule to apply in a similar way for e.g. both $\acute{\sigma}_\mu \acute{\sigma}_\mu \sigma_\mu$ strings and $\acute{\sigma}_\mu \acute{\sigma}_{\mu\mu} \sigma_\mu$ strings, turning the binary tone span that resulted from High Doubling into a ternary one. Spreading by SHD runs up to μ_3; the inclusion of another mora following it, μ_4, is intended to prevent association to word-final moras.[9]

The rules in (13) accurately describe the quantity-sensitive nature of the tone spreading pattern. However, the rules do not connect this quantity sensitivity to a deeper principle. That is, the analysis implies that the strings of light and heavy syllables undergoing tone spreading in CB are grouped *arbitrarily*. This suggests that, all else being equal, the attested pattern of CB is no more expected than any alternative pattern that the rule-based theory allows. For example, well-formed variations on the rules in (13) might contain a different number of moras or syllables, require light or heavy syllables in any given position, and allow optional elements in any given position. We believe this generative freedom does not accord with typological limits on the treatment of syllable weight. For instance, although quantity-sensitive languages generally treat a string of two light syllables similarly to a single heavy syllable (e.g. in terms of stress foot placement or reduplication, see McCarthy and Prince 1986; Hayes 1995), a purely autosegmental rule-based formalism permits rules that

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[9]This formulation is inadequate, because the inclusion of μ_4 in the SHD rule predicts that μ_3 must be non-final for *any* secondary spreading to occur. However, it is possible for tone to spread to both moras of a heavy syllable even when that syllable is in penultimate position, as evidenced by the form [tu.ka.b<u>á</u>.ʃíí.ka bwii.no] 'we will bury them well' (Bickmore and Kula 2013:112, (20b)). In this case, the word-final mora in [tu.ka.b<u>á</u>.ʃíí.ka] matches μ_3 in the SHD context, and no fourth mora is present. This is not a major analytical problem; the rule could be repaired by making the presence of μ_3 optional.

run counter to this generalization. For example, the rule in (14) describes binary tone spreading taking place exclusively across a syllable boundary. This rule performs binary spreading for light syllables, i.e. $/\acute{\sigma}_{\mu}\sigma_{\mu}/ \rightarrow [\acute{\sigma}_{\mu}\acute{\sigma}_{\mu}]$, and spreads similarly from the second mora of a heavy syllable to the next syllable, or from a light syllable to the initial mora of a following heavy syllable. However, tone is static for heavy syllables with lexical High tone on the initial mora, so that $/\hat{\sigma}_{\mu\mu}/ \rightarrow [\hat{\sigma}_{\mu\mu}]$.

(14)   Light Syllable Spreading

To our knowledge, patterns such as that generated by the rule in (14), that prioritize spreading on a pair of light syllables to the exclusion of spreading within a heavy syllable, are unattested. In general, the typology of quantity sensitivity (QS) is an ongoing field of research, and our present aim is not to measure the accuracy of an autosegmental rule-based formalism against this typology in great detail. However, we note that QS facts have played a major role in the development of metrical theory. Consequently, we claim that if a successful metrical-plus-autosegmental account of the CB data can be found, this account represents not merely a fortuitous pairing of data and theory, but connects the CB data to a more principled account of quantity sensitivity in natural language than a purely autosegmental, rule-based account has to offer.

We propose, then, that the CB spreading domain indeed has more principled underpinnings: The domain is definable through foot structure. A foot-based generalization connects the various different weight sequences of the spreading pattern to each other through the following observation: The domain is always exactly one mora longer than a quantity-sensitive iamb (Hayes 1995). We demonstrate this in Table 2 by showing iambs whose left edge is anchored to the sponsor TBU for each of the contexts. We discuss non-foot-based representational alternatives in Sect. 7.2.

We conclude that deriving this iamb+mora domain is a worthwhile goal for a formal account of CB bounded tone spreading. In the next section, we show that Weak Layering, despite having access to the quantity-sensitive iamb, is unable to capture this generalization.

3 Problems for Weak Layering

The previous section established that an account of CB bounded tone spreading benefits from access to a template consisting of a quantity-sensitive iamb and an additional mora. Here, we show that none of the traditional methods of deriving such ternarity using binary feet can be applied to Copperbelt Bemba.

We begin by considering extrametricality. Since extrametricality takes an edgemost element out of the equation, it is a device suitable for describing edgemost ternarity (Hayes 1980; Harris 1983; Halle and Vergnaud 1987; Poser 1989; Hayes

Table 2 CB bounded tone spreading fits the QS iamb+mora template

Seen in..	Domain shape	Example form and gloss
(6)	$(\sigma_\mu \sigma_\mu) + \mu$	(bá.ká).pá.ta.kó 'they will hate'
(7)	$(\sigma_{\mu\mu}) + \mu$	tu.(léé).mú.ʃii.ki.la bwii.no 'we are burying well for him'
(8)	$(\sigma_\mu \sigma_{\mu\mu}) + \mu$	(bá.kéé).mbí.la.kó 'they will dig for'
(10)	$(\sigma_\mu \sigma_\mu) + \mu$	(bá.ká).ʃíi.ka.kó 'they will bury'
(11)	$(\sigma_{\mu\mu}) + \mu$	tu.(léé).lóo.ndo.lo.la.kó 'we are introducing'
(12)	$(\sigma_\mu \sigma_{\mu\mu}) + \mu$	ú.kú.$^!$(tá.láá).ntáa.nta ku.kú.lú 'the big stumbling'

1995; Kager 1995). In the case of CB bounded tone spreading, this is not useful, because the pattern is not guaranteed to occur near an edge. We demonstrate the problem for extrametricality in (15), showing a possible surface form (SF). We have "helped out" by suggesting a foot position, but crucially, marking the final syllable extrametrical does not help to determine that position, nor does it help to answer why tone spreading ends where it does.

(15)   *(possible SF)*   tu.(léé).mú.ʃii.ki.la bwii.<no>
                    'we are burying well for him'   KB15:158, (20b)

Secondly, the concept of the loose minimal word (LMW) also offers no help. Itô and Mester (1992) describe the LMW not as a separate prosodic category, but as a structure that falls out from conditions on parsing; ternarity arises as a minimality effect in strings that are just large enough to contain one foot and one unparsed syllable. However, the ternary tonal domain in CB also arises in contexts that contain a multitude of unparsed syllables.

Thus, although a prosodic word could provide a ternary domain for tone spreading, as in (16a), there is no mechanism that ensures that a Prosodic Word category is indeed placed in this position, and not somewhere else, such as in (16b).

(16)   a. *(possible SF)*   tu.[(léé).mú]$_{PrWd}$.ʃii.ki.la bwii.no
                          'we are burying well for him'
         b. *(problematic SF)*   [tu.(léé)]$_{PrWd}$.mú.ʃii.ki.la bwii.no
                          'we are burying well for him'

Finally, we consider Weak Local Parsing (WLP, Hayes 1995). Under WLP, feet are placed iteratively while leaving an unparsed light syllable between pairs of adjacent feet, where possible. Hayes derives this specification from minimality:

> "I assume that it must be the smallest definable prosodic distance, namely a single mora. Since foot construction cannot split up syllables [...] this is equivalent to a single light syllable." (Hayes 1995:308)

Thus, WLP is a suitable device for *iterative* ternarity. Again, this does not match up with the nature of CB bounded tone spreading, because it is not iterative; the

presence of one tone span does not imply the presence of other tones further along the domain. However, to show that WLP is not successful even when given a fairer shot, we consider an implementation of WLP for CB tone spreading that makes some supporting assumptions. Specifically, we could assume that CB does iteratively build feet, left-to-right, which come into play only with tone spreading; tone could be assumed to spread rightward until it hits a left foot boundary. In some cases, this is sufficient to make a successful prediction, such as in (17a), where the application of WLP has positioned a left foot boundary exactly a ternary distance from the start of the sponsor, /lé/. However, even with these assumptions, one property of WLP remains problematic for an account of CB tone: WLP never skips over heavy syllables. WLP has this property by design; the theory is inspired by crosslinguistic observations about stress languages with ternary rhythm. In (17b), the WLP-induced feet are not in sync with the tone span, due to a heavy syllable that is in an infelicitous position. Again assuming a left-to-right application of foot building with WLP, the string starts with two adjacent feet because WLP cannot skip over the heavy syllable /loo/. Under our assumption that tone spreads until it hits a left foot boundary, we expect tone from /bá/ to spread only once, giving *(bá.ká).(loo).ndo.(lo.la).kó, which is falsified by the CB data.

(17)   a. *(possible SF)*   (tu.léé).mú.(ʃii).ki.(la bwii).no
                                   'we are burying well for him'
        b. *(problematic SF)*   (bá.ká).(lóo).ndo.(lo.la).kó
                                   'they will introduce'

In summary, because the ternary domain of Copperbelt Bemba bounded tone spreading is neither edgemost, nor related to minimality, nor iterative, all three of the Weak Layering mechanisms fall short of accounting for it. In the next section, we introduce layered feet and show that they can be used to describe the necessary ternary domain.

4 A layered feet account of Bemba ternary

In this section, we propose an alternative, foot-based interpretation of the structure of the CB bounded tone spreading domain. Our primary focus in this paper is on this structural analysis. However, further questions about the analysis can be asked concerning the derivation (or perhaps more generally stated, the computation) of foot positions and associations between tonal autosegments and footed anchors. We will briefly take up these matters in Sect. 4.2.

4.1 Layered feet

Generally speaking, a layered foot is a maximally trisyllabic constituent that parses another foot along with some small, dependent element. This concept originated, under different names, in the seminal works of Selkirk (1980) and Prince (1980). Its developmental path in the literature has been more diffuse than that of binary foot theory, surfacing occasionally throughout the 1990s (Dresher and Lahiri 1991; Rice 1992; Kager 1994). Recently, there has been a more concerted effort to explore the

Table 3 Layered feet capture the CB bounded tone spreading domain

Seen in..	Layered footing	Example form and gloss
(6)	$((\sigma_\mu\sigma_\mu)\sigma_\mu)$	((bá.ká).pá).ta.kó 'they will hate'
(7)	$((\sigma_{\mu\mu})\sigma_\mu)$	tu.((léé).mú).ʃii.ki.la bwii.no 'we are burying well for him'
(8)	$((\sigma_\mu\sigma_{\mu\mu})\sigma_\mu)$	((bá.kéé).mbí).la.kó 'they will dig for'
(10)	$((\sigma_\mu\sigma_\mu)\mu)\mu$	((bá.ká).ʃí)i.ka.kó 'they will bury'
(11)	$((\sigma_{\mu\mu})\mu)\mu$	tu.((léé).ló)o.ndo.lo.la.kó 'we are introducing'
(12)	$((\sigma_\mu\sigma_{\mu\mu})\mu)\mu$	ú.kú.ˈ((tá.láá).ntá)a.nta ku.kú.lú 'the big stumbling'

ramifications of layered feet representations, inspired by work on recursive prosody (Itô and Mester 2007; Itô and Mester 2013; Elfner 2015). Layered feet have been applied to a variety of foot-governed phonotactics and tonotactics (Jensen 2000; Davis and Cho 2003; Bennett 2012; Martínez-Paricio 2013; Martínez-Paricio and Kager 2016; Breteler 2017; Kager and Martínez-Paricio 2018a); to account for stress windows (Kager 2012); stress typology (Martínez-Paricio and Kager 2015); and edge effects typically solved with extrametricality (Buckley 2014; Kager and Martínez-Paricio 2018b).

In our present conception of the layered foot, it consists of a flat, binary foot and an adjunct element, which might be a syllable or a mora. Because the layered foot has internal structure, we can specify the parsing properties of its constituents independently of each other. For Copperbelt Bemba, layered feet allow a specification in line with the observations we made about the pattern back in Sect. 2.3, Table 2. The inner foot should parse as a quantity-sensitive iamb. Previous work on layered feet has generally assumed syllabic adjuncts. However, we propose here that for CB, the adjunct must be specified to parse moraically, so that it always parses exactly one mora (see also Kager and Martínez-Paricio 2018b on Gilbertese). With these specifications, we derive representations for the CB data as shown in Table 3. We discuss the representation of tone contact cases such as (12) in Sect. 5.1.

The layered feet in Table 3 overlap exactly with the tone spans. Consequently, we can further simplify our generalization for the CB bounded tone distributions: Tone surfaces on all and only footed TBUs.[10]

As a tradeoff for this simpler generalization, we have assumed a more complex foot. In particular, we have parsed the forms in (10-12) so that only the first mora of the final syllable is included in the foot. This means that these forms contain a syllable integrity violation (SIV). We show an example of this structure in Fig. 1. Since only the first mora of the heavy syllable is footed, only that mora will be associated with the tone, leading to the desired falling tone at the surface.

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[10]See Idsardi and Purnell (1997) for the related proposal that Shingazidja "tone" is purely metrical structure.
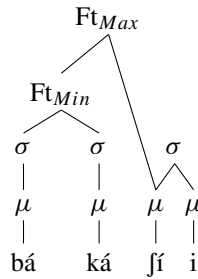
Fig. 1 A syllable-integrity violation, causing a falling-toned heavy syllable

In suggesting SIVs, we are implicitly making claims about syllable structure and the makeup of heavy syllables in CB. That is, we suggest that long vowels are tauto-syllabic, rather than heterosyllabic sequences of two identical light vowels. We think this claim is backed up first of all by the tonal data itself, noting that both the various metrical interpretations we propose in the paper, as well as the autosegmental analysis of B&K, rely crucially on the syllabic status we propose. In particular, the tonal pattern does not fit a situation where syllable structure is absent (Hyman 1983; Labrune 2012), since mora counting by itself underdetermines the size of the tonal spreading domain; recall (9).

A second reason to suspect CB long vowels are tautosyllabic are the restrictions on vowel hiatus, which Kula (2013:3) summarizes as follows: "[V]owel hiatus is not permissible between short vowels in Bemba. The only instances of sequences of vowels found are between a long and a short vowel. Short vowel sequences result in fusion or coalescence that may also involve gliding." (See also Kashoki 1968; Hamann and Kula 2015). For these facts, the syllable offers a straightforward means of explaining why vowel hiatus resolution occurs between two short vowels, since they can coalesce into a tautosyllabic long vowel, but not between a long vowel followed by a short one, since their fusion would grow beyond the bimoraic syllabic template.

The status of SIVs as a part of natural language is controversial, with the traditional view being that SIVs are universally disallowed. In Sect. 6, we discuss evidence for SIVs in other languages, and we integrate the facts of CB into an Optimality Theory account of SIVs.

4.2 The issue of computing foot placement and tone-foot association

A full account of the data at hand should include statements not just about the structure of the surface form, as we have discussed above, but also about the *computation* of those structures. While a full discussion of those issues would take us beyond the scope of this paper, we will touch on two issues to suggest that our proposal poses no major problems on this front.

Firstly, in the data above, left foot edges always coincided with left edges of sponsor moras. However, forms such as [tu.léé.mú.ʃii.ki.la bwii.no] 'we are burying well for him' show that not all sponsor moras are initial in their prosodic domain. Consequently, our analysis could benefit from more detailed statements about foot positioning. One approach to ensure that feet are always positioned properly with respect

to tone sponsors is to use licensing constraints, proposed as early as Kang (1997) and refined by Breteler (2017) in the context of Harmonic Serialism (McCarthy 2000 et seq., and briefly considered in Prince and Smolensky 1993). In this approach, licensing constraints reward foot construction only when all of a tone's anchors would otherwise remain unfooted. The licensing constraints are coupled with alignment constraints that pull the feet maximally rightward, together giving rise to left foot edge anchoring as is needed for Copperbelt Bemba.

Secondly, given that feet are in the desired position, a remaining concern is how this leads to the desired tone associations. There exists a rich literature on the relation between feet and tone, including works that again suggest a role for licensing constraints (see e.g. De Lacy 2002 and references in Sect. 1). As it happens, in the CB case it is sufficient to posit a simple, high-ranked constraint that drives such tone association, defined in (18).

(18) $\mu_{Ft} \rightarrow$ H
        Assign one violation mark for each footed mora that is not associated to a high tone.

In the next section, we will take up data where tone does not always spread ternarily because of the OCP, and we will put $\mu_{Ft} \rightarrow$ H to use.

5 Boundary hopping: A binary feet alternative

In this section we consider one more binary feet alternative. Mirroring the bipartite structure of the layered foot, we consider a binary feet account composed of two processes. The idea is to have only the quantity-sensitive part of the tone domain captured by a binary foot. The final mora, which in our layered foot was parsed as an adjunct, will here instead receive its tone through non-metrical means. Derivationally speaking, we propose that tone first spreads to cover an iambic foot, after which a second process extends the tone span by one additional mora. Since this second process in effect causes tone to extend rightward just beyond the foot boundary, we refer to this account as "boundary hopping." An example of a derivation is shown in (19).

(19)   1. $(\acute{\sigma}_\mu \sigma_\mu) \sigma_\mu \sigma_\mu ...$
            Build binary, iambic feet over sponsors
       2. $(\acute{\sigma}_\mu \acute{\sigma}_\mu) \sigma_\mu \sigma_\mu ...$
            Spread tone through the foot
       3. $(\acute{\sigma}_\mu \acute{\sigma}_\mu) \acute{\sigma}_\mu \sigma_\mu ...$
            Spread tone to the first mora following the foot

If boundary hopping is generally successful, it could avoid both the need for positing SIVs and the extension of metrical theory in terms of foot layering, thus undermining our layered feet proposal from the previous section. However, in Sect. 5.1 we will present additional data to argue that boundary hopping is still crucially dependent on SIVs, and that it loses out to foot layering when it comes to independent, crosslinguistic motivation. Afterward, we will briefly show how the data can be integrated into our layered feet approach in Sect. 5.2.

5.1 More SIVs: Tonal contact data

We now consider boundary hopping as a potential alternative to allowing SIVs, and will argue that it fails in this respect. To this end, we look at further bounded spreading data in CB, coming from contexts where multiple tonal autosegments are in proximity to one another. As before, we have taken the data from reports by B&K. The data are relevant to boundary hopping because they introduce more falling tones, which we will argue require an analysis with SIVs. In Sect. 5.2, we will argue that the data are easily fitted with our layered feet analysis.

With the discussion of tonal (near-)contact below, we subsume discussion of another tonal phenomenon in CB: ternary tone spread avoids association to a word-final mora. For example, B&K report the datum [tu-ka-bá-ʃíík-a bwiino] (*tu-ka-bá-ʃíík-á) 'we will bury them well' (Bickmore and Kula 2013:112, (20b)). We claim that the tonal behavior for avoiding final moras is analogous to the tonal behavior for avoiding tone contact. Consequently, we work out considerations for this latter issue only, and leave implicit the application of our insights to word-level tonal non-finality for the sake of brevity.

When two tones are near each other, i.e. a tone is within or adjacent to the ternary domain of the tone that precedes it, then the usual generalizations on tone spreading, as laid out in Sect. 2, break down for this preceding tone. Bickmore and Kula do not propose a generalization for cases where sponsors are on adjacent TBUs,[11] but for the remaining cases, there are two scenarios. Firstly, if the sponsors are separated by a single mora, then the left tone will spread to this mora, and a downstep occurs between it and the second sponsor. Examples of this are shown in (20). We follow Bickmore and Kula's interpretation of the downstep: referencing Odden (1986), they state "downstep can be structurally defined as occurring between two TBUs linked to distinct H[igh] tones, therefore not requiring any floating L[ow] in a language that otherwise is best analyzed as contrasting H vs. ∅" (2013:115). Under this interpretation, the constellation in (20) is the only case in CB where the Obligatory Contour Principle (OCP) is violated (Myers 1997). This reveals that other phonological forces are competing with the OCP, as we will formalize below.

(20) $\acute{\sigma}_{\mu} \sigma_{\mu} {}^{!} \acute{\sigma}_{\mu}$
         a. bá-ká-ˈlás-á   'they will hit'   BK13:115, (25a)
         b. kálíp-ˈá   'be nervous!'   BK13:115, (25f)

The second tone contact scenario is triggered when more than one mora separates the two sponsors but a full ternary spread from the left tone would still bring it into contact with the right tone. In this scenario, the left tone will only spread as far rightward so as to leave one mora between it and the right tone, with no regard to syllable structure. This gives rise to shortened tone spans of two or three moras, as demonstrated in examples (21–23). The forms in (23) are particularly informative because they show

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[11]There are several forms with adjacent sponsors in the examples of B&K: (21a,b; 22a) in Bickmore and Kula (2013:113–114); and the second form in (21g) in Kula and Bickmore (2015:161). In all these cases, high tone appears on all sponsors, as well as possibly spreading beyond the rightmost sponsor. There is no downstep in any of these cases, which invites an analysis involving tone fusion; we leave this to future research.

that when a full ternary spread is blocked, CB tone spreading does not default to a bimoraic span, but will still associate to as many moras as are available.

(21) $\underline{\acute{\sigma}_\mu}\acute{\sigma}_\mu\sigma_\mu\underline{\acute{\sigma}_\mu}$
    a. <u>bá</u>-ká-mu-<u>lás</u>-á (*<u>bá</u>-ká-mú-ˈ<u>lás</u>-á)
      'they will hit him/her'   BK13:116, (27a)
    b. <u>kál</u>íp-il-<u>á</u> (*<u>kál</u>íp-íl-ˈ<u>á</u>)
      'be upset at!'   BK13:116, (27e)

(22) $\underline{\acute{\sigma}_\mu}\hat{\sigma}_{\mu\mu}\underline{\acute{\sigma}_\mu}$
    a. <u>bé</u>léeŋ-<u>á</u> (* <u>bé</u>lééˈŋg-á)   'read!'   BK13:116, (29b)
    b. <u>bá</u>-ʃíik-<u>íl</u>-é (* <u>bá</u>-ʃííˈk-íl-é)   'bury for them!' BK13:116, (29c)

(23) $\underline{\acute{\sigma}_\mu}\acute{\sigma}_{\mu\mu}\sigma_\mu\underline{\acute{\sigma}_\mu}$
    a. <u>bé</u>lééŋg-el-<u>á</u> (*<u>bé</u>léeŋg-el-á)   'read for!'   BK13:116, (29d)
    b. <u>tú</u>-ʃíík-il-<u>é</u> (*<u>tú</u>-ʃíik-il-<u>é</u>)   'that we bury for' BK13:116, (29e)

In the following, we will provide an OT analysis of these data and show that it needs reference to output candidates with SIVs. Like B&K, we interpret the data in (21–23) as suggesting a role for the OCP. The data in (20) above, schematically $\underline{\acute{\sigma}_\mu}\acute{\sigma}_\mu$ˈ$\underline{\acute{\sigma}_\mu}$, prove that OCP is not absolute, meaning that it cannot be top-ranked in the OT analysis. Something else must take precedence over the satisfaction of OCP; we suggest it could be either foot binarity (coupled with high priority on foot-driven spreading), or the constraint driving hopping, which we will simply term HOP. We show this dilemma in (25, 26), with constraints as defined in (24). We have included candidates with and without boundary hopping, and with unary or binary footing. In addition, we will assume for this and the following tableaux that left foot edges always coincide with left edges of sponsor moras—an assumption we discussed in Sect. 4.2. We leave out candidates that do not associate tone to one or more footed positions; such an effect can for example be enforced by top-ranking a constraint $\mu_{Ft}{\to}$H.

(24)   Constraints for boundary hopping

    a. $\mu_{Ft}{\to}$H
        Assign one violation mark for each footed mora that is not associated to a high tone.

    b.   FT=$\mu\mu$(MIN)
        Assign one violation mark for each foot that does not parse at least two moras.

    c.   OCP
        Assign one violation mark for each pair of adjacent moras that are associated to different tones.

    d.   HOP
        Assign one violation mark for each tone linked to the rightmost mora of a foot but not the mora immediately following it [here assessed only for leftmost tones].

(25) Light-syllable OCP case with tone contact (prioritizing foot binarity)

$\acute{\sigma}_\mu\sigma_\mu\acute{\sigma}_\mu$	FT=$\mu\mu$(MIN)	OCP	HOP
a. ☞ $(\acute{\sigma}_\mu\acute{\sigma}_\mu)^!\acute{\sigma}_\mu$		*	*
b. $(\acute{\sigma}_\mu)\sigma_\mu\acute{\sigma}_\mu$	*!		*
c. $(\acute{\sigma}_\mu)\acute{\sigma}_\mu^!\acute{\sigma}_\mu$	*!	*	

(26) Light-syllable OCP case with tone contact (prioritizing hopping)

$\acute{\sigma}_\mu\sigma_\mu\acute{\sigma}_\mu$	HOP	OCP	FT=$\mu\mu$(MIN)
a. $(\acute{\sigma}_\mu\acute{\sigma}_\mu)^!\acute{\sigma}_\mu$	*!	*	
b. $(\acute{\sigma}_\mu)\sigma_\mu\acute{\sigma}_\mu$	*!		*
c. ☞ $(\acute{\sigma}_\mu)\acute{\sigma}_\mu^!\acute{\sigma}_\mu$		*	*

From the data in (21), schematically $\acute{\sigma}_\mu\acute{\sigma}_\mu\sigma_\mu\underline{\acute{\sigma}_\mu}$, we know that OCP cannot be bottom-ranked. If it were bottom-ranked, *both* binary foot-based spreading and hopping should have applied. This is demonstrated with the counterfactual ranking in (27), showing an undesirable winner indicated with the symbol ↯. The desirable-but-losing candidates, i.e. those that match the attested phonetics, are indicated with the symbol ☺.

(27) Bottom-ranked OCP leads to an incorrect prediction

$\acute{\sigma}_\mu\sigma_\mu\sigma_\mu\acute{\sigma}_\mu$	FT=$\mu\mu$(MIN)	HOP	OCP
a. ☺ $(\acute{\sigma}_\mu\acute{\sigma}_\mu)\sigma_\mu\acute{\sigma}_\mu$		*!	
b. ☺ $(\acute{\sigma}_\mu)\acute{\sigma}_\mu\sigma_\mu\acute{\sigma}_\mu$	*!		
c. ↯☞ $(\acute{\sigma}_\mu\acute{\sigma}_\mu)\acute{\sigma}_\mu^!\acute{\sigma}_\mu$			*

Consequently, we are left with the two possible rankings in (25, 26). However, without SIV candidates, neither ranking can generate desirable outcomes for the tone contact data involving heavy syllables, as was presented in (22, 23). We will show the tableaux for both rankings in (28, 29) below, and indicate undesirable winners as before with the symbol ↯. Additionally, when we wish to single out one of two tautosyllabic moras, for example for tone association or SI-violating foot building, we write both moras in full. We further indicate this by showing syllable boundaries before and after the moras, with the symbol '.'. We do not indicate syllable boundaries in other cases, i.e. when symbols on either side of the boundary already denote syllables.

(28) Heavy-syllable OCP cases, with binary footing (ranked as (25))

$\acute{\sigma}_\mu\sigma_{\mu\mu}\acute{\sigma}_\mu$	FTMIN=$\mu\mu$(MIN)	OCP	HOP
a. ↯☞ $(\acute{\sigma}_\mu\acute{\sigma}_{\mu\mu})^!\acute{\sigma}_\mu$		*	*
b. ☺ $(\acute{\sigma}_\mu).\acute{\mu}\mu.\acute{\sigma}_\mu$	*!		
$\acute{\sigma}_\mu\sigma_{\mu\mu}\sigma_\mu\acute{\sigma}_\mu$			
c. ☞ $(\acute{\sigma}_\mu\acute{\sigma}_{\mu\mu})\sigma_\mu\acute{\sigma}_\mu$			*
d. $(\acute{\sigma}_\mu\acute{\sigma}_{\mu\mu})\acute{\sigma}_\mu^!\acute{\sigma}_\mu$		*!	
e. $(\acute{\sigma}_\mu).\acute{\mu}\mu.\sigma_\mu\acute{\sigma}_\mu$	*!		

(29)   Heavy-syllable OCP cases, with hopping (ranked as (26))

$\acute{\sigma}_\mu \sigma_{\mu\mu} \acute{\sigma}_\mu$	HOP	OCP	FTMIN=$\mu\mu$(MIN)
a. $(\acute{\sigma}_\mu \acute{\sigma}_{\mu\mu})^!\acute{\sigma}_\mu$	*!	*	
b. ☞ $(\acute{\sigma}_\mu).\acute{\mu}\mu.\acute{\sigma}_\mu$			*
$\acute{\sigma}_\mu \sigma_{\mu\mu} \sigma_\mu \acute{\sigma}_\mu$			
c. ☺ $(\acute{\sigma}_\mu \acute{\sigma}_{\mu\mu})\sigma_\mu \acute{\sigma}_\mu$	*!		
d. $(\acute{\sigma}_\mu \acute{\sigma}_{\mu\mu})\acute{\sigma}_\mu{}^!\acute{\sigma}_\mu$		*!	
e. ↯☞ $(\acute{\sigma}_\mu).\acute{\mu}\mu.\sigma_\mu \acute{\sigma}_\mu$			*

Both possible rankings generate at least one undesirable winner. The heavy-syllable OCP data reveal that these analyses fall short because they are too rigid; strictly prioritizing syllable integrity respecting foot binarity leads to unwanted OCP violations in (28a), and strictly prioritizing hopping leads to impoverished spreading in (29e).

The introduction of candidates with SIVs allows for the needed compromise: Foot binarity is sometimes won by building a bimoraic, SI-violating foot, leading to maximal OCP-respecting spreading. This is shown in (30).[12]

(30)   Heavy-syllable OCP cases, with binary footing

$\acute{\sigma}_\mu \sigma_{\mu\mu} \acute{\sigma}_\mu$	FTMIN=$\mu\mu$(MIN)	OCP	HOP
a. ☞ $(\acute{\sigma}_\mu.\acute{\mu})\mu.\acute{\sigma}_\mu$			*
b. $(\acute{\sigma}_\mu \acute{\sigma}_{\mu\mu})^!\acute{\sigma}_\mu$		*!	*
c. $(\acute{\sigma}_\mu).\acute{\mu}\mu.\acute{\sigma}_\mu$	*!		
d. $(\acute{\sigma}_\mu.\acute{\mu})\acute{\mu}.^!\acute{\sigma}_\mu$		*!	
$\acute{\sigma}_\mu \sigma_{\mu\mu} \sigma_\mu \acute{\sigma}_\mu$			
e. $(\acute{\sigma}_\mu \acute{\sigma}_{\mu\mu})\sigma_\mu \acute{\sigma}_\mu$			*!
f. $(\acute{\sigma}_\mu \acute{\sigma}_{\mu\mu})\acute{\sigma}_\mu{}^!\acute{\sigma}_\mu$		*!	
g. ☞ $(\acute{\sigma}_\mu.\acute{\mu})\acute{\mu}.\sigma_\mu \acute{\sigma}_\mu$			
h. $(\acute{\sigma}_\mu).\acute{\mu}\mu.\sigma_\mu \acute{\sigma}_\mu$	*!		

We conclude that the boundary hopping account needs to allow SIVs, in order to have access to output candidates that can balance the pressures of foot binarity, the OCP, and hopping. Consequently, on the issue of SIVs there is no benefit to using the binary feet boundary hopping approach compared to our layered feet approach.

In the following, we sketch how our layered feet proposal deals with the tonal contact data.

5.2 Tonal contact in the layered feet analysis

Our layered feet account has neither particular solutions for, nor particular trouble with, the OCP data presented in this section. Consequently, here we will only sketch how our account can integrate the OCP data. Firstly, the "minimal tone binarity"

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[12]The alternative ranking, where HOP is top-ranked, selects a structurally different but phonetically identical winning candidate: It selects (30c) as a winner along with (30g).

effect, i.e. the fact that tone will spread at least one mora even if this leads to an OCP violation, is accounted for through the minimal binarity of FtMin, as was done with $\text{FT}=\mu\mu(\text{MIN})$ before. We drive the construction of larger, layered feet with a parsing constraint, PARSE-μ, defined in (31).

(31)　PARSE-μ
　　　Assign one violation mark for each unfooted mora.

The interaction of these constraints with the OCP gives rise to layered feet that are just small enough that the two tone spans stay separate. We demonstrate this in (32) with an analysis of $\underline{\acute{\sigma}_\mu}\acute{\sigma}_{\mu\mu}\sigma_\mu\underline{\acute{\sigma}_\mu}$ cases, from the data in (23).

(32)　Reduced parsing and spreading to avoid tone contact

$\acute{\sigma}_\mu\sigma_{\mu\mu}\sigma_\mu\acute{\sigma}_\mu$	$\mu_{Ft}{\to}\text{H}$	OCP	PARSE-μ
a. ☞ $(\acute{\sigma}_\mu\acute{\sigma}_{\mu\mu})\sigma_\mu\acute{\sigma}_\mu$			**
b. $(\acute{\sigma}_\mu.\acute{\mu})\acute{\mu}.\sigma_\mu\acute{\sigma}_\mu$			***!
c. $((\acute{\sigma}_\mu\acute{\sigma}_{\mu\mu})\acute{\sigma}_\mu)^{'}\acute{\sigma}_\mu$		*!	*
d. $((\acute{\sigma}_\mu\acute{\sigma}_{\mu\mu})\sigma_\mu)\acute{\sigma}_\mu$	*!		*

For brevity, we refrain from presenting an exhaustive OT account; we claim that our representations come out as in (33).[13]

(33)　(20)　(ká.lí).ˈpa　　'be nervous!'
　　　(21)　(ká.lí).pi.lá　　'be upset at!'
　　　(22)　(bé.lé)e.ŋgá　　'read!'
　　　(23)　(bé.léé).ŋge.lá　'read for!'

With this, we conclude that the layered foot analysis we proposed in Sect. 4 can incorporate the tonal contact data.

5.3 Independent motivations for layering vs. hopping

In the preceding subsections, we have tested boundary hopping on its ability to avoid the use of syllable-integrity violating feet, and found that it does not offer an improvement compared to layered feet in this respect. Here, we will argue that boundary hopping also does no better—and arguably, worse—with respect to its crosslinguistic support. We are not aware of any previous literature proposing a perfectly analogous mechanism to boundary hopping. In the following, we will mention some proposals and linguistic phenomena that come close, but in each case we note that there are also

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[13]As in the rest of the paper, we are not concerned with the representation of rightmost tones. This is mainly because their behavior does not reveal anything about the metrical structure needed for CB; if rightmost tones spread at all (i.e. if they aren't underlyingly final), this is due to the unbounded spreading process in the language, which does not distinguish between heavy and light syllables. It is likely that an expanded and more exhaustively applied version of the OT analysis we present here would still place feet on rightmost tones, even if those feet do not drive or delimit tone spreading.

crucial differences that complicate the translation from those proposals to boundary hopping.[14]

Firstly, there have been some proposals for stress or accent systems to target a position just outside a foot. Kiparsky (2003, crediting Golston 1990; Sauzet 1989) suggests a generalization for accent in Ancient Greek, quoted in (34).

(34)   RECESSIVE ACCENT RULE:
        Accent the mora immediately to the left of the final foot, otherwise [i.e. if there is no such mora], accent the leftmost element of the final foot.

This generalization is reminiscent of boundary hopping in the sense that it targets a position just outside the foot. However, as is revealed in Kiparsky's *implementation* of this generalization, there is still a difference between positioning an accent and spreading a (tonal) feature; Kiparsky uses a faithfulness constraint on accent that effectively "prevents recessive accent from landing on the final foot." His analysis additionally uses a gradient accent alignment constraint to ensure that the accent lands only minimally outside the foot, i.e. just to the left of the final foot. The result of this approach is a process that targets a position just next to a foot boundary. This process might resemble the boundary hopping analysis we discuss for CB, but things are more complicated. For a hopping analysis of CB, tone must associate both inside and outside the foot. This means that the exclusionary effect of Kiparsky's faithfulness constraint cannot be copied over to the CB case. Additional problems also exist for the formulation of the alignment constraints, since tone no longer merely approaches the foot the way accent does in Ancient Greek; rather, the alignment constraints would somehow have to promote an outcome where tone association straddles the foot boundary. The latter issue applies similarly to approaches with opposite-edge alignment constraints (McCarthy and Prince 1993a; Hyde 2012); additional postulations about the "edges" of tones or TBUs are needed before these approaches might apply to tone spreading.

One application of alignment concepts to tone is Bickmore (1996), who analyzes various tone spreading and shifting phenomena with a combination of alignment and *misalignment* constraints. For example, to analyze trisyllabic tone spreading, Bickmore utilizes the insight that a tripartite tone span is the optimal size with regard to allowing a minimally misaligned distance between the first and third TBU, i.e. they are separated only by the second TBU of the span. The exact implementation of this analysis makes reference to the left and right edges of leftmost and rightmost TBUs in surface and underlying tone spans. Here too the application of this minimal misalignment approach to boundary hopping comes with some objections. Firstly, we note that Bickmore's proposal was an alternative for the explicitly *rejected* option of analyzing tonal reassociation with feet. Secondly—assuming the possibility of misalignment between feet and features—the misalignment approach comes with wider typological predictions; it entails that some languages might achieve misalignment by spreading *less* when the spreading feature is contained in a foot, stopping short of associating to a foot edge. In the extreme, a single language could even combine

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[14]We are grateful to three anonymous reviewers for their suggestions of boundary hopping analogues.

underspreading in some contexts with overspreading (i.e. boundary hopping) in other contexts. We are not aware of attestations of such foot-feature interactions.[15]

Lastly, some spreading phenomena reminiscent of boundary hopping are attested in Bantu tonology. For some Shona dialects, stepwise spreading has been proposed, where an initial binary or long-distance stem-level spread is followed by minimal spreading in the context of larger morphosyntactic domains (Myers 1987; Hyman and Mathangwane 1998). However, there is no evidence to support boundary hopping in CB along these lines, since, as Bickmore and Kula (2013) note, the ternary spreading is an across-the-board, word-level phenomenon. Another process found in many Bantu languages is one whereby a tone at the edge of a word can spread into the neighboring word. As reported by Ebarb (2016:e180), in Kabarasi this process even operates over a distance: modulo the OCP, a stem-initial High tone is spread onto the final TBU of the preceding word. Crucially, these effects always occur between words; in the wording of Hyman and Katamba (1993), they cross a "domain juncture." Boundary hopping is not similarly junctural in this way, since there is no guarantee that the foot edge triggering boundary hopping is one side of a foot juncture, nor that it coincides with the edge of a word. The target TBU of boundary hopping can be an unfooted, word-medial mora, so the boundary hop describes tonal activity not across a juncture between equal prosodic constituents, but in the context of a prosodic "cliff," downward from the foot level to the mora level. We are not aware of other cases where features interact with prosodic constituency in a similar way.

In contrast to the above, the representational theory of layered feet that we used here was lifted from previous literature virtually unchanged (cf. Sect. 6). As we pointed out in Sect. 4.1, layered feet have previously found fruitful application to a variety of stress and non-stress phenomena (e.g. Martínez-Paricio 2013). In general, our current conception of layered feet has grown out of the study of related concepts stretching back decades (Prince 1980; Selkirk 1980). In conclusion, while boundary hopping might avoid an extension of the traditional foot inventory, we suggest that in terms of independent crosslinguistic motivation, the layered foot analysis is nevertheless the preferable alternative.

6 Towards a typology of syllable-integrity violations

Syllable integrity is typically held to be inviolable (Hayes 1995; Hyde 2007). However, there is some evidence of SIVs in languages with purely moraic footing. Shimoji (2009) proposes a foot-based account of rhythmically alternating High and Low tone in Irabu Ryukyuan. Irabu has no stress or word accent; the pitch contour of the *bunsetsu* domain, which consists of a noun and certain affixes, is predictable from the length of the domain. As Shimoji analyzes, tone starts out High and then alternates

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[15] A reviewer suggests that OCP avoidance behavior, where a tone spreads less than the language's default distance in order to avoid TBU contact with another tone, could be interpreted as a case of underspreading. We leave further study of this possibility to future research—noting that if such an interpretation is fruitful, it should also involve a meaningful role for foot structure in order to be construable as evidence for the present boundary hopping analysis.

between Low and High every two moras, with no regard for syllable structure. Some tonal restrictions apply, but in forms whose mora count is a multiple of four, the pattern can be perfectly demonstrated, for example in [káń-gama-ḿmí-nagi] 'little crabs, and so on' (Shimoji 2009:118). Shimoji's analysis entails SIVs; forms such as [á.máir] 'bulb' must be footed [(á.má)$_{\mu\mu}$(ir)$_{\mu\mu}$] to correctly derive the tone distribution (Shimoji 2009:95; Martínez-Paricio 2013:260). Indeed, Shimoji discusses several cases where a foot "crosscuts" a syllable, concluding that "it is possible to state that syllable boundary and foot boundary do not necessarily coincide ... in the Prosodic Hierarchy of Irabu, the mora is directly governed by the foot[.]" (110*f.*) One piece of evidence for analyzing long vowels as tautosyllabic is a process of word-final tonal fall formation where long vowels pattern with diphthongs, to the exclusion of heterosyllabic short vowel pairs ("Final lowering," p. 93*f.*). Additionally, the second parts of long vowels pattern with coda consonants in applying a delayed tonal rise when the relevant mora is foot-initial (Shimoji 2009:110).

Blevins and Harrison (1999) present data on stress and tone in Gilbertese, suggesting that the language has an iterative trimoraic footing pattern. More recently, Kager and Martínez-Paricio (2018b) followed up on this with an explicit layered feet account of Gilbertese where heavy syllables can even be part of two different feet, for example footing the string [ni^H.ˈka.kaa^H.ˈea] 'in search of him' as [((ni^H.ˈka).ka)((a^H.ˈe)a)], where a superscript H indicates a preceding high-toned syllable. Evidence for syllabification in Gilbertese comes mainly from native speaker intuitions and sonority-based restrictions on segment sequences, while additional evidence might be adduced from vowel coalescence and reduplication phenomena (Blevins and Harrison 1999:206–208).

We conclude that some languages parse feet strictly based on mora count, parsing moras directly where needed (Prince 1983; Halle and Vergnaud 1987; Halle 1990; Halle and Kenstowicz 1991; Buller et al. 1993; Kager 1993; Everett 1996; Blevins and Harrison 1999; Kager and Martínez-Paricio 2018b). On the other hand, the vast majority of the world's languages only allow feet to parse syllables—even if syllable weight, and hence mora count, might still play a role in the exact distribution of feet. For a framework with flat feet, this is the end of the story. However, the layered feet framework has two layers of organization, and therefore leads us to ask whether any language might blend these two styles of parsing. As we showed above, Copperbelt Bemba can be analyzed as the first identified case of such blended parsing—building inner feet with syllables, and adjuncts with moras. We give an overview of these various parsing styles and their resulting structures in Fig. 2.

Natural language might allow for other types of blended parsing. In order to make specific predictions, we require a more specific theory of how parsing principles are organized. In the remainder of this section, we develop such a theory.

6.1 Syllable-integrity violations in Optimality Theory

To make explicit the organizing components that give rise to the continuum, we use Optimality Theory (OT, Prince and Smolensky 1993) to model when and where grammars decide to violate syllable integrity. Kager and Martínez-Paricio (2018b) provide a previous OT implementation of SIVs with layered feet. They analyze SIVs as follows:
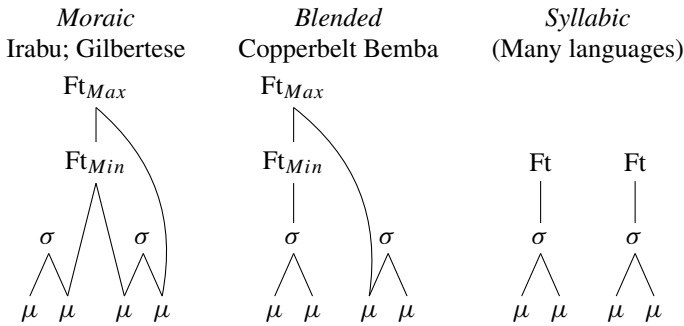
Fig. 2 Moraic, blended, and syllabic parsing

"[...] syllable-integrity disrespecting metrical parsing emerges under duress of foot shape constraints, which take priority over constraints that disfavor metrical parsing of morae immediately dominated by feet." (Kager and Martínez-Paricio 2018b:3)

Kager and Martínez-Paricio's approach in essence recasts the Strict Layering relationship between feet and syllables (Selkirk 1984) as violable. Thus, their approach follows the intuition that, all else being equal, grammars will prefer syllabic parsing. However, particular constraints on the mora count of feet or adjuncts can throw the grammar off from this parsing preference. Kager and Martínez-Paricio show that their constraint set successfully models the Gilbertese data. While an inspection of the factorial typology of the constraint set is beyond the scope of the present work, we will suggest an amendment to the constraint set based on an application of it to the Copperbelt Bemba facts. The relevant constraint set from Kager and Martínez-Paricio (2018b) is defined in (35).[16] Here, the term FtMin refers to feet that are minimal (Itô and Mester 2007), meaning that they do not themselves contain another foot. This holds for all inner feet in a layered foot, as well as for flat binary feet.

(35) | *Constraint* | *Definition* |
|---|---|
| ADJUNCT-μ | Assign * for every adjunct that is not monomoraic |
| PARSE-μ | Assign * for every mora not parsed by a foot |
| EXHAUSTIVITY-FT | Assign * for every mora directly dominated by a foot |
| FTMIN=$\mu\mu$(MIN) | Assign * for every FtMin that has fewer than two moras |
| FTMIN=$\mu\mu$(MAX) | Assign * for every FtMin that has more than two moras |

Perhaps the most relevant constraint for our present discussion is EXHAUSTIVITY-FT, which militates against syllable-integrity violations by penalizing the existence

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[16]As a reviewer points out, the constraint ADJUNCT-μ can be understood as an instance of the avoidance of prominent material in prosodically weak positions, similar to early formulations of the Weight-to-Stress principle (Hayes 1980; Hammond 1986).

of feet that opt to parse moras directly instead of parsing them indirectly through the syllable level. In the following, we will discuss several interactions between this and the other constraints.

Firstly, the tableau in (36) shows that the ranking ADJUNCT-μ ≫ PARSE-μ ≫ EXHAUSTIVITY-FT gives rise to monomoraic adjuncts, even if it means breaking up a heavy syllable. To focus on the adjunct in this tableau, we abstract away from the weight of the first two syllables, simply building disyllabic feet over them. In addition, we do not consider candidates which place the adjunct to the left of the inner foot; such forms can be excluded by top-ranking an alignment constraint that militates against them, such as TROCHEE$_{NonMin}$ (Martínez-Paricio and Kager 2015).

(36)   Different ways of dealing with a heavy syllable in dependent position

$\sigma.\sigma.\mu\mu$	ADJUNCT-μ	PARSE-μ	EXHAUSTIVITY-FT
a. $(\sigma\sigma)\sigma_{\mu\mu}$		**!	
b. $((\sigma\sigma)\sigma_{\mu\mu})$	*!		
c. ☞ $((\sigma\sigma).\mu)\mu$		*	*

Candidates (36a) and (36b) are syllabic parses of the string, building no adjunct and a bimoraic adjunct, respectively. However, these syllabic parsings make unnecessary sacrifices; as (36c) shows, it is better to violate low-ranking EXHAUSTIVITY-FT and parse only a single mora in order to find the right balance between adjunct size and parsing constraints.

The above tableau establishes a partial ranking. We now turn to a full ranking for Copperbelt Bemba, using our layered feet generalization as presented in Sect. 4, Table 3, as our target forms. However, we will show that this is not achievable with the constraint set from Kager and Martínez-Paricio (2018b): a ranking paradox arises. That is, the parsing behavior of CB falls outside of the typological worldview suggested by Kager and Martínez-Paricio's constraint set. We will end the section with suggestions on how to amend the constraint set in order to account for CB.

Firstly, among our target forms, ADJUNCT-μ and FTMIN=$\mu\mu$(MIN) are surface-true; all forms have a monomoraic dependent, and none have a FtMin of size fewer than two moras. In the following tableaux, we simplify the presentation by excluding these constraints and all candidates that would violate either of them. From the tableau above, we can further deduce PARSE-μ ≫ EXHAUSTIVITY-FT. This leaves the position of FTMIN=$\mu\mu$(MAX) to be determined. A consideration of strings starting in $\sigma_\mu\sigma_{\mu\mu}$ reveals that either EXHAUSTIVITY-FT or PARSE-μ must outrank FT-MIN=$\mu\mu$(MAX), as shown in (37). In the tableau, we abbreviate EXHAUSTIVITY-FT as EXH-FT.

(37)   Quantity-sensitive iambic parsing

$\sigma_\mu\sigma_{\mu\mu}\sigma_\mu$	PARSE-μ	EXH-FT	FTMIN=$\mu\mu$(MAX)
a. ☞ $((\sigma_\mu\sigma_{\mu\mu})\sigma_\mu)$			*
b. $((\sigma_\mu.\mu)\mu).\sigma_\mu$	*!	**	

This tableau shows that parsing and syllable integrity preferences can drive a quantity-sensitive iambic parsing of the $\sigma_\mu\sigma_{\mu\mu}$ string, as in (37a). However, consideration of strings starting in a heavy syllable shows that parsing in Copperbelt

Bemba is not always maximized. This is demonstrated in the tableau in (38). The only way to derive this effect is by ranking FTMIN=$\mu\mu$(MAX) higher than PARSE-μ, rather than lower.

(38)   Limited parsing in heavy-initial strings

$\sigma_{\mu\mu}\sigma_\mu\sigma_\mu$	FTMIN=$\mu\mu$(MAX)	PARSE-μ	EXH-FT
a. $\quad((\sigma_{\mu\mu}\sigma_\mu)\sigma_\mu)$	*!		
b. ☞ $((\sigma_{\mu\mu})\sigma_\mu)\sigma_\mu$		*!	

While a full parse of the string as in (38a) was optimal for strings starting in $\sigma_\mu\sigma_{\mu\mu}$, CB prefers a FTMIN=$\mu\mu$(MAX)-respecting parse as in (38b) for strings starting in heavy syllables.

We summarize the ranking arguments from the preceding tableaux in (39).

(39)   a.   PARSE-μ ≫ EXHAUSTIVITY-FT
                 Per (36), dependents break up heavy syllables
         b.   PARSE-μ ≫ FTMIN=$\mu\mu$(MAX)
                 OR
                 EXHAUSTIVITY-FT ≫ FTMIN=$\mu\mu$(MAX)
                 Per (37), CB prefers $((\sigma_\mu\sigma_{\mu\mu})\sigma_\mu)$ to $((\sigma_\mu.\mu)\mu)\sigma_\mu$
         c.   FTMIN=$\mu\mu$(MAX) ≫ PARSE-μ
                 Per (38), CB prefers $((\sigma_{\mu\mu})\sigma_\mu)\sigma_\mu$ over $((\sigma_{\mu\mu}\sigma_\mu)\sigma_\mu)$

Combining (39a) and (39c), the paradox can be boiled down to the two opposing statements "PARSE-μ or EXHAUSTIVITY-FT ≫ FTMIN=$\mu\mu$(MAX)"; and "FTMIN=$\mu\mu$(MAX) ≫ both PARSE-μ and EXHAUSTIVITY-FT." The paradox can be solved by introducing another constraint into the set, which can take over the role of one of the involved constraints—thus allowing more flexibility in the ranking. Adding a constraint has the benefit of leaving intact the original constraint set, which was independently motivated. This ensures that all originally modellable patterns can still be modeled—with the new constraint adding more patterns, such as that of Copperbelt Bemba, to the factorial typology. A variety of additions is possible; our preferred implementation is to divide the labor of EXHAUSTIVITY-FT.

Crucially, the two cases where EXHAUSTIVITY-FT is relevant take place in different constituents. (39b) occurs in a FtMin context, whereas (39a) occurs in the context of a FtNonMin, i.e. a foot that dominates another foot. Thus, a solution to the paradox is to state, in line with (39a), that the general EXHAUSTIVITY-FT constraint is indeed low-ranked, but that (39b) is accounted for by a higher-ranking version of EXHAUSTIVITY-FT that is specific to FtMin contexts, i.e. the constraint EXHAUSTIVITY-FTMIN defined in (40).

(40)   EXHAUSTIVITY-FTMIN
         Assign * for each mora directly dominated by a FtMin

Conceptually, this addition entails that grammars have more tools to safeguard syllable integrity in their inner, minimal feet than they do in the outer foot layer. With this addition, we can account for the parsing behavior of CB in OT. The new constraint is added above the constraint ranking used in the tableau. Thus, the final ranking

comes out as { FtMin=$\mu\mu$(Min), Adjunct-μ, Exhaustivity-FtMin } $\gg$ Ft-Min=$\mu\mu$(Max) $\gg$ Parse-μ $\gg$ Exhaustivity-Ft. We provide tableaux for all cases in Sect. 6.2 below, using the expanded constraint set.

In summary, in this section we have modeled a syllable-integrity violating grammar in OT, building on results from Kager and Martínez-Paricio (2018b) to show that Copperbelt Bemba adds new considerations to the construction of a descriptively adequate constraint set.

6.2 Tableaux for layered feet with SIVs

Here we list the full set of tableaux for parsing in Copperbelt Bemba, using the new constraint Exhaustivity-FtMin we proposed above. Fundamentally, we will consider two different syllable weights—light and heavy—and because we assume maximally trisyllabic layered foot representations, we consider trisyllabic strings. Consequently, there are $2^3 = 8$ different inputs to consider. However, for strings beginning with a heavy syllable it is never optimal to parse four moras, as can be gleaned from tableaux (45, 46). Thus we show only six strings, leaving out $\sigma_{\mu\mu}\sigma_\mu\sigma_{\mu\mu}$ and collapsing the two cases of initial $\sigma_{\mu\mu}\sigma_{\mu\mu}$.

In the tableaux, Exhaustivity-FtMin is abbreviated as Exh-FtMin, FtMin=$\mu\mu$(Max) as $\mu\mu$Max, Parse-μ as Parse, and Exhaustivity-Ft as Exh-Ft.

(41)

$\sigma_\mu\sigma_\mu\sigma_\mu$	Exh-FtMin	$\mu\mu$Max	Parse	Exh-Ft
a. ☞ $((\sigma_\mu\sigma_\mu)\sigma_\mu)$				
b. $(\sigma_\mu\sigma_\mu)\sigma_\mu$			*!	

(42)

$\sigma_\mu\sigma_\mu\sigma_{\mu\mu}$	Exh-FtMin	$\mu\mu$Max	Parse	Exh-Ft
a. ☞ $((\sigma_\mu\sigma_\mu).\mu)\mu$			*	*
b. $(\sigma_\mu\sigma_\mu)\sigma_{\mu\mu}$			**!	

(43)

$\sigma_\mu\sigma_{\mu\mu}\sigma_\mu$	Exh-FtMin	$\mu\mu$Max	Parse	Exh-Ft
a. ☞ $((\sigma_\mu\sigma_{\mu\mu})\sigma_\mu)$		*		
b. $(\sigma_\mu\sigma_{\mu\mu})\sigma_\mu$		*	*!	
c. $((\sigma_\mu.\mu)\mu).\sigma_\mu$	*!		*	**
d. $(\sigma_\mu.\mu)\mu.\sigma_\mu$	*!		**	*

(44)

$\sigma_\mu\sigma_{\mu\mu}\sigma_{\mu\mu}$	Exh-FtMin	$\mu\mu$Max	Parse	Exh-Ft
a. ☞ $((\sigma_\mu\sigma_{\mu\mu}).\mu)\mu$		*	*	*
b. $(\sigma_\mu\sigma_{\mu\mu})\sigma_{\mu\mu}$		*	**!	
c. $((\sigma_\mu.\mu)\mu).\sigma_{\mu\mu}$	*!		**	**
d. $(\sigma_\mu.\mu)\mu.\sigma_{\mu\mu}$	*!		***	*

(45)

$\sigma_{\mu\mu}\sigma_\mu\sigma_\mu$	EXH-FTMIN	$\mu\mu$Max	PARSE	EXH-FT
a. ☞ $((\sigma_{\mu\mu})\sigma_\mu)\sigma_\mu$			*	
b. $(\sigma_{\mu\mu})\sigma_\mu\sigma_\mu$			**!	
c. $((\sigma_{\mu\mu}\sigma_\mu)\sigma_\mu)$		*!		
d. $(\sigma_{\mu\mu}\sigma_\mu)\sigma_\mu$		*!	*	

(46)

$\sigma_{\mu\mu}\sigma_{\mu\mu}$	EXH-FTMIN	$\mu\mu$Max	PARSE	EXH-FT
a. ☞ $((\sigma_{\mu\mu}).\mu)\mu$			*	*
b. $(\sigma_{\mu\mu})\sigma_{\mu\mu}$			**!	
c. $(\sigma_{\mu\mu}\sigma_{\mu\mu})$		*!		

7 Discussion

7.1 SIVs and multiply stressed syllables

A classic objection against SIVs is that they predict syllable-internal stress contrasts (Hayes 1995), where a language might realize some heavy syllables with first-mora stress, and others with second-mora stress. Although this type of contrast indeed seems rare, we believe the case of Banawá is an important counterexample (Buller et al. 1993; Everett 1996; Hyde 2007). Nevertheless, Hyde (2007) provides a syllable-integrity respecting analysis of Banawá (though see Martínez-Paricio and Kager 2019), and raises a different objection to allowing SIVs, noting that they "open the door to [...] multimoraic syllables that have stress on more than one mora" (241). We note that this wording might include any stressed heavy syllable; following a reviewer's suggestion, we focus our attention on multimoraic syllables with more than one *distinct* stress. Indeed, we are not aware of the attestation of such a structure. However, since we propose to allow SIVs, such structures could indeed be represented, e.g. two non-contiguous stresses on a trimoraic syllable as in (47). Consequently, we predict that human cognition, specifically human phonological grammar, is at least theoretically capable of processing these structures.

(47)   A syllable with multiple, non-contiguous stressed moras due to SIV feet
         $(\sigma.'\mu)\mu('\mu.\sigma)$

We leave the reconciliation of this prediction with the apparent non-attestation of multi-stressed syllables as an open research problem. However, we do offer two potentially relevant observations here. Firstly, the form in (47) could only surface under typologically extreme conditions. Future research, particularly on diachrony, might show that it is unlikely for a language to arise that has both trimoraic syllables and a grammar that promotes co-occurrence of iambs and trochees. Secondly, the evidence in favor of SIVs comes from languages with a tonal aspect, whereas the objections to it come from stress languages (Kager and Martínez-Paricio 2018b). Consequently, the stress–tone distinction might be a source of explanation about the non-attestation of stress phenomena predicted by the allowance of SIVs. Hyman (2006, 2009, 2011)

notes how the diversity found in tone typology supersedes that found in other phonological domains. It is possible that this asymmetry links to a broader array of factors than phonology alone. Future research might find that the phonetics underlying tone allow for a larger variety of acquisitional and diachronic developments; based on the findings in this paper, it would be worthwhile to see if such factors can account for the (non-)emergence of SIVs in stress and tone languages.

7.2 Implications for theories with featural domains

Although our focus in this paper has been on binarity vs ternarity, the CB facts have implications for another debate too. We have modeled the tone spreading domain with feet, but there are alternative theories available for such domain-based spreading. Optimal Domains Theory (ODT) suggests that features (such as tones) surface as headed domains, and constituents in the domain can vary in whether they "express" the domain's feature or not (Cole and Kisseberth 1994; Cassimjee and Kisseberth 1998). Similarly, Headed Spans theory suggests that sponsoring features (such as tone) form headed feature spans at the surface (McCarthy 2004; applied to tone by Key 2007; Key and Bickmore 2014). In both of these frameworks, constraints on the length of the domain (or span) serve to coerce the domain to have a certain size. ODT has a constraint *MONOHD that militates against unary heads; together with constraints that minimize domain size,[17] this can cause binary domains to be optimal. In the Headed Spans account of Key and Bickmore (2014:41), binarity is enforced directly through a constraint SPBIN(H) that assigns a violation mark "for each H span that does not parse some part (i.e., at least one mora) of exactly two syllables."

Fortunately, these approaches are flexible enough to accommodate ternarity because to some extent, the constraints are arbitrary; no principle blocks the introduction of similar constraints for ternary domain sizes in order to accommodate ternary domains (Breteler 2017:Sect. 5.2). However, even under the assumption of such extensions to the constraint set, these domain constraints assess violations by counting the number of constituents. This is where the contribution of CB comes in; although it is a domain-based spreading pattern, the domain size is not derivable from a counting rule. The table in (48) demonstrates this, showing the varying syllable and mora counts for all shapes of the domain. We count falling-toned heavy syllables ($\hat{\sigma}_{\mu\mu}$), where only one of two tautosyllabic moras undergoes tone spreading, as 0.5 unit of syllable association.

(48)

Domain shape	Syllable count	Mora count
$\acute{\sigma}_\mu\acute{\sigma}_\mu\acute{\sigma}_\mu$	3	3
$\acute{\sigma}_{\mu\mu}\acute{\sigma}_\mu$	2	3
$\acute{\sigma}_\mu\acute{\sigma}_{\mu\mu}\acute{\sigma}_\mu$	3	4
$\acute{\sigma}_\mu\acute{\sigma}_\mu\hat{\sigma}_{\mu\mu}$	2.5	3
$\acute{\sigma}_{\mu\mu}\hat{\sigma}_{\mu\mu}$	1.5	3
$\acute{\sigma}_\mu\acute{\sigma}_{\mu\mu}\hat{\sigma}_{\mu\mu}$	2.5	4

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[17]In Optimal Domains Theory, these are the "Basic Alignment" constraints that keep the edges of the domain aligned (gradiently) with the edges of the tone sponsor.

As we have argued throughout this paper, a principled generalization of CB requires reference to syllable weight groupings, i.e. quantity-sensitive feet. We see no way of incorporating such quantity sensitivity in ODT or Headed Spans theory, especially if the aim is to avoid restating all of metrical representational theory. Consequently, we claim that the case of Copperbelt Bemba strongly favors a quantity-sensitive foot-based interpretation over accounts that use competing theoretical frameworks for tone spreading. For bounded tone patterns in general (Bickmore 1996), the present results strengthen the case for a foot-based typological account (Breteler 2017).

7.3 Vowels before pre-nasalized consonants

Silke Hamann (p.c., June 2017) notes that all CB data for sequences starting in $\sigma_\mu \sigma_{\mu\mu}$ have a pre-nasalized onset consonant (NC) following the heavy syllable.[18] Before NC, Bemba has no lexical contrast between short and long vowels. Furthermore, while vowels before NC are phonetically longer than regular short vowels, they are still phonetically shorter than regular long vowels, as measured by Hamann and Kula (2015). In general, literature on NC sequences, particularly in Bantu languages, has noted that in some languages the mora associated with the nasal does not function as a tone-bearing unit, despite contributing to the mora count for weight-sensitive morphophonological operations, such as reduplication and choice of allomorph (Hyman 1992; Hubbard 1995a,b,c; Downing 2005). In sum, for the case of CB there is reason to be suspicious about the phonological length of vowels in $\sigma_\mu \sigma_{\mu\mu}$-initial sequences. This is particularly important because these are the only sequences that we counted as quadrimoraic instead of trimoraic—excluding OCP cases. Consequently, Hamann suggests that an alternative description of CB ternary spread might be available: If one interprets pre-NC vowels as phonologically short, then tone spreading is always trimoraic, regardless of syllable weight make-up.

From Bickmore and Kula (p.c., May 2018), we received further data with $\sigma_\mu \sigma_{\mu\mu}$-initial sequences that contain no NC cluster. These data, shown in (49), show quadrimoraic spreading, patterning with the data reported by B&K earlier and consistent with our interpretation of the data earlier in the paper.

(49) $\underline{\acute{\sigma}_\mu}\sigma_{\mu\mu}\acute{\sigma}_\mu$

a.	<u>bá</u>-shíík-íl-a bwiino	'they bury for each other well'
b.	<u>bá</u>-nóón-én-a bwiino	'they sharpen for each other well'
c.	<u>bá</u>-póós-él-an-a bwiino	'they throw to each other well'

The data in (49) upholds the interpretation that the CB ternary spreading domain can extend to the full width of a quantity-sensitive iamb plus an additional mora, which led us to propose a foot-based analysis. This means that our layered feet analysis from Sect. 4 still holds for the non-NC data, although as we will discuss below, further considerations might apply to data with pre-NC vowels.

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[18]Since we are interested only in the vowel length and tonal association facts, we remain agnostic here about the structural analysis of NC. Kula (1999, 2002) discusses analyzing NC as a sequence of separate consonants in Bemba (though not specifically Copperbelt Bemba).

We also received further data for another syllable sequence where there *is* a difference between NC and non-NC cases. Heavy-syllable sponsors have been represented in this paper and earlier reports exclusively by non-NC sequences. In those cases, spreading is disyllabic, as we presented earlier in (7), repeated in (50a). However, spreading is trisyllabic if the sponsor syllable is followed by NC, as shown in (50b).

(50) $\acute{\sigma}_{\mu\mu}\acute{\sigma}_{\mu}$ / $\acute{\sigma}_{\mu\mu}\acute{\sigma}_{\mu}\acute{\sigma}_{\mu}$
         a.   i.   tu-ka-léét-él-an-a=kó
                     'we will bring for each other'   BK13:112, (19a)
              ii.   tu-léé-mú-ʃiik-il-a bwiino
                     'we are burying well for him'   KB15:158, (20b)
         b.   i.   tu-ka-sáánsámúk-a sáaná   'we will feel happy a lot'
              ii.   tu-ka-kóóntól-án-a sáaná   'we will break each other a lot'

Tentatively, it seems that tone spreading applies prior to lengthening of pre-NC vowels (Hyman 1992; Hubbard 1995b, Bickmore and Kula, p.c.; Hamann, p.c.); for the heavy sponsor cases above, this would explain why pre-NC sponsors spread trisyllabically, as if they were light sponsor syllables. However, we think these data call for further investigation of pre-NC mora behavior in CB. Such an investigation falls outside the scope of this paper, but we will note two relevant points for future work here.

A first point of interest is that among the available data is one case of vowel coalescence before NC, shown in (51). Hamann and Kula (2015:67) report that vowel coalescence leads to derived long vowels, although their examples do not include sequences with NC. Consequently, (51) might reveal whether CB also has an active vowel length neutralization process before NC.

(51)   tw-aa-léé-mw-íimb-il-a=kó
         'we used to dig for him'   BK13:112, (19c)
         /tu-a-lée-mu-imb-il-a-kó/

Secondly, as we discussed in Sect. 5.1, vowels before NC pattern with lexically long vowels in creating falling tones to avoid tone contact, rather than inserting downstep as is done by lexically short vowels. All three vowel types are shown in (52)—using the transcriptions of B&K.

(52)   a. bá-ká-ˈlás-á   'they will hit'   BK13:115, (25a)
         b. béléeŋg-á   'read!'   BK13:116, (29b)
         c. bá-ʃíik-íl-é   'bury for them!'   BK13:116, (29c)

These facts are compatible with the idea that pre-NC vowels undergo lengthening at a later stage in the phonology; the lack of downstep in (52b) follows from the intervening toneless mora that is present after lengthening. Nevertheless, we note the fact here because it might be relevant for alternative accounts; any such account should incorporate statements about the nature of downstep, and the reason for its apparent absence in cases such as (52b). Future research could also examine more data on tone contact sequences, ideally including all weight sequences for both pre-NC and regular long vowels.

8 Conclusion

Based on the data and descriptive generalizations of Bickmore and Kula (2013), Kula and Bickmore (2015), we have identified Copperbelt Bemba bounded tone spreading as displaying a type of ternarity that has been underdiscussed in the literature on metrical theory. The ternary tone spreading domain freely allows multiple unparsed syllables on either side, which we have shown poses a major problem for Weak Layering accounts. Our account, using layered feet consisting of an inner iambic foot and a right-adjoined mora, successfully captured the spreading facts of CB in a single domain specification.

We have argued that both our layered feet account and a binary feet alternative require syllable-integrity violating representations. Consequently, our analysis of CB provides evidence in favor of treating SIVs as a part of representational theory. From the CB data, we have deduced a specific contribution to such a theory, arguing that constraints for SIVs in layered feet should be sensitive to the (non-)minimality of the foot type. Future research is needed to determine the broader typological predictions following from such constraint sets, as well as possible extragrammatical restrictions on the emergence of syllable-integrity violations.

We are hopeful that our metrical interpretation of the CB facts might offer some considerations for future development of metrical theory to draw on, and conversely, that metrical theory might help direct further inquiry into the nature of Copperbelt Bemba and related tone systems.

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