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RESEARCH

Deriving bounded tone with layered feet in Harmonic Serialism: The case of Saghala

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This paper proposes an approach to bounded tone shift and spread as found in Bantu languages. Its core intuition is that the bounding domain is delimited by foot structure. The approach uses layered foot representations to capture ternary phenomena, following Martinez-Paricio & Kager (2015). A set of licensing and structural constraints regulate tone-foot interactions. Harmonic Serialism is adopted as the grammatical framework, to allow for an account of opaque patterns (Prince & Smolensky 1993/2004; McCarthy 2010a).

The present approach improves on previous accounts in two ways. Firstly, the size of the tonal bounding domain follows from independently motivated foot representations, rather than being stipulated in the constraint set. Secondly, the approach obviates the need for markedness constraints that refer to underlying structure, because all relevant lexical information is reflected in foot structures.

The approach is demonstrated on Saghala (Patin 2009). Saghala shows both shift and spread in a trisyllabic domain. There are six tone patterns, dependent on the contact or near-contact of tones, and the position of word boundaries. An analysis is presented that accounts for all patterns. The success of the analysis shows that the foot-based approach is equipped to deal with a variety of bounded tone phenomena.

Keywords: Harmonic Serialism; layered feet; foot structure; tone; Bantu; prosodic typology

1 Introduction

Some Bantu languages display tone shift or spread, but only over a short distance. That is, the target tone-bearing unit (TBU) for the shift or spread is at most a few units away from the underlying position of the tone. The TBU hosting the tone in the underlying form is here termed the sponsor TBU. The unit span across which tonal activity takes place is termed the bounding domain. An overview of attested bounded tone patterns is shown in Table 1.

The crosslinguistic generalization from Table 1 is that the bounding domain is maximally three TBUs in size, counting from the sponsor TBU to the last TBU of the surface tonal span. That is, there are no attested cases of e.g. quaternary shift or spread.

In the autosegmental literature, most instances of bounded tone phenomena could straightforwardly be accounted for with locally defined rules. For example, (1) shows a typical definition of a tone shift rule, taken from Kenstowicz & Kisseberth (1990).

(1)

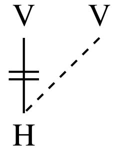

Table 1: A typology of attested bounded tone patterns.[1]

Pattern	*UF*	*SF*	*Example attestation*
Binary spreading	..*μ́μ*..	..*μ́μ́*..	Ekegusii
Ternary spreading	..σ́σσ..	..σ́σ́σ́..	Copperbelt Bemba
Binary shift	..σ́σ..	..σσ́..	Rimi
Ternary shift	..*μ́μμ*..	..*μμμ́*..	Sukuma
Bin. shift + bin. spread	..σ́σσ..	..σσ́σ́..	Saghala

In Optimality Theory (OT, Prince & Smolensky 1993/2004), demands on surface well-formedness and input-output correspondence are separated. Consequently, the direct formulation of the tone shift process as in (1) is unavailable. Despite this, constraint-based frameworks like OT are an appealing option for typological research, because they relate analytic choices to explicit typological predictions. Consequently, various OT approaches to the typology of Bantu bounded tone have been proposed. Bickmore (1996) uses alignment constraints to derive a variety of bounded tone patterns. Two other approaches explore the merits of recasting tonal representations in featural domains: Optimal Domains Theory (Cassimjee & Kisseberth 1998), and Headed Spans (Key 2007). However, the above approaches suffer from two problems. As will be argued in section 5.2, all three approaches use well-formedness constraints that run counter to the OT tenet of output orientation. Furthermore, the representational approaches stipulate the size of the bounding domain.

This paper presents a new constraint-based approach to bounded tone that avoids the above problems. Its core intuition is that the bounding domain is defined by foot structure. For example, a language with binary spreading would map /σσ́σσ/ to [σ(σ́σ́)σ], using a foot to determine the spreading domain.

The idea of relating metrical structure to tone is already present in the autosegmental literature (see Sietsema 1989; Bickmore 1995 for overviews). However, it was applied mainly to unbounded tone phenomena; tone was analysed as being attracted to metrically prominent positions near word or phrase edges. For bounded tone, an early foot-based approach was considered, and rejected, in an OT proposal by Bickmore (1996). In particular, Bickmore noted that the ternary nature of some bounded tone patterns posed a problem for binary feet.

Apart from Bickmore's study, the foot-based approach has remained underexplored.[2] This may have been due in part to the complexity of accounting for tonal shift. A foot-based approach to tone shift would need multiple steps: first a foot should be placed relative to a tone, and only then could the tone be shifted with reference to the foot. This is an opaque pattern, i.e. it requires intermediate forms. However, evaluation in OT is parallel, so it does not allow for intermediate forms. This problem will be demonstrated in detail in section 2.3.

Recent research provides solutions to both the ternarity and opacity problems. Based on independent work on stress and foot representations, a layered, ternary foot was proposed by Kager (2012); Martínez-Paricio (2013); Marínez-Paricio & Kager (2015) *et seq.,* hereafter MPK (see also Bennett 2012). The ternary foot provides a natural way of defining the bounding domain for ternary tone phenomena.

[1] References: Ekegusii (Bickmore 1996); Copperbelt Bemba (Bickmore & Kula 2013); Rimi (Olson 1964; Schadeberg 1979; Myers 1997); Sukuma (Sietsema 1989); Saghala (Patin 2009).

[2] One other paper employing feet for an OT analysis of bounded tone is Kang (1997). The author thanks Clemens Poppe for pointing out this study. Kang combines foot structure and complex underlying tones (LH sequences) to derive tone shift in Sukuma. While there is some support for such tonal representations in Sukuma, this may not be the case for all bounded tone languages. Consequently, the present paper aims to develop an account of bounded tone processes that does not rely on complex underlying tones.

The opacity problem is not unique to bounded tone, and research on accounting for opacity in OT has spawned a rich inventory of analytical tools. The present foot-based approach is couched in the Harmonic Serialism framework (HS, Prince & Smolensky 1993/2004; McCarthy 2000; 2010a). HS is a variant of OT that employs derivations. HS's ability to account for opaque processes is limited; while it can accomodate the opacity of tone shift that is required here, it can only account for some types of counter-bleeding opacity and has no way of dealing with counterfeeding opacity (McCarthy 2007: 36–8; Elfner 2016). It should be noted that HS is motivated not just by a need to deal with opacity; compared to OT, it can lead to different typological predictions that may exclude unattested patterns (McCarthy 2000; 2010b). It will be shown that HS lends itself particularly well to the present case, because the derivations are independent from morphological cycles.

It is beyond the scope of this paper to account for the full typology of bounded tone. Rather, the foot-based analysis is demonstrated for Saghala, as described by Patin (2002; 2009). Saghala is a complex bounded tone system; it contains most of the phenomena seen in other bounded tone languages. In the default pattern, underlying /σ́σσ/ maps to [σσ́σ́]. This means Saghala shows both shift and spread characteristics, and covers a trisyllabic domain. Furthermore, as will be detailed below, the tonal pattern is sensitive to a number of factors. Specifically, one of five deviating patterns can arise, depending on tonal adjacency or near-adjacency and the position of word boundaries.

No previous constraint-based analysis of Saghala exists.[3] Consequently, the present goal is twofold. First, this paper will present the first constraint-based account of Saghala tonology. Second, through giving this account, the paper aims to demonstrate the general ability of the present proposal to deal with the complexities of trisyllabic domains, opaque patterns like tone shift, and interactions between metrically driven tone behavior and other tonal phenomena.

Section 2 outlines the foot-based Harmonic Serialism approach to bounded tone. Section 3 presents the data of Saghala, followed by an analysis in section 4. Section 5 discusses the proposal in the context of previous literature, after which the paper wraps up with a conclusion.

2 The foot-based approach in Harmonic Serialism

This section will outline a foot-based approach to Bantu bounded tone in a constraint-based context. First, section 2.1 discusses the layered foot representations assumed here. Then, section 2.2 details the constraint set used to relate tones and feet to each other. Section 2.3 shows why OT's parallel evaluation is problematic, and describes the Harmonic Serialism architecture adopted here. The representations, constraints, and grammatical framework are put together in section 2.4, which demonstrates the approach with a schematized example of binary rightward tone shift.

2.1 Layered feet

Following MPK, who build on Selkirk (1980), Prince (1980), and Kager (1994), it is assumed that feet can be layered. That is, a flat, binary foot can be parsed together with an unfooted syllable to form a layered, trisyllabic foot.[4] Figure 1 shows examples of these foot structures.

[3] Patin (2009) provides a descriptively adequate analysis that uses a rule-based theory. Since the present focus is on developing a constraint-based account of the typology of bounded tone, this paper refrains from drawing a comparison to Patin's analysis.

[4] MPK's framework still includes unary feet as well. However, since unary feet will play no role in the present analysis, they are left out of consideration in the remainder of this paper. This simplification can be represented formally with a top-ranked markedness constraint banning the presence of unary feet.

(a) A flat, binary foot. (b) A layered, ternary foot.

Figure 1: Binary and ternary foot types in the MPK framework.

The layered foot proposal mirrors the more generally formulated program of recursively deployed prosodic categories advanced by Ito & Mester (a.o. 2007; 2013). It also adopts their practice of distinguishing between structurally different constituents of the same prosodic category in terms of (non)minimality and maximality. A foot is maximal if it is not dominated by another foot. This holds for binary feet that are not part of a layered foot, such as in Figure 1a, and for the higher foot layer of ternary feet, as in Figure 1b. A foot is minimal if it does not dominate another foot. In the present paper, all and only binary feet are instances of minimal feet. A foot is nonminimal or nonmaximal if it does not have the relevant property. This terminology can be used in constraint formulations, so that constraints can target specific types of feet. The necessity of referring to nonminimal constituents – specifically phonological phrases – has been argued for in Elfner (2013; 2015).

MPK assume that foot layering cannot be applied beyond the construction of ternary feet, making it different from the potentially infinitely recursed structures in Ito & Mester's work. Martínez-Paricio (2013: 56*ff*) cites the absence of any typological evidence to the contrary as a motivation for this assumption, and suggests that this fact may be related to the different *raison d'être* for foot structure compared to prosodic categories above the prosodic word.

Adopting a layered foot is advantageous for the analysis of Bantu bounded tone. It allows for a straightforward definition of the bounding domain in ternary tonal patterns, such as ternary spread, ternary shift, and the Saghala mixed pattern of binary shift and binary spread.

In the present approach, there is no role for foot headedness or stress, so their implementation for layered feet is not discussed here. Section 5.4 of the discussion returns to the issue of foot headedness.

The next section will discuss the constraints that are needed to model tonal activity within the bounding domain.

2.2 Constraints

This section presents a constraint set to regulate the relationship between tone and feet. A major previous work on this topic is De Lacy (2002). Comparison between the present proposal and De Lacy's is taken up in section 5.4.

The relationship between tone and feet is an indirect one, as tone does not link directly to foot nodes, but rather to smaller tone-bearing units. This section takes the syllable as the TBU.[5] Consequently, the constraints presented here bear on the autosegmental links between tones and footed syllables.

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[5] This is not a claim about the universal nature of TBUs, but rather a choice made to simplify the presentation, as there are no moraic effects discussed in the present paper.

It is proposed here that CON needs to allow for two effects: attraction, where the grammar promotes a tone-foot association; and repulsion, where the grammar militates against such an association. Examples of attraction are cases of tone-driven stress, where feet are ideally placed so that they overlap with a (high) tone (De Lacy 2002: 2*ff*). An example of repulsion is found in Lamba, where tone shifts away from its sponsor if the sponsor is in a rhythmically weak position (Bickmore 1995; De Lacy 2002: 18*f*). In general, repulsion is necessary to derive tone shift; attraction by itself does not drive the delinking of tone from its underlying position. In the following, constraint types for attraction and repulsion are discussed. First, the general format for the constraints is presented. Afterwards, it is discussed how they can be instantiated to target specific foot types and edges.

To drive the association between tones and feet, the present proposal adopts a set of licensing constraints (Zoll 1996: especially 147–152). Crucially, these constraints can take either the tone or the foot as the locus of violation. In other words, there are tone-licensing constraints and foot-licensing constraints. Both types are exemplified below by LICENSE(H, FT) and LICENSE(FT, H), respectively.[6] In general, LICENSE(X, Y) here means that an element of type X should be licensed by an element of type Y.

(2) LICENSE(H, FT)
For each H tone, assign one violation mark if it is not associated to a footed syllable.

(3) LICENSE(FT, H)
For each foot, assign one violation mark if none of its syllables are associated to a H tone.

For a given candidate, these two constraints may assign different numbers of violation marks. To demonstrate this, Table 2 shows the violation counts of various forms for LICENSE(H, FT) and LICENSE(FT, H).

Candidate 2a shows perfect one-to-one association between tones and feet, and candidate 2b shows complete nonassociation. For these candidates, the violation profiles are

Table 2: Tone and foot licensing violations.

	LICENSE(H, FT)	LICENSE(FT, H)
a. (σσ)(σσ) H H		
b. (σσ)(σσ) H H	**	**
c. (σσ)(σσ) H H		*
d. (σσ)(σσ) H	*	**

[6] All references to tone in the constraint formulations are written with H for high tone, rather than T for any tone. This is only to reflect the privative tone system of Saghala and many other bounded tone languages, where syllables are underlyingly toneless or high-toned. Accounting for the typology of multi-level tone languages is beyond the scope of this paper.

symmetrical. However, there are ways in which the violations assigned by the licensing constraints can differ. One example is in cases of multiple linking, as shown in 2c. Both tones have been licensed by a foot, satisfying LICENSE(H, FT), but only the leftmost foot has been licensed by a tone, causing a violation of LICENSE(FT, H) for the rightmost foot. Moreover, candidate 2d shows that even in complete nonassociation, the violation counts can be different if the number of tones does not equal the number of feet. LICENSE(H, FT) is violated once because there is one unlicensed tone, while LICENSE(FT, H) is violated twice for two unlicensed feet.

The second tone-foot interaction that needs to be modeled is repulsion. It will be modeled using structural constraints.[7] These constraints militate against an association between a H tone and a foot. An example is *H/FT:

(4) *H/FT
Assign one violation mark for each association between a H tone and a footed syllable.

In the case of structural constraints, the locus of violation is the association itself. Consequently, there is no distinction between a tone version and a foot version of the structural constraints.

The above definitions are the general forms of the proposed constraints. These general constraints coexist with more specific versions that target either the left or right edge of a specific foot type. For example, the following three constraints show instantiations of the constraint types for the right edges of minimal feet (MinFt):

(5) LICENSE(H, MIN-R)
For each H, assign one violation mark if it is not associated to a syllable that is rightmost in a MinFt.

(6) LICENSE(MIN-R, H)
For each MinFt, assign one violation mark if its rightmost syllable is not associated to a H tone.

(7) *H/MIN-R
Assign one violation mark for each association between a H tone and a syllable that is rightmost in a MinFt.

With the use of these fine-grained constraints it is possible to model attraction and repulsion in specific contexts. Moreover, a grammar can now mix repulsion in one context with

[7] An obvious alternative are constraints with the opposite function of licensing, i.e. NON-LICENSE(H, FT): "Assign one violation mark for each H that is associated to a footed syllable" and vice versa for NON-LICENSE(FT, H). These constraints were rejected for the present framework because of their potentially undesirable typological predictions, briefly outlined below, whose evaluation is beyond the scope of the present paper.
Since an association link necessarily involves both a tone and a foot, any candidate that violates a tone-non-licensing constraint will also violate its commensurate foot-non-licensing constraint at least once. In effect, then, both a gradient and a categorical non-licensing constraint are part of the grammar. The categorical version allows for two potentially undesirable effects. Firstly, it can create a magnet effect, causing all tones to associate to one violating foot. Secondly, in derivational frameworks such as Harmonic Serialism it can cause a situation where repair strategies are only available to candidates with a minimal number of violating association links. For cases where a full repair would take multiple steps, e.g. multiple applications of delinking, no repair is started on, because a partial repair does not lead to a reduction in violation marks.

attraction in another. It is essential that the grammar has this flexibility, because this is exactly the type of situation that derives tone shift.

It is also possible to posit a constraint type that instantiates only to a specific edge, or only to a specific foot type. The analysis of Saghala does not motivate any such constraint, so these constraints will not be considered in the remainder of this paper. Their desirability for the analysis of other languages is a topic for further research.

So far, this section has discussed constraints that handle the relationship between tone and feet. These constraints interact with constraints that pertain only to tone or only to feet. Of particular note are the constraints used to derive attraction of feet to one or the other edge of the footing domain. These constraints can put demands on foot placement that are orthogonal to those of the licensing constraints. As will be shown below, this is another ingredient required for an account of tone shift. In cases involving multiple feet, foot-to-edge attraction constraints also influence whether feet are built from right to left or the other way around. To derive these effects, the present paper adopts the pair of constraints CHAIN-L(σ_ω) and CHAIN-R(σ_ω), proposed in Martínez-Paricio & Kager (2015), which are formulated in terms of non-intervention:

(8) CHAIN-L(σ_ω)
"For every unfooted syllable $(\sigma)_\omega$, assign a violation mark if some foot intervenes between $(\sigma)_\omega$ and the [left] edge of its containing ω [here: footing domain]."
(Martínez-Paricio & Kager 2015: 12)

Although MPK define the constraint for a prosodic word, the analysis of Saghala requires phrasal feet, as will be argued in section 4.1. Consequently, the definition of this constraint is amended here to refer to any footing domain that may be relevant in a language. Taken as such, Chain-L penalizes any unfooted syllable that is not in a chain, i.e. an unbroken sequence, of unparsed syllables starting from the left edge of the footing domain. Because it pushes unfooted syllables to the left, this constraint in effect pulls *feet* to the *right*. Similarly, its mirror image, Chain-R, has the effect of pulling feet to the left.

The constraint types discussed here will be relevant for the analysis of Saghala in section 4, but before that, their use will be demonstrated in the following sections, which discuss the adoption and practice of Harmonic Serialism.

2.3 Harmonic Serialism

In OT, foot-driven bounded tone shift is problematic, because it is opaque; a foot must be placed relative to the tone's underlying position, and only after this has been achieved is the tone free to shift across the foot. Table 3 demonstrates this in more detail. In this and following tableaux, some constraint names are shortened; in particular, the word LICENSE is denoted by $\mathscr{L}$. Various output candidates are listed for the input /σσ́σσ/, including the surface form corresponding to rightward foot-driven tone shift, which is [σ(σσ́)σ]. Only candidates with a single association link are considered, so that the example can abstract away from the matter of delinking from the sponsor position. The constraint set consists of the following elements needed for a foot-driven tone shift: LICENSE(H, Ft) to drive foot construction over the tone; CHAIN-L to pull the foot rightward; LICENSE(H, Min-R) to drive a tone to the right foot edge; and a catch-all faithfulness constraint FAITH-LINK inhibiting changes in tone association.

Candidates 3a–c show various legitimate outcomes given the constraint set, none of which shift the tone in any way. The desired candidate is 3e, which positions the foot based on the underlying tone association and positions surface tone so it is at the right

Table 3: Harmonically bounded, foot-driven bounded tone shift in OT.

σσ́σσ	ℒ(H, Ft)	Chain-L	ℒ(H, Min-R)	Faith-Link
a. σσ́σσ	*		*	
b. σ(σ́σ)σ		*	*	
c. (σσ́)σσ		**		
d. σσ(σσ́)				*
e. ☹ σ(σσ́)σ		*!		*

edge of the foot. However, it is harmonically bounded by candidate 3d, which shows that if tone can shift, it might as well shift all the way to the right edge so as to optimally accomodate rightward foot attraction. Consequently, there is no ranking under which local, bounded tone shift is preferred over a global, edgemost alternative.

To address this problem, the present framework adopts Harmonic Serialism (HS, Prince & Smolensky 1993/2004; McCarthy 2000; 2010a), a variant of OT. Like OT, HS evaluates candidates through interaction of a ranked set of violable constraints. However, it deviates from OT in two ways. Firstly, Gen is limited to generating candidates that differ minimally from the input. Secondly, an evaluation happens serially; the output form of one tableau becomes the input form of another tableau. This repeats until the winning candidate is one that makes no change to the input. At that point, further evaluation would not yield any change, and so the winning form is the final result of the evaluation.

Candidates in HS can only differ from the input form by the application of one operation. The exact nature of the set of operations that a learner may acquire or carry innately is an open research question. This article will make use of the operations in (9):

(9)
 i. Link a tone to a TBU.
 ii. Delink a tone from a TBU.
 iii. Merge two tones (tone fusion).
 iv. Build a foot.

The construction of a layered foot takes two steps: first, two syllables are parsed into a flat foot. Then, the flat foot and a third syllable are parsed into a layered foot. An application of the foot-building operation can correspond to either of these steps (Martínez-Paricio & Kager 2013). It is assumed that faithfulness to metrical structure is absolute, so that Gen can never delete, shift, or otherwise alter a foot ("Strict Inheritance", Pruitt 2010: 486).

The operations in (9) suffice for the arguments made in this paper, but it is not claimed that these must be the only operations that can apply to tone and feet. For example, other grammars may make use of operations to delete, insert, or modify tones. The present operation set closely follows previous work on this topic. See Pruitt (2010; 2012) for an in-depth treatment of implementing metrical structure and stress in HS, and see McCarthy et al. (2012) for previous work on tone.[8] This paper further follows previous work in assuming that a tone shift operation is not part of Gen (McCarthy et al. 2012: 267*ff*, but

[8] A major conclusion made by McCarthy et al. (2012) is that in HS, tone cannot be lexically linked in any language. This is at odds with the present approach, where lexical linking is assumed. Resolving this conflict is a matter for future research.

see Gietz et al. 2015 for an opposing view). As will be shown in the remainder of the paper, a shift operation is not necessary to derive tone shift effects, since they can also be derived from a combination of foot-driven spreading and delinking steps.

HS is particularly suitable for the present purposes because a foot-based analysis of bounded tone may involve several intermediate steps between underlying and surface levels. Specifically, foot placement needs to be relative to the position of tone, after which tone association must readjust itself to the presence of feet. Furthermore, nothing suggests that these steps are related to different morphological cycles, which could have provided another source of derivationality. Consequently, the amorphological derivationality provided by HS is ideally suitable for a foot-based analysis of bounded tone.[9]

The next section will demonstrate the foot-based HS approach to bounded tone on a schematized example.

2.4 *Example: Binary tone shift using feet in Harmonic Serialism*

This section will demonstrate the foot-based approach to bounded tone in HS using an abstract example of rightward binary tone shift, where a tone surfaces on the TBU to the right of its sponsor. This pattern is attested among others in Rimi (Olson 1964), Kikuyu (Clements 1984), and Zululand Zulu (Downing 1990). Concretely, this section will derive the mapping of /σσ́σσ/ to [σσ́σσ]. The example will serve both as an elaboration of the approach and as the foundation for the analysis of Saghala in section 4.

The constraints used in the OT example above are called upon once again. One additional constraint is needed: *H/MinFt-L. This constraint penalizes an association of H tone to the left edge of a minimal foot. This will be crucial to force tone to delink from its sponsor location, effecting a tone shift rather than only a spreading process.

To save space, the tableaux below do not include candidates that are the result of a tone deletion or tone insertion operation. This choice is not problematic, because such operations can be ruled out by high-ranking Max-T and Dep-T constraints. Candidates with gapped autosegmental structures or floating tones are also left out of consideration. These candidates can be ruled out with markedness constraints (see e.g. McCarthy et al. 2012).

The derivation is presented below, starting with Table 4. Adjacent high tones indicate spreading. That is, σσ́σ́σ denotes a form with one H tone, linked to two syllables. If adjacent syllables link to different tones, this will be indicated with subscript indices. For example, σ́σ́$_1$σ́$_2$σ́ denotes a form with two H tones each linked to two syllables. Since this paper does not consider gapped autosegmental constructions, forms such as σ́σσ́ necessarily contain two H tones, and do not need to be explicitly marked with indices.

Table 4: Binary rightward shift in HS, step 1.

σσ́σσ	ℒ(H, Ft)	Chain-L	ℒ(H, Min-R)	*H/Min-L	Faith-Link
a. σσ́σσ	*!		*		
b. ☞σ(σ́σ)σ		*	*	*	
c. (σσ́)σσ		**!			
d. σσ́(σσ)	*!		*		
e. σσ́σ́σ	*!		*		*

[9] Frameworks that are more tightly linked to morphology, such as Stratal OT (Bermúdez-Otero 1999; Kiparsky 2000) may still be able to accomodate a foot-based analysis of bounded tone. However, because Saghala tone operates postlexically (as argued in section 4.1), this will require the positing of multiple post-lexical levels. See Jones (2014) for a related proposal.

Table 5: Binary rightward shift in HS, step 2.

σ(σ́σ)σ		$\mathcal{L}$(H, Ft)	Chain-L	$\mathcal{L}$(H, Min-R)	*H/Min-L	Faith-Link
a. σ(σ́σ)σ			*!	*	*	
b. ☞ σ((σ́σ)σ)				*	*	
c. (σ(σ́σ))σ			*!	*	*	
d. σ(σ́σ́)σ			*!		*	*
e. σ́(σ́σ)σ			*!	*	*	*

Here, because License(H, Ft) is top-ranked, the most urgent thing for the grammar to do is to license the H tone. This is achieved by placing a foot over the sponsor syllable. Both candidates 4b and 4c do so. However, the exact placement of the foot is left to Chain-L, which pulls unparsed syllables to the left, and hence feet to the right. This makes 4b the optimal candidate.

Candidate 4d has placed the foot so far to the right that it does not dominate the high-toned syllable. This favors rightward foot attraction, but under the present constraint ranking it is suboptimal. Candidate 4e demonstrates that tone spreading is in no way beneficial at this point in the derivation; there is no valid spreading target to satisfy License(H, Min-R) yet.

Table 5 shows the next step in the derivation. Now that the tone has been licensed, Chain-L(σ_ω) is the most important constraint to satisfy. This is done by reducing the number of unparsed syllables that are not in a sequence at the left edge of the domain. Candidate 5b shows how: building a layered foot to incorporate the last unparsed syllable at the right.

Candidate 5c shows another way of expanding the binary foot into a ternary one, but in the wrong direction, yielding no reduction in violation marks. Candidate 5d shows an instance of premature spreading, ignoring the urgency of Chain-L(σ_ω).

Another spreading candidate is 5e. Although spreading outside the foot does not satisfy any constraint, it does not incur additional violations of any markedness constraint either. In particular, spreading outside the foot does not violate License(H, Ft). This is because the constraint is satisfied as soon as the H tone is licensed anywhere; it evaluates at the level of the tone, and not at the level of the syllable. Consequently, it does not require that every TBU carrying the H is in a licensed position, but just that one of them is.

As the final three steps are more straightforward, they are presented in Table 6, a multi-step tableau (Pruitt 2012). The semi-circle arrows to the left side of the tableau indicate which form at a given step is selected as the input form for the next step. Thus, for example, candidate 6b is optimal at step three, and becomes the input form for candidates 6c, d, e in step four.

In step three, footing is complete, and the grammar can attend to the position of tone within the foot. The winning move is to simply spread rightward, reaching the right edge of the minimal foot, as shown in candidate 6b. This takes away the violation of License(H, Min-R).

In step four, there are several linking and delinking options. The winning candidate, 6d, demonstrates the satisfaction of *H/Min-L through delinking of tone from the left foot edge. Candidate 6e shows a ternary high tone span covering the entire layered foot. Although it is not optimal with the given constraint ranking, it could be made optimal with some different rankings of tone-foot constraints. Specifically, a constraint License(H, NonMin-R) could induce spreading to the right edge of the non-minimal foot. This shows the framework is able to account for ternary spread patterns, as attested in Copperbelt Bemba (Bickmore & Kula 2013).

Table 6: Binary rightward shift in HS, steps 3–5.

$\sigma((\acute{\sigma}\sigma)\sigma)$	$\mathscr{L}$(H, Ft)	Chain-L	$\mathscr{L}$(H, Min-R)	*H/Min-L	Faith-Link
Step 3					
a. $\sigma((\acute{\sigma}\sigma)\sigma)$			*!	*	
b. ☞ $\sigma((\acute{\sigma}\acute{\sigma})\sigma)$				*	*
Step 4					
c. $\sigma((\acute{\sigma}\acute{\sigma})\sigma)$				*!	
d. ☞ $\sigma((\sigma\acute{\sigma})\sigma)$					*
e. $\sigma((\acute{\sigma}\acute{\sigma})\acute{\sigma})$				*!	*
Step 5 – convergence					
f. ☞ $\sigma((\sigma\acute{\sigma})\sigma)$					
g. $\sigma((\sigma\acute{\sigma})\acute{\sigma})$					*!

In step five, the faithful candidate, 6f, has no violation mark for any constraint. Since it is optimal to make no further changes, the evaluation converges here and the output form of the derivation is [σ((σσ́)σ)], which is equal to the desired [σσσ́σ], modulo foot structure. Candidate 6g shows that further spreading is unnecessary with the current constraint set. However, inclusion of License(H, NonMin-R) could again turn this into the optimal candidate, making the binary shift plus binary spread pattern derivable. This pattern is the default behavior of tone in Saghala, which is the topic of the next section.

3 Saghala tone

This and the following section provide an in-depth case study for the foot-based HS framework. The case at hand is the tonology of noun phrases in Saghala (Guthrie's E74b), spoken in southeastern Kenya. All data here are transcriptions taken from Patin (2002) and Patin (2009), which are based on Patin's fieldwork.[10] Glosses from Patin (2002) use adjectives as predicates, whereas similar phrases in Patin (2009) are glossed with the adjectives used attributively; I assume that this does not reflect a relevant difference between the two data sets. Glosses from Patin (2002) have been translated from French by the present author.

Saghala has several properties that make it a suitable test case. Firstly, it features both tone shift and tone spread. Secondly, this tonal activity takes place in a trisyllabic domain. Thirdly, there is no involvement of morphology in the tonal patterns. Finally, the tonal pattern is complex: there are six patterns, depending on the phonological context, specifically the proximity of tones to each other and to the position of word boundaries.

This section describes the data, while the next section takes up their formal analysis. The presentation essentially follows that of Patin (2009), although the patterns have been renamed and a sixth pattern has been added. Further following Patin, since there seems to be no role for low tone in the language, a privative analysis is pursued. That is, it is

[10] Patin does not mention how his transcriptions relate to IPA; presumably, all symbols are IPA except for y, which represents IPA j.

assumed that all syllables are phonologically either H-toned or toneless, and that toneless syllables receive a default low pitch only after the phonological derivation.

The nature of the Saghala lexicon precludes the attestation of certain data. Specifically, all words in Saghala carry at most one H. Furthermore, all words in the sample are either two or three syllables in length.[11] Lastly, only determiners can carry H on a word-final syllable. This means that there are no contexts which have three tones adjacent to each other. In addition, because there are no monomoraic words, it is impossible to create contexts with multiple word boundaries on sequential syllables.

3.1 Default context

The default pattern in Saghala is the following: the two syllables following a sponsor receive high tone, while the sponsor itself is low-toned at the surface. The term default pattern is defined as the tonal pattern displayed when there is no effect of tonal proximity or word boundaries.

The location of sponsors is an analytical claim. To support this claim, the data in (10) show alternation of a toneless word in isolated context with two contexts where it is preceded by another word. In this and the following examples, proposed sponsor syllables are indicated by boldface and a following subscript H.

(10)	a.		nɟovu	‘elephant(s)’
	b.	**i**$_H$ zí	nɟóvu	‘that elephant’
	c.	i**lya**$_H$	nɟóvú	‘these elephants’

The bare noun in (10a) is toneless, but tone can be contributed to it from the preceding words in (10b, c). This suggests that tone was specified on these words. Furthermore, these words differ in terms of onset of the tonal span and, relatedly, the degree to which the span crosses into the next word. This suggests that tone in Saghala is linked underlyingly, and can be linked to different places in a word.

The tone shifting nature of Saghala is apparent from (10c). Here, tone was contributed by the first word, yet surfaces exclusively on the second, suggesting a rightward shift. Another observation confirming the notion of rightward shift is that noun phrase-initial syllables never surface with high tone.[12]

3.2 Long Spreading

In a specific context, surface tone spans across three syllables, rather than the default two. This pattern is dubbed Long Spreading. Examples of Long Spreading and its non-application are shown in (11). The string *aa* denotes two syllables; length is not contrastive in Saghala.

(11)	a.	i.	ivi**lya**$_H$ vóŋgó víbwaa	‘those heads are big’
		ii.	i**lya**$_H$ mbúlá mbwáa	‘that big nose’
		iii.	i**lya**$_H$ mízí míbwaa	‘those villages are big’
	b.	i.	ivi**lya**$_H$ vítánda vibwaa	‘those big beds’
		ii.	**i**$_H$zí nɟóvu	‘that elephant’

[11] Patin (2002) contains one instance of a quadrisyllabic word, [nizamɲaŋge] ‘white PL.’. In some attestations containing this word, the coda [m] is marked with surface H tone. Since the role of coda [m] here is not well understood, this word has been excluded from consideration.

[12] This refers to words that are initial in the noun phrase, which is what Patin (2009) reported on. It is not known how this relates to higher syntactic or prosodic structures.

In the cases in (11a) the tonal span is extended to a third syllable. Crucially, this third syllable is word-initial. These forms also show that Saghala tone can cross more than one word boundary. There is no tone span extension if the third syllable is not word-initial. Examples of this are in (11b), where tone shows a binary spread, rather than a ternary spread or even a quaternary spread to reach a word-initial syllable.

The second example, (11bii), repeated from (10b), shows that the tonal span remains binary even if that causes it to end in a word-initial syllable. This means that the word-initial syllable high is a goal, not a means; it is not used as a stepping stone to form a ternary span, e.g. *__i__$_H$zí nɟóvú. Furthermore, as noted above, phrase-initial syllables are never high-toned at the surface, despite the present observation that word-initial syllables can warrant a larger tone spread. Moreover, Long Spreading will never motivate a tone to surface on its sponsor syllable. This suggests that the drive for tone shift in Saghala is stronger than that of associating H to word-initial syllables.

Summarizing so far, Saghala shows a ternary span following the sponsor if the third syllable following the sponsor is word-initial, and a binary span in other cases. The following discussion will delve into contexts containing more than one tone in close proximity.

3.3 Adjacent Sponsors

If a word with a word-final sponsor is followed by a word with a word-initial sponsor, this is termed an Adjacent Sponsors context. In such contexts, high tone surfaces only on the second sponsor. Strikingly, there is no tonal span of two or three syllables. Examples are shown in (12).

(12) a. i**lya**$_H$ **mbú**$_H$zi ‘that goat’
b. i**lya**$_H$ **ʃí**$_H$mba ‘that lion’
c. uɣu**lya**$_H$ **mwé**$_H$zi mbwaa ‘that moon is big’

The adjacency of TBUs linked to different tones here leads to an outcome that is highly different from the patterns seen so far. In line with this, some of the following subpatterns display a strategy of avoiding adjacent tone spans.

3.4 Blocked Spreading

When sponsors are separated by a single syllable, one of two scenarios can occur. In the default case, both tones can shift, but the left H tone cannot spread, in effect keeping its one-syllable distance to the following tone. This is referred to as the Blocked Spreading context. Blocked Spreading is demonstrated in (13).

(13) a. **i**$_H$hí **mbu**$_H$zí ‘this goat’
b. **i**$_H$hí **me**$_H$zí míbwaa ‘these moons are big’
c. **a**$_H$wá **wa**$_H$ná wá**le**$_H$lé ‘these tall children’

Examples (13a, c) also demonstrate the behavior of tone that is near the right edge of the domain. In these cases too, the tone will shift, despite the lack of opportunity for spreading. In addition, (13c) shows that Saghala allows two different tones to surface on the same word.

The Blocked Spreading context shows that the language may preserve some distance between tones. If the tones operated completely independently from another, then the first tone should be able to spread to the second sponsor syllable, resulting in a potential four-syllable tone span, e.g. *__i__$_H$hí **mé**$_H$zí míbwaa.

3.5 Straddled Word-Initial Syllable

A different scenario applies when the syllable in between the two sponsors is word-initial. This context is called Straddled Word-Initial Syllable or SWIS. This is the second context that is dependent on a specific position of the word boundary, along with the Long Spreading context discussed above.

In SWIS contexts, the surface form looks as if the second tone was never there; tone surfaces on the two syllables to the right of the first sponsor, and there is no trace of tone from the second sponsor. This is shown in (14).

(14)	a.	i**lya**$_H$ zá**wá**$_H$di	'that gift'
	b.	ilyi**lya**$_H$ í**zí**$_H$so ibwaa	'that eye is big'
	c.	wa**lye**$_H$ wá**lú**$_H$me wa**le**$_H$lé	'those men are big'

If this context followed the Blocked Spreading pattern above, then the two tones should have shifted separately, e.g. showing *i**lya**$_H$ zá**wa**$_H$dí. Instead, the surface span resulting from the two tones covers a smaller domain than expected, reminiscent of the Adjacent Sponsors context. Patin (2009) reports no indication that the surface tone span consists of two parts, which could for example be signaled by a downstepped second high syllable. Moreover, his analysis treats the surface tonal span as representing a single tone. Consequently, this paper assumes that a single surface tone is an appropriate representation for the SWIS data.

Together, the Blocked Spreading and SWIS contexts cover all outcomes for sponsors that are one syllable apart. For contexts with a two-syllable distance between sponsors, there should generally be no expectation of tonal interaction, since both sponsors have enough room to shift and spread. However, there is one plausible exception: if the first tone is in a position to trigger Long Spreading, it is possible that the resulting three-syllable span causes tonal contact. The discussion of the sixth subpattern below tests this scenario.

3.6 Blocked Long Spreading

Although rare in the data sample, there is an instance of the context described above. It is shown in (15).

(15) izi**lya**$_H$ ŋgúkú **nɟa**$_H$cé 'those little chickens'

If the Long Spreading pattern applied here, the first tone could cover a ternary span, because the third syllable after the sponsor is word-initial. Combined with the influence of the second tone, this could result in a quaternary surface span: *izi**lya**$_H$ ŋgúkú **nɟá**$_H$cé. This is not the case, but the attested form does show the influence of both tones independently of each other. Consequently, this subpattern is most comparable to the Blocked Spreading pattern, rather than the contracted cases of Adjacent Sponsors and SWIS.

3.7 Overview

The six patterns are listed in Table 7 below. The context descriptions have been schematized. Word boundaries are only shown where relevant to the description of the context. All descriptions use enough syllables to show the end of the tone span, as indicated by a following low-toned syllable, but this final low syllable is not essential to the context; Saghala does not repel tones from the right phrase edge.

4 A foot-based HS analysis of Saghala tone

This section will account for all the Saghala subpatterns described in the previous section. First, the relationship between foot and word in Saghala is discussed below. Then, the constraint ranking for Saghala is presented. Finally, HS derivations are presented for all subpatterns.

4.1 The relationship between foot and word

In Saghala, tone spreading freely crosses word boundaries. If this process is to be analysed by feet, then feet need to be similarly free to straddle word boundaries. This is in fact the route taken here, with foot attraction being evaluated by CHAIN-L/R at the phrasal level. However, the process of Long Spreading shows that there is still a phonological role for the word to be played; word-initial syllables invite spreading from the previous word. This means that feet and prosodic word constituents must both be active, independently from each other.

The structures in Figure 2 show two ways of representing a foot straddling a word boundary.

In Figure 2a, a foot is dominated by both of the words whose syllables it parses. Syllable membership can then be calculated through orientation: in double-dominated feet, the left syllable belongs to the left dominating word, and the right syllable to the right dominating word. This approach violates the common assumption that every (non-root) node has exactly one dominating node ("Proper Bracketing", Itô & Mester 1992).

In Figure 2b, the phrase acts as the footing domain, directly dominating the foot as well as the word. While this goes against the original conception of the Prosodic Hierarchy by Nespor & Vogel (1986), it is in line with revisions by Inkelas (1989) and Downing (1998; 2006) who propose a split of the Prosodic Hierarchy into a prosodic and a metrical hierarchy (as summarized in Poppe 2015). Their arguments are based on distinctions between phonology and morphosyntax and the frequent absence of overlap between the two, rather than on the type of situation that obtains in Saghala, where feet need to straddle Prosodic Word boundaries. However, the Saghala case is not unique; Buckley (2014)

Table 7: Six tonal patterns in Saghala.

Context	***UF***	***SF***
Default: Surface high tone on the two syllables following the sponsor.	..σ́σσσ..	..σσ́σ́σ..
Long Spreading: Surface high tone on the three syllables following the sponsor if the final syllable is word-initial, and not a sponsor syllable.	..σ́σσ#σσ..	..σσ́σ́#σ́σ..
Adjacent Sponsors: A single surface high tone on the rightmost of two sponsor syllables.	..σ́$_1$#σ́$_2$σ..	..σ#σ́σ..
Blocked Spreading: Surface high tone only on the first syllable following the sponsor if the syllable after that is also a sponsor (tone from this second sponsor also shifts away).	..σ́σ#σ́σσσ..	..σσ́#σσ́σ́σ..
Straddled Word-Initial Syllable: Surface high tone on the two syllables following the leftmost of two sponsors, if those sponsors straddle a word-initial syllable.	..σ́#σσ́σ..	..σ#σ́σ́..
Blocked Long Spreading: No Long Spreading if the third syllable of a potential ternary tone span is itself a sponsor.	..σ́σσ#σ́σσσ..	..σσ́σ́#σσ́σ́σ..

(a) Two words dominating one foot. **(b)** A phrase directly dominating two words and a foot.

Figure 2: Two representations of a foot straddling a word boundary.

reports a combination of word-straddling feet and word-level information being accessed at the phrase level for Kashaya.

For the analysis in the remainder of this section, the choice between the structures in (2) is not crucial; all that is needed is that footing can occur phrasally while syllables can still be checked for word-initiality.

4.2 Constraint ranking and definitions

The core of the constraint ranking is shown in (16), with the ranks numbered, 1 being the highest.

(16)
1. LICENSE(H, FT)
   Assign one violation mark for each H that is not associated to a footed syllable.
2. CHAIN-L(σ_ω)
   For every unfooted syllable [σ_i], assign a violation mark if some foot intervenes between σ_i and the left edge of the footing domain (in Saghala: phrase).
3. *H/MIN-L
   Assign one violation mark for each association between a H and the leftmost syllable of a Min foot.
4. LICENSE(H, MIN-R)
   Assign one violation mark for each H tone that is not associated to the rightmost syllable of a Min foot.
5. LICENSE(H, NONMIN-R)
   Assign one violation mark for each H tone that is not associated to the rightmost syllable of a NonMin foot.
6. DEP-LINK, MAX-LINK, UNIFORMITY(H)

This constraint set is similar to the one presented for the binary rightward shift example in section 2.4. The main addition is another licensing constraint: LICENSE(H, NONMIN-R). This constraint promotes association of H to the rightmost syllable of a layered foot. As a result, the grammar has cause to associate a H to two locations: the right edge of the minimal and of the nonminimal foot.

The schematized example mapped /σσ́σσ/ to [σ((σσ́)σ)]. With the inclusion of LICENSE(H, NONMIN-R), the grammar will instead settle on [σ((σσ́)σ́)]. This is exactly the result found in the Saghala default pattern, which will be derived below.

At the bottom of the ranking are faithfulness constraints against tone linking, tone delinking, and tone fusion. The bottom-ranked position of these constraints means that the related operations may be applied to satisfy any markedness constraint in the ranking.

Some further additions to the constraint set are needed to account for the other subpatterns. Firstly, it was apparent from the Long Spreading and SWIS contexts that word-initial syllables have a special status in Saghala. This is modeled in the grammar with LICENSE(PRWD-L, H):

(17) LICENSE(PRWD-L, H)
For each PrWd, assign one violation mark if its leftmost syllable is not associated to a H tone.

As will be discussed below, this constraint must be quite low-ranked. This is supported by the observation that not all word-initial syllables in the language are high-toned, and that tone can shift away even from word-initial sponsors.

A further addition to the grammar is the OCP (Myers 1997). The constraint is here defined as follows:

(18) OCP-H
For each pair of H tones, assign one violation mark if they are associated to the same or adjacent syllables.

Although surface forms in Saghala never violate OCP-H, it does not have a high rank. This is because, as will be shown below, tonal contact must be allowed during the derivation of the SWIS context, so OCP-H should not rule this out. Furthermore, most of the avoidance of tonal contact is already achieved by the tone shifting behavior.

A third addition is LICENSE(FT, H). This constraint militates against tonally "empty" feet. In practice, this has two effects. Firstly, feet are not created in positions where there is no H-toned syllable. This runs counter to foot attraction constraints such as CHAIN-L, which promotes foot building if this helps to avoid unfooted syllables in certain positions. The second effect is that tone cannot delink from a syllable if that were to cause a toneless foot. In this sense, LICENSE(FT, H) acts as a faithfulness constraint; licensed feet cannot lose their license. The definition of the constraint is as follows:

(19) LICENSE(FT, H)
For each foot, assign one violation mark if none of its syllables are associated to a H tone.

The final addition to the constraint set involves several constraints meant to regulate the direction of foot expansion and its timing, i.e. the step in the derivation where foot expansion occurs. For the default pattern, the rightward expansion ((σσ)σ) is correct and could be constructed right away. However, to account for some of the other subpatterns, the grammar must be able to delay foot expansion to a later step in the derivation, and even be able to expand leftward. Three constraints are adopted to achieve this extra flexibility. The first is CHAIN-R(σ_ω), which is the counterpart of previously seen CHAIN-L(σ_ω). It has the effect of pulling feet to the left, which means that it favors leftward foot expansion.

The other two constraints place demands on the presence or absence of tones with regards to layered feet:

(20) *H/NONMIN-L
Assign one violation mark for each association between a H and the leftmost syllable of a NonMin foot.

(21) LICENSE(NONMAX-R, H)
Assign one violation mark for each NonMax foot whose rightmost syllable is not associated to a H tone.

Crucially, these constraints only come into action in the context of layered feet, since flat binary feet are neither nonminimal nor nonmaximal. Consequently, the grammar is free to place flat binary feet, but must pass the criteria of the two constraints above before being allowed to expand. The criteria are demonstrated by means of Table 8.

The tableau is split into three parts: candidates 8a,b show leftward and rightward expansion from σ(σσ́)σ; 8c, d from σ(σ́σ)σ; and 8e, f from σ(σ́σ́)σ. The default pattern of rightward expansion is only optimal from a σ(σσ́)σ starting point. In the case of candidates

Table 8: Violations of foot expansions.

	*H/NonMin-L	ℒ(NonMax-R, H)	Chain-L	Chain-R
a. ☞ σ((σσ́)σ)				*
b. (σ(σσ́))σ			*!	
c. σ((σ́σ)σ)	*!	*		*
d. ☞ (σ(σσ́))σ		*	*	
e. σ((σ́σ́)σ)	*!			*
f. ☞ (σ(σ́σ́))σ			*	

8c, e, rightward expansion is blocked by *H/NonMin-L because it situates a H tone at the left edge of a nonminimal foot.

License(NonMax-R, H) does not favor either leftward or rightward expansion. However, it can serve as a deterrent from foot expansion in general; candidates 8c, d both incur violations from this constraint. This way, the constraint allows for a delay in foot expansion until a tone has reached the right edge of a prospective nonmaximal foot.

The full ranking, shown in (22), consists of the core constraint set and the additions discussed above. Constraints listed within the same rank are not crucially ranked with respect to each other.

(22)
1. Max-T, Dep-T, NoFloat, NoGap,
   *H/NonMin-L
   Assign one violation mark for each association between a H and the leftmost syllable of a NonMin foot.
   License(H, Ft) (abbreviated ℒ(H, Ft))
   Assign one violation mark for each H that is not associated to a footed syllable.
   License(Ft, H) (abbreviated ℒ(Ft, H))
   For each foot, assign one violation mark if none of its syllables are associated to a H tone.
   License(NonMax-R, H) (abbreviated ℒ(NonMax-R, H)) Assign one violation mark for each NonMax foot whose rightmost syllable is not associated to a H tone.
2. CHAIN-L(σ_ω) (abbreviated Chain-L)
   For every unfooted syllable [σ_i], assign a violation mark if some foot intervenes between σ_i and the left edge of the footing domain (in Saghala: phrase).
3. *H/Min-L
   Assign one violation mark for each association between a H and the leftmost syllable of a Min foot.
4. Chain-R(σ_ω) (abbreviated Chain-R)
   For every unfooted syllable [σ_i], assign a violation mark if some foot intervenes between σ_i and the right edge of the footing domain (in Saghala: phrase).
5. License(H, Min-R) (abbreviated ℒ(H, Min-R))
   Assign one violation mark for each H tone that is not associated to the rightmost syllable of a Min foot.

6. LICENSE(H, NONMIN-R) (abbreviated $\mathscr{L}$(H, NONMIN-R))
   Assign one violation mark for each H tone that is not associated to the rightmost syllable of a NonMin foot.
7. LICENSE(PRWD-L, H) (abbreviated $\mathscr{L}$(ω-L, H))
   For each PrWd, assign one violation mark if its leftmost syllable is not associated to a H tone.
8. UNIFORMITY(H), MAX-LINK, DEP-LINK,
   OCP-H
   For each pair of H tones, assign one violation mark if they are associated to the same or adjacent syllables.

The composition of the above constraint set is principled, despite its size. About half of the constraints are instantiations of the constraint format put forth in section 2.3. The remaining constraints are taken from previous literature, and are established in mainstream OT literature. The only potential exception to this are the CHAIN constraints, which are an innovation of Martínez-Paricio & Kager (2015). However, the general concept of constraints deriving foot attraction is also an established part of OT literature, and nothing in the present proposal depends on the novel aspects of the CHAIN constraints as compared to e.g. ALL-FEET-LEFT/RIGHT (McCarthy & Prince 1993, in Kager 1999).

4.3 *Derivations*

4.3.1 Default context

In the default context, tone surfaces on the two syllables following the sponsor. The relevant examples from section 3 are repeated below.

(10)	b.	**i**$_H$zí	nɟóvu	'that elephant'
	a.	i**lya**$_H$	nɟóvú	'these elephants'

The derivation of the Saghala default pattern will be shown for a five-syllable form with H tone linked to the second syllable underlyingly: /σσ́σσσ/. From a five-syllable form it can be seen that the algorithm is not dependent on the adjacency of a tone to a word edge. The five-syllable string is an abstraction; all words in Patin (2002; 2009) are shorter, so any five-syllable string in Saghala will contain a word boundary. As will be argued in the discussion on Long Spreading below, the presence of word boundaries is inconsequential to the derivation of the default pattern, except when a word boundary precedes the third syllable following the sponsor. This is the Long Spreading context, and its derivation will be treated separately. Given the underlying form with second-syllable tone, the desired surface form has tone only on the third and fourth syllables: [σσσ́σ́σ], which is indeed the output of the derivation, modulo foot structure. The steps followed by the derivation are shown in Table 9.

The order of these steps follows from the constraint ranking, which is based on consideration of all patterns. Hence, although the order of some steps here is not crucial, the constraint rankings needed for the derivation of the other patterns force the default derivation into this order. The following tableaux will show each of the steps in detail. The top-ranked and bottom-ranked faithfulness constraints are left out of the tableaux. Furthermore, LICENSE(PRWD-L, H) and OCP-H are irrelevant to the derivation of the default pattern and left out of the tableaux.

Firstly, Table 10 shows the first step taken from the underlying form. This step is similar to the first step of the schematized example in Table 4. Because of high-ranking LICENSE(H, FT), it is optimal to construct a foot in such a way that it contains the high-toned syllable.

The decision between having this syllable at the left or right edge of the foot is left to Chain-L, which prefers having feet pulled rightward. Consequently, candidate 10b is optimal, since it incurs less violations of Chain-L than 10c.

The derivation diverges from the schematized example in Table 11. Despite high-ranking Chain-L, it is not possible to expand the foot at this point. An attempt at foot expansion is shown in candidate 11c, but it runs into violations of the anti-expansion constraints *H/NonMin-L and License(NonMax-R, H). The leftward expansion attempted by candidate 11d fails as well because it does not license the nonmaximal foot, i.e. the binary foot within the layered foot, with a H tone on its rightmost syllable. Consequently, the winning candidate 11b is optimal because it spreads tone to the right edge of the minimal foot, satisfying License(H, Min-R).

An alternative candidate not shown in Table 11 is σ(σ́σ)(σσ). This candidate creates an extra foot, but the foot does not dominate any high-toned syllable. Consequently, it is

Table 9: Steps of the default derivation.

	Form	***Comment***
0.	σσ́σσσ	Underlying form
1.	σ(σ́σ)σσ	Foot placement
2.	σ(σ́σ́)σσ	Spreading to the right edge of MinFt
3.	σ(σσ́)σσ	Delinking from the left edge of MinFt
4.	σ((σσ́)σ)σ	Rightward foot expansion
5.	σ((σσ́)σ́)σ	Spreading to the right edge of NonMinFt
6.	σ((σσ́)σ́)σ	Convergence of the HS algorithm; this is the output form

Table 10: Default context, step 1.

/σσ́σσσ/	*H/NonMin-L	ℒ(H, Ft)	ℒ(NonMax-R, H)	Chain-L	*H/Min-L	Chain-R	ℒ(H, Min-R)	ℒ(H, NonMin-R)
a. σσ́σσσ		*!					*	*
b. ☞ σ(σ́σ)σσ				**	*	*	*	*
c. (σσ́)σσσ				***!				*

Table 11: Default context, step 2.

σ(σ́σ)σσ	*H/NonMin-L	ℒ(H, Ft)	ℒ(NonMax-R, H)	Chain-L	*H/Min-L	Chain-R	ℒ(H, Min-R)	ℒ(H, NonMin-R)
a. σ(σ́σ)σσ				**	*	*	*!	*
b. ☞ σ(σ́σ́)σσ				**	*	*		*
c. σ((σ́σ)σ)σ	*!		*	*	*	*	*	*
d. (σ(σ́σ))σσ			*!	**	*		*	*

ruled out by high-ranking LICENSE(FT, H), which is not shown in the tableau. For the following tableaux, candidates with unlicensed feet are not considered.

Table 12 shows that after the spreading step, rightward expansion as in 12c is still blocked by *H/NONMIN-L, but leftward expansion is possible. The higher permissibility of leftward expansion compared to rightward expansion will be crucial in deriving the Adjacent Sponsors pattern. For the present case, the left-expanding candidate, 12d, is suboptimal. Its expansion step satisfies CHAIN-R, but there is a more important constraint that can be satisfied: *H/MIN-L. This is achieved by the winning candidate 12b, by delinking from the left edge of the minimal foot.

Table 13 shows the remaining steps of the derivation. Firstly, step 4 shows that rightward expansion, in 13b, is now the optimal move. This is because tone has moved away from the left foot edge and positioned itself at the right edge, passing the criteria of both anti-expansion constraints. Candidate 13c shows leftward expansion. This is suboptimal because CHAIN-L outranks CHAIN-R, causing the grammar to value rightward over leftward expansion.

After foot expansion, the second spreading target has become available – the right edge of the nonminimal foot. Spreading is the winning strategy in step 5 by candidate 13e.

Table 12: Default context, step 3.

σ(σ́σ́)σσ	*H/NONMIN-L	ℒ(H, FT)	ℒ(NONMAX-R, H)	CHAIN-L	*H/MIN-L	CHAIN-R	ℒ(H, MIN-R)	ℒ(H, NONMIN-R)
a. σ(σ́σ́)σσ				**	*!	*		*
b. ☞ σ(σσ́)σσ				**		*		*
c. σ((σ́σ́)σ)σ	*!			*	*	*		*
d. (σ(σ́σ́))σσ				**	*!			

Table 13: Default context, steps 4–6.

σ(σσ́)σσ	*H/NONMIN-L	ℒ(H, FT)	ℒ(NONMAX-R, H)	CHAIN-L	*H/MIN-L	CHAIN-R	ℒ(H, MIN-R)	ℒ(H, NONMIN-R)
Step 4								
a. σ(σσ́)σσ				**!		*		*
b. ☞ σ((σσ́)σ)σ				*		*		*
c. (σ(σσ́))σσ				**!				
Step 5								
d. σ((σσ́)σ)σ				*		*		*!
e. ☞ σ((σσ́)σ́)σ				*		*		
Step 6 – convergence								
f. ☞ σ((σσ́)σ́)σ				*		*		
g. σ((σσ)σ́)σ				*		*	*!	

After reaching both its spreading targets and delinking from the sponsor, the derivation is complete. Step 6 shows the convergence of the algorithm as the faithful mapping is the optimal candidate. Candidate 13g shows that further delinking is unwarranted, as it causes tone to no longer be licensed by the rightmost syllable of a minimal foot. After step 6, the derivation is finished. The output is σ((σσ́)σ́)σ, with surface tone at the two syllables following the sponsor, as desired.

4.3.2 Long Spreading

In Long Spreading, there is a ternary surface span ending in a word-initial syllable. The relevant examples from section 3 are repeated below.

(11)	a.	i.	ivi**lya**$_H$ vóŋgó víbwaa	'those heads are big'
		ii.	i**lya**$_H$ mbúlá mbwáa	'that big nose'
		iii.	i**lya**$_H$ mízí míbwaa	'those villages are big'

The difference between the default pattern and Long Spreading is encoded solely in the constraint promoting word-initial H tone: License(PrWd-L, H). This constraint is ranked below all the other constraints shown in the default derivation. The default derivation has no ties for winning candidate, which means that at every step in the derivation, some constraint that is ranked higher than License(PrWd-L, H) was decisive. Consequently, there is no way in which License(PrWd-L, H) could influence the default derivation. Moreover, it means a derivation for Long Spreading will initially go through the same steps as the default context. However, instead of converging, the derivation will go through two extra steps.

For the Long Spreading derivation, the form used in the default context will be changed to include a word boundary between the second and third syllable after the tone sponsor. A sixth syllable is added at the end of the form, to show where tone spreading ends. The new underlying form is /σσ́σσ#σσ/. The derivation will pick up at the end of the default pattern, with the intermediate form σ((σσ́)σ́)#σσ.

The steps of the Long Spreading derivation are shown in Table 14. The last three steps are shown in the multi-tableau in Table 15. Because the leftmost syllable can never be parsed, Chain-R is irrelevant here. There are also no opportunities for foot expansion in this form, so there is no role to play for the anti-expansion constraints. Consequently, these constraints have been taken out. License(PrWd-L, H) and Dep-Link are relevant here and have been added to the constraint set.

At step 6, faithful candidate 15a has two word-initial syllables without H tone. In comparison to winning candidate 15b, this is one too many; extending the tonal span to a third syllable is optimal. The repair of the two violations of Chain-L, which would give σ((σσ́)σ́)#(σσ), is suboptimal, because the extra foot would not be licensed by a tone.

In step 7, the foot placement has become a valid option since tone has spread, potentially licensing the foot in its new position. This development is leveraged by the winning candidate, 15d. The new footing does come at the cost of violating *H/Min-L, since there is now an association between a H tone and a syllable that is leftmost in a minimal foot.

Finally, the Long Spreading derivation converges in step 8. Candidate 15*f* shows that further spreading is suboptimal; it incurs a violation of Dep-Link because it introduces another association link, but this comes at no gain. None of the other constraints motivate additional spreading. This is because the grammar is centered on tone licensing. Since the tone is already licensed by the layered foot on the left, it does not need to seek further validation from the newly created foot on the right.

Table 14: Steps of the Long Spreading derivation.

	Form	***Comment***
5.	σ((σσ́)σ́) # σσ	(*previous steps collapsed*) Default pattern
6.	σ((σσ́)σ́) # σ́σ	Spreading to word-initial syllable
7.	σ((σσ́)σ́) # (σ́σ)	Footing
8.	σ((σσ́)σ́) # (σ́σ)	Convergence

Table 15: Long Spreading, steps 6–8 (following the default derivation).

σ((σσ́)σ́)#σσ	$\mathscr{L}$(H, Ft)	Chain-L	*H/Min-L	$\mathscr{L}$(H, Min-R)	$\mathscr{L}$(H, NonMin-R)	$\mathscr{L}$(ϖ-L, H)	Dep-Link
Step 6							
a. σ((σσ́)σ́)#σσ		**				**!	
b. ☞σ((σσ́)σ́)#σ́σ		**				*	*
Step 7							
c. σ((σσ́)σ́)#σ́σ		*!*				*	
d. ☞σ((σσ́)σ́)#(σ́σ)			*			*	
Step 8 – convergence							
e. ☞σ((σσ́)σ́)#(σ́σ)			*			*	
f. σ((σσ́)σ́)#(σ́σ́)			*			*	*!

The output form is [σ((σσ́)σ́)#(σ́σ)], showing a trisyllabic tonal span following the sponsor, with the third syllable from the sponsor being a word-initial syllable. This matches the description of the Long Spreading pattern.

4.3.3 Adjacent Sponsors

In the Adjacent Sponsors context, two adjacent syllables from different words are both sponsors. At the surface, this results in H tone only on the second sponsor. The examples from section 3 are repeated below:

(12)
a. **ilya**$_H$ **mbú**$_H$zi ‘that goat’
b. **ilya**$_H$ **ʃí**$_H$mba ‘that lion’
c. uɣu**lya**$_H$ **mwé**$_H$zi mbwaa ‘that moon is big’

The derivation will account for the abstract case of /σσ́$_1$#σ́$_2$σ/ mapping to [σσ#σ́σ]. As before in section 2, here and in the following, subscripts indicate tone indices. That is, a string σ́$_1$σ́$_2$ denotes two different tones associated to adjacent syllables, while σ́σ́ denotes a single tone spread to two syllables. The steps of the derivation are shown in Table 16.

The adjacency of the two sponsors causes two crucial deviations from the default pattern. Firstly, the binary foot is placed over both tones, rather than more to the right. Secondly, foot expansion is leftward, rather than rightward. The differences in foot structure then lead to the singly-linked tone, rather than the default binary tone span.

Tables 17 through 19 will show how the constraint set motivates the steps in Table 16.

In Table 17, the optimal move is to place a foot over both sponsors, as shown in 17b. This is the only way to avoid both violations of License(H, Ft). An alternative is to first resolve the clash between the two tones through tone fusion, shown by 17c. This has several benefits: since there is only one tone now, all the tone licensing constraints are only violated once, instead of twice. Furthermore, although not shown, this also resolves the violation of low-ranked OCP-H. However, this candidate still incurs a critical violation of License(H, Ft), which makes it suboptimal.

The result of placing the foot more to the right is shown in 17d. With this rightmost foot, the first H tone is not licensed, and so the candidate incurs a violation of License(H, Ft). Consequently, the usual tendency of the language to pull feet rightward is not followed here.

In Table 18, resolving the tone contact is still not urgent enough, ruling out 18d. The highest markedness constraint that is violated is Chain-L. However, satisfying it, as shown in candidate 18c, incurs a violation of high-ranked *H/NonMin-L, because it situates a H tone at the left edge of a nonminimal foot. The next highest violated constraint, *H/Min-L, can also not be satisfied, because there is no means of moving away the first

Table 16: Steps of the Adjacent Sponsors derivation.

	Form	***Comment***
0.	$\sigma\acute{\sigma}_1 \# \acute{\sigma}_2\sigma$	Underlying form
1.	$\sigma(\acute{\sigma}_1 \# \acute{\sigma}_2)\sigma$	Foot placement around both tones
2.	$(\sigma(\acute{\sigma}_1 \# \acute{\sigma}_2))\sigma$	Leftward foot expansion
3.	$(\sigma(\acute{\sigma} \# \acute{\sigma}))\sigma$	Tone fusion
4.	$(\sigma(\sigma \# \acute{\sigma}))\sigma$	Tone delinking
5.	$(\sigma(\sigma \# \acute{\sigma}))\sigma$	Convergence

Table 17: Adjacent Sponsors, step 1.

$\sigma\acute{\sigma}_1 \# \acute{\sigma}_2\sigma$	*H/NonMin-L	$\mathcal{L}$(H, Ft)	$\mathcal{L}$(NonMax-R, H)	Chain-L	*H/Min-L	Chain-R	$\mathcal{L}$(H, Min-R)	$\mathcal{L}$(H, NonMin-R)
a. $\sigma\acute{\sigma}_1 \# \acute{\sigma}_2\sigma$		*!*					**	**
b. ☞ $\sigma(\acute{\sigma}_1 \# \acute{\sigma}_2)\sigma$				*	*	*	*	**
c. $\sigma\acute{\sigma} \# \acute{\sigma}\sigma$		*!					*	*
d. $\sigma\acute{\sigma}_1 \# (\acute{\sigma}_2\sigma)$		*!			*	**	**	**

Table 18: Adjacent Sponsors, step 2.

$\sigma(\acute{\sigma}_1 \# \acute{\sigma}_2)\sigma$	*H/NonMin-L	$\mathcal{L}$(H, Ft)	$\mathcal{L}$(NonMax-R, H)	Chain-L	*H/Min-L	Chain-R	$\mathcal{L}$(H, Min-R)	$\mathcal{L}$(H, NonMin-R)
a. $\sigma(\acute{\sigma}_1 \# \acute{\sigma}_2)\sigma$				*	*	*!	*	**
b. ☞ $(\sigma(\acute{\sigma}_1 \# \acute{\sigma}_2))\sigma$				*	*		*	*
c. $\sigma((\acute{\sigma}_1 \# \acute{\sigma}_2)\sigma)$	*!				*	*	*	**
d. $\sigma(\acute{\sigma} \# \acute{\sigma})\sigma$				*	*	*!		*

H tone from the left edge of the minimal foot. This is because tone deletion and floating tone have been assumed to be ruled out by top- ranked constraints, and a tone shift operation is not part of GEN. Instead, the winning candidate 18b removes a violation of CHAIN-R by expanding to the left. Leftward expansion is sometimes blocked by LICENSE(NONMAX-R, H), but is allowed here because the second H tone is situated at the right edge of the potential nonmaximal foot.

A crucial result of leftward expansion is that it lines up the two spreading targets in Saghala. That is, the right edge of the minimal and nonminimal foot coincide on the same syllable. This is also why candidate 18b incurs one less violation of LICENSE(H, NONMIN-R) than the faithful candidate; by virtue of the foot placement, the tone is now licensed by a rightmost syllable in a nonminimal foot. Because the two spreading targets are on the same syllable, there is no binary tone span at the surface; associating to the single syllable satisfies both tone licensing constraints already, so further spreading is unwarranted. This will be shown in the following steps, presented in the multi-tableau in Table 19.

In step 3, satisfaction of neither CHAIN-L nor *H/MIN-L is possible. Consequently, at this stage the fusion of the two tones is optimal. This is shown by winning candidate 19b.

With tone fusion applied, there is an opportunity for tone to move away from the left edge of the minimal foot. This is what takes place in step 4, in candidate 19d. Candidate 19e delinks at the right edge of the foot, and therefore unnecessarily misses out on satisfaction of the licensing constraints.

The winning candidate at step 4 has only a single violation mark left, on the CHAIN-L constraint. This violation cannot be remedied because any further foot placement would be unlicensed and consequently blocked by $\mathscr{L}$(FT, H). Consequently, there is no way to improve on the candidate, and it is selected as the output form in the next step (not shown).

In conclusion, the derivation produces the surface form [(σ(σ#σ́))σ]. This fits the description of Adjacent Sponsors: tone surfaces solely on the second sponsor syllable.

4.3.4 Blocked Spreading

In Blocked Spreading, two tones separated by a single syllable will both shift, but the leftmost tone will not show a binary tone span. Examples from section 3 are repeated in (13).

Table 19: Adjacent Sponsors, steps 3 and 4.

(σ(σ́$_1$ # σ́$_2$))σ	*H/NONMIN-L	$\mathscr{L}$(H, FT)	$\mathscr{L}$(NONMAX-R, H)	CHAIN-L	*H/MIN-L	CHAIN-R	$\mathscr{L}$(H, MIN-R)	$\mathscr{L}$(H, NONMIN-R)
Step 3								
a. (σ(σ́$_1$ # σ́$_2$))σ				*	*		*!	*
b. ☞ (σ(σ́ # σ́))σ				*	*			
Step 4								
c. (σ(σ́ # σ́))σ				*	*!			
d. ☞ (σ(σ # σ́))σ				*				
e. (σ(σ́ # σ))σ				*	*!		*	*

(13) a. **i**$_H$hí **mbu**$_H$zí 'this goat'
b. **i**$_H$hí **me**$_H$zí míbwaa 'these moons are big'
c. **a**$_H$wá **wa**$_H$ná wá**le**$_H$lé 'these tall children'

The derivation of the Adjacent Sponsors pattern above has shown that the grammar is likely to apply tone fusion to tones that are in contact. Since the Blocked Spreading pattern shows two independent tones at the surface, the grammar should avoid creating a situation of tonal contact, to prevent tonal fusion. This is achieved in the derivation by letting the tones shift one at a time, beginning with the rightmost tone. The steps of the derivation are shown in Table 20 below.

The order of foot placement in steps 1 and 2 is due to rightward foot attraction, enforced by CHAIN-L(σ_ω). A layered foot encompassing both tones, e.g. ((σ́σ)#σ́)σ, takes two steps to construct in Harmonic Serialism. Since the first step places a foot rightmost, the only possible layered structure after step 1 would be σ́(σ#(σ́σ)), which does not cover both sponsors. Consequently, layered feet are ruled out for Blocked Spreading.

The tableaux of the derivation will skip the footing steps, and start from step 3, in Table 21. Since there is no room for layered feet in these examples, the constraints referring to layered feet are not shown in the tableaux.[13] In addition, since the domain is already completely footed, foot attraction constraints are inconsequential and have also been left out.

At step 3, in Table 21 the highest markedness constraint that the grammar can satisfy is LICENSE(H, MIN-R). There are two ways this can be achieved: by spreading either the left or right tone. The optimal choice is to spread the right tone, as shown by candidate 21b. Candidate 21c demonstrates why spreading the left tone is suboptimal: It creates tonal contact in violation of OCP-H.

Table 20: Steps of the Blocked Spreading derivation.

	Form	*Comment*
0.	σ́σ # σ́σ	Underlying form
1.	σ́σ # (σ́σ)	Foot placement, rightmost
2.	(σ́σ) # (σ́σ)	Foot placement
3.	(σ́σ) # (σ́σ́)	Spreading to the right edge of a minimal foot
4.	(σ́σ) # (σσ́)	Delinking
5.	(σ́σ́) # (σσ́)	Spreading to the right edge of a minimal foot
6.	(σσ́) # (σσ́)	Delinking
7.	(σσ́) # (σσ́)	Convergence

Table 21: Blocked Spreading, step 3.

(σ́σ) # (σ́σ)	*H/MIN-L	ℒ(H, MIN-R)	ℒ(ω-L, H)	OCP-H
a. (σ́σ) # (σ́σ)	**	**!		
b. ☞ (σ́σ) # (σ́σ́)	**	*		
c. (σ́σ́$_1$) # (σ́$_2$σ)	**	*		*!

[13] In contexts where the first sponsor is preceded by another syllable, CHAIN-R will motivate a leftward foot expansion, analogously to the the Adjacent Sponsors context. The tone associations are unaffected, coming out as (σ(**σ**$_H$σ́))#(**σ**$_H$σ́). This is because the rightmost tone shifts first, thereby ensuring that the two tones never associate to adjacent syllables, which means there is no possibility of tone fusion.

The tone spreading in step 3 opens up an opportunity for delinking. At the next step, in Table 22, this opportunity is taken right away by winning candidate 22b. Candidate 22c shows the result of performing more tone spreading. Although this satisfies LICENSE(H, MIN-R), it is suboptimal because it does not reduce the violation of higher-ranked *H/MIN-L.

After this initial delinking step, the process is repeated for the left tone. Steps 5 and 6 in Table 23 mirror the preceding two steps: tone spreads and then immediately delinks.

Step 7 shows the convergence of the derivation. The tendency shown in Long Spreading to continue spreading to reach a word-initial syllable is not displayed in Blocked Spreading. Candidate 23*f* shows why: spreading the left tone to the word-initial syllable causes it to cross over into the next foot. As a consequence, it creates a violation of *H/MIN-L. This makes it suboptimal compared to the faithful candidate.

As will be shown below, the situation is different for SWIS: tone does cross into the next foot, and the tones do come into contact.

4.3.5 Straddled Word-Initial Syllable

In the SWIS context, two sponsors separated by a word-initial syllable cause tone to surface on the two syllables following the first sponsor. The examples from section 3 are repeated in (14).

(14)	a.	**ilya**$_H$ zá**wá**$_H$di	'that gift'
	b.	ilyi**lya**$_H$ **ízí**$_H$so ibwaa	'that eye is big'
	c.	wa**lye**$_H$ wál**ú**$_H$me wa**le**$_H$lé	'those men are big'

At the surface, SWIS looks exactly like a default context pattern, assuming only 1 sponsor. However, the foot structure reflects the fact that SWIS has two sponsors underlyingly. The foot structure, and the steps to construct it, are shown in Table 24.

As in Blocked Spreading, foot construction proceeds in right-to-left fashion. The crucially different step is step 3: in SWIS, the left tone spreads first. This sets SWIS on a

Table 22: Blocked Spreading context, step 4.

(σ́σ) # (σ́σ)	*H/MIN-L	ℒ(H, MIN-R)	ℒ(ω-L, H)	OCP-H
a. (σ́σ) # (σ́σ́)	**!	*		
b. ☞ (σ́σ) # (σσ́)	*	*	*	
c. (σ́σ́$_1$) # (σ́$_2$σ́)	**!			*

Table 23: Blocked Spreading context, steps 5–7.

(σ́σ) # (σσ́)	*H/MIN-L	ℒ(H, MIN-R)	ℒ(ω-L, H)	OCP-H
Step 5				
a. (σ́σ) # (σσ́)	*	*!	*	
b. ☞ (σ́σ́) # (σσ́)	*		*	
Step 6				
c. (σ́σ́) # (σσ́)	*!		*	
d. ☞ (σσ́) # (σσ́)			**	
Step 7 – convergence				
e. ☞ (σσ́) # (σσ́)			**	
f. (σσ́) # (σ́$_1$σ́$_2$)	*!		*	*

different derivational path since it includes tonal contact. Tableaux for the derivations pick up at this spreading step, starting with Table 25.

Table 25 shows that after footing, it is optimal to spread to the syllable separating the two tones, as shown by 25b.[14] This is because this syllable is word-initial, so spreading to it satisfies License(PrWd-L, H). Since License(PrWd-L, H) outranks OCP-H, spreading here is applied despite creating tonal contact.

As was the case for Blocked Spreading, the spreading step is followed by a delinking step, shown in Table 26. Any other operation, such as tone fusion in 26c, is suboptimal because it does not resolve the violation of high-ranking *H/Min-L.

The tonal contact is resolved in the next step, shown in Table 27. The winning candidate 27b fuses the tones, crucially repairing a violation of License(H, Min-R) caused by the

Table 24: Steps of the Straddled Word-Initial Syllable derivation.

	Form	***Comment***
0.	$\acute{\sigma}$ # $\sigma\acute{\sigma}\sigma$	Underlying form
1.	$\acute{\sigma}$ # $\sigma(\acute{\sigma}\sigma)$	Foot placement, rightmost
2.	$(\acute{\sigma}$ # $\sigma)$ $(\acute{\sigma}\sigma)$	Foot placement
3.	$(\acute{\sigma}$ # $\acute{\sigma}_1)$ $(\acute{\sigma}_2\sigma)$	MinFt spreading across a word boundary
4.	$(\sigma$ # $\acute{\sigma}_1)(\acute{\sigma}_2\sigma)$	Delinking
5.	$(\sigma$ # $\acute{\sigma})(\acute{\sigma}\sigma)$	Fusion
6.	$(\sigma$ # $\acute{\sigma})(\acute{\sigma}\sigma)$	Convergence

Table 25: Straddled Word-Initial Syllable context, step 3.

$(\acute{\sigma}$ # $\sigma)$ $(\acute{\sigma}\sigma)$	*H/Min-L	$\mathcal{L}$(H, Min-R)	$\mathcal{L}$(ω-L, H)	OCP-H
a. $(\acute{\sigma}$ # $\sigma)$ $(\acute{\sigma}\sigma)$	**	**!	*	
b. ☞ $(\acute{\sigma}$ # $\acute{\sigma}_1)$ $(\acute{\sigma}_2\sigma)$	**	*		*
c. $(\acute{\sigma}$ # $\sigma)$ $(\acute{\sigma}\acute{\sigma})$	**	*	*!	

Table 26: Straddled Word-Initial Syllable context, step 4.

$(\acute{\sigma}$ # $\acute{\sigma}_1)$ $(\acute{\sigma}_2\sigma)$	*H/Min-L	$\mathcal{L}$(H, Min-R)	$\mathcal{L}$(ω-L, H)	OCP-H
a. $(\acute{\sigma}$ # $\acute{\sigma}_1)$ $(\acute{\sigma}_2\sigma)$	**!	*		*
b. ☞ $(\sigma$ # $\acute{\sigma}_1)$ $(\acute{\sigma}_2\sigma)$	*	*	*	*
c. $(\acute{\sigma}$ # $\acute{\sigma})$ $(\acute{\sigma}\sigma)$	**!			

Table 27: Straddled Word-Initial Syllable context, step 5.

$(\sigma$ # $\acute{\sigma}_1)$ $(\acute{\sigma}_2\sigma)$	*H/Min-L	$\mathcal{L}$(H, Min-R)	$\mathcal{L}$(ω-L, H)	OCP-H
a. $(\sigma$ # $\acute{\sigma}_1)$ $(\acute{\sigma}_2\sigma)$	*	*!	*	*
b. ☞ $(\sigma$ # $\acute{\sigma})$ $(\acute{\sigma}\sigma)$	*		*	
c. $(\sigma$ # $\acute{\sigma}_1)$ $(\acute{\sigma}_2\acute{\sigma})$	*		*	*!

[14] Candidate 25b achieves this goal by spreading the left tone. The same violation profile is achieved by spreading the right tone leftward, i.e. $(\acute{\sigma}_1\#\acute{\sigma}_2)(\acute{\sigma}\sigma)$. There is no constraint in the set that distinguishes between these two candidates, so they are tied. The tie is inconsequential; derivations for both forms converge on the same output. Readers that prefer a situation without ties can assume a bottom-ranked constraint that militates against spreading across a foot boundary or against a foot containing multiple H tones.

second tone, which was not associated to any right edge of a minimal foot. Fusion also reduces violations of unshown LICENSE(H, NONMIN-R), and satisfies OCP-H. Candidate 27c shows the suboptimality of spreading the right tone rightward.

After selecting 27b, the derivation has reached a similar point as at the end of Long Spreading: a single violation of *H/MIN-L remains, but delinking tone to solve it would cause an unlicensed foot. Consequently, the candidate cannot be further improved upon, and the derivation converges in the next step (not shown). The result, as attested, has surface H tone on the two syllables following the left sponsor.

4.3.6 Blocked Long Spreading

Blocked Long Spreading involved two tones, where Long Spreading for the first tone was blocked because it would cause tonal contact. It was exemplified in the previous section by the data repeated in (15) below.

(15) izi**lya**$_H$ ŋgúkú **nɟa**$_H$cé 'those little chickens'

The derivation of Blocked Long Spreading does not involve any novel processes. Consequently, the derivation is not presented with a full set of tableaux, but only with the steps in Table 28.

Each of the steps has an analogy to a step in one of the other derivations. Steps 1 and 2 show right-to-left foot building, comparable to the first steps of Blocked Spreading and SWIS. After this, there is a spreading and delinking step for the leftmost foot, which gets priority because it spreads to a word-initial syllable, comparable to the SWIS case. In step 5, tone in the leftmost foot has moved so that the foot can expand rightward, as in the default pattern. Steps 6 and 7 show spreading and delinking for the rightmost foot, and only then does the leftmost tone spread to the right edge of the layered foot in step 8. This order is motivated by the higher rank of LICENSE(H, MIN-R) compared to LICENSE(H, NONMIN-R), but also by the fact that spreading to the non-minimal foot edge first would cause tonal contact, which is blocked by OCP-H, just as in the Blocked Spreading case. After these steps, the derivation converges. While further spreading of the leftmost tone would help it reach another word-initial syllable, this is suboptimal because it would at the same time reach the left edge of a minimal foot, in violation of high-ranking *H/MIN-L. This is similar to the end state of the Blocked Spreading derivation, and it is the reason why Long Spreading is blocked by the presence of a tone on the word-initial syllable.

Table 28: Steps of the Blocked Long Spreading derivation.

	Form	*Comment*
0.	σσ́ # σσ # σ́σ	Underlying form
1.	σσ́ # σσ # (σ́σ)	Foot placement, rightmost
2.	σ(σ́ # σ)σ # (σ́σ)	Foot placement
3.	σ(σ́ # σ́)σ # (σ́σ)	MinFt spreading across a word boundary
4.	σ(σ # σ́)σ # (σ́σ)	Delinking
5.	σ((σ # σ́)σ) # (σ́σ)	Rightward foot expansion
6.	σ((σ # σ́)σ) # (σ́σ́)	MinFt spreading
7.	σ((σ # σ́)σ) # (σσ́)	Delinking
8.	σ((σ # σ́)σ́) # (σσ́)	NonMinFt spreading
9.	σ((σ # σ́)σ́) # (σσ́)	Convergence

4.4 Summary

The data for Saghala were presented in section 3. It characterized Saghala as a tone shift language that usually had binary or ternary tonal spans. Furthermore, unexpectedly short tone spans appeared to be a result of tonal contact. On the other hand, in some cases it seemed tonal contact was avoided. Finally, there was some role to be played by word-initial syllables.

This section gave a formal account of these observations. Firstly, the tone shift process was modeled as an interaction between rightward foot attraction and tone repulsion from leftmost positions in feet. Secondly, the observation of surface tonal spans was also reinterpreted through the lens of foot structure. That is, in the account presented in section 4, there is nothing explicitly stating that Saghala should have surface tone spans. Rather, there are simply two targets for tone to spread to, and these targets are usually adjacent. In other words, the generalization in Saghala is that tone is always licensed by the rightmost syllable of a minimal foot, and of a nonminimal foot where possible.

The shortness of tonal spans in tone contact situations, i.e. in Adjacent Sponsors and SWIS cases, is accounted for by the combination of foot structure and tone licensing effects. In both cases, tones have merged, and the resulting tone requires association to only one rightmost syllable each of minimal and nonminimal foot. Once such a position is associated to, spreading requirements have been satisfied. Consequently, there is no drive to create long tonal spans.

Avoidance of tonal contact, where applicable, was due in part to the effect of OCP-H. It was also due to the tone repulsion from left foot edges; tones were discouraged from entering into the next tone's foot domain by *H/MIN-L.

The significance of word-initial syllables was expressed by LICENSE(PRWD-L, H). Although low-ranked, this constraint caused the priority of spreading across word boundaries. This resulted in ternary spreading in Long Spreading contexts, and tonal contact in SWIS contexts.

The underlying form to footed surface form mappings for all cases are listed in Table 29.

In conclusion, this section gave a descriptively adequate account of Saghala noun phrase tonology based on three factors. Firstly, the analysis used layered feet to define the shifting and spreading domain. Secondly, a principled constraint set regulated tone-foot interactions. Finally, the Harmonic Serialism framework enabled opaque analyses where footing precedes tone activity, which was necessary for the tone shift and tonal contact cases.

The next section will discuss this approach and compare the choices made here to other approaches taken in the literature.

5 Discussion

5.1 Finding acoustic evidence for foot structure in Saghala

The layered foot structures proposed for Saghala are based on phonological arguments. Further support for the presence of feet might be found by inspecting the acoustics. Specifically, feet might be signalled by differences in pitch, amplitude, duration, or vowel quality

Table 29: The underlying and footed surface forms for the six Saghala contexts.

Type	*UF*	*SF*
Default	..σ́σσ..	..((σσ́)σ́)..
Long Spreading	..σ́σσ#σσ..	..((σσ́)σ́)#(σ́σ)..
Adjacent Sponsors	..σσ́$_1$#σ́$_2$..	..(σ(σ#σ́))..
Blocked Spreading	..σ́σ#σ́σσ..	..(σσ́)((#σσ́)σ́)..
Straddled Word-Initial Syllable	..σ́#σσ́σ..	..(σ#σ́)(σ́σ)..
Blocked Long Spreading	..σ́σσ#σ́σσ..	..((σσ́)σ́)#((σσ́)σ́)..

of the syllables involved. The ideal test cases are those contexts where the analysis predicts identical surface tones with different foot structures. An example of this is shown in (23).

(23) a. Default $\sigma((\boldsymbol{\sigma}_{H}\#\acute{\sigma})\acute{\sigma})\sigma$
b. Straddled Word-Initial Syllable $(\sigma(\boldsymbol{\sigma}_{H}\#\acute{\sigma}))(\boldsymbol{\acute{\sigma}}_{H}\sigma)$

In (23a), foot structure follows the default dactylic pattern starting from the sponsor, which is word-final. In (23b), tone comes from two sponsors underlyingly, and this is reflected in the foot structure, with each sponsor syllable contained in a different foot. Crucially, the forms are otherwise equal; in both cases, high tone surfaces only on the two syllables following the word boundary. Hence, (23) shows a metrical minimal pair, and it is possible that this metrical difference is reflected in the acoustics.

However, even if an investigation of the acoustics finds no evidence of foot structure, this is not a counterargument to a foot-based analysis. This was noted previously by Goldsmith (1992), in a footnote for his analysis of Llogoori:

> "[T]he present analysis adds to a growing body of literature that supports the position that metrical structure plays a role in the organization of language in a large number of cases in which there is no phonetic evidence of alternating stress or overt rhythm. If this is correct, as I am convinced that it is, it is more appropriate to say that metrical structure arises not when the data of a language permits it, but rather when the data of the language does not forbid it." (Goldsmith 1992: 92)

In summary, further research is warranted to determine if the proposed foot structure is reflected in the acoustics of Saghala. However, the absence of such acoustic evidence does not invalidate the present proposal.

5.2 Alternative OT approaches to Bantu bounded tone

Within the context of OT, at least three lines of previous research on Bantu bounded tone can be recognized: Optimal Domains Theory, minimal (mis)alignment, and Headed Spans theory. In the following, these approaches are discussed and compared to the present framework.

Optimal Domains Theory (ODT) centers around the idea of relating underlying tones to surface-level tone domains (Kisseberth 1993; Cole & Kisseberth 1994; Cassimjee & Kisseberth 1998). Bounded tone patterns then follow from restrictions on the size of such tone domains.

Bickmore (1996) proposes an approach using minimal (mis)alignment, which derives surface tone patterns from a family of alignment and misalignment constraints that can cause tone to spread to TBUs at a minimal distance away from their sponsor. The minimal distance effect is due to the gradient evaluation of the alignment constraints.

Headed Spans theory proposes that surface forms are parsed exhaustively into domains for each feature (feature spans), notably tone (Key 2007; Key & Bickmore 2014, building on McCarthy 2004). Much like in ODT, bounded patterns are derived by placing requirements on the size of such feature spans.

Determining whether the above proposals allow for an account of Saghala tonology is beyond the scope of this paper. However, comparisons can be made in two other aspects, proving favorable to the foot-based HS approach. Unlike the present proposal, the above proposals suffer from the following: stipulation of domain size and use of two-level constraints. These issues are discussed below.

5.2.1 Stipulation of domain size

One of the goals for any account of Bantu bounded tone is to derive tonal spans over multiple TBUs starting from a tone with only a single underlying association. To this end, ODT employs a *MONOHD constraint to enforce binary domains.

(24) *MONOHD
"A HD [High tone domain] should not be monomoraic/monosyllabic."
(Cassimjee & Kisseberth 1998: 18)

Likewise, in the Headed Spans framework, binarity is achieved through SP-BIN(H).

(25) SPBIN(H)
"Assign a violation mark for each H span that does not parse some part (i.e., at least one mora) of exactly two syllables." (Key & Bickmore 2014: 41)

In both frameworks the impetus for binarity is stipulated; it does not follow from the theory of the representation. Furthermore, neither framework has a way of accounting for ternary domains. Ternarity could be achieved by adding constraints such as *BINHD for ODT or SPTRI(H) for Headed Spans, but this adds further stipulations. Furthermore, there is no account for the fact that there are presumably no constraints such as *TRIHD or SPQUAD(H) that could drive construction of quaternary tonal spans.

In the present approach, binarity and ternarity are linked to the nature of the foot, the size of which is motivated independently by cross-linguistic studies of stress systems and metrically driven phonological processes. A quaternary domain cannot be derived straightforwardly, matching the typological picture of Bantu bounded tone.

The maximally ternary nature of the foot in the MPK framework is itself a stipulation. However, this stipulation was made based on consideration of a wider range of language phenomena, and was not motivated by the typology of Bantu bounded tone. Consequently, getting ternarity from the representation without domain-specific stipulations is an improvement over previous approaches.

5.2.2 Two-level constraints

The term two-level constraint denotes a type of constraint that places well-formedness restrictions on the surface level, but also makes reference to structure at the input level. In the analysis of Bantu bounded tone, two-level constraints occur when constraint formulations use the concept of a sponsor. Sponsorship is a property of a TBU at the underlying level of representation. Making requirements on surface structure with reference to sponsors means that both levels of representation are involved. The previous approaches discussed here make use of such two-level constraints. One example is the ODT constraint INCORPORATE (F-SPONSOR), shown in (26). F stands for a feature in general, but for the present purpose could be instantiated as H tone.

(26) INCORPORATE (F-SPONSOR)
"[E]very F-sponsor is in a domain." (Cassimjee & Kisseberth 1998: 12)

The evaluation of this constraint involves both levels of representation; H-domains are present only in surface forms, whereas the location of H-sponsors requires reference to the underlying location of the H tone.

The Headed Spans framework has a similar constraint FAITHHDSP(αF) to which the same reasoning applies. In minimal (mis)alignment, alignment constraints can make reference to lexical structure. An example is (*)ALIGN (H,L)-I/O:

(27) (*)ALIGN (H,L)-I/O
"The left edge of a HTS [High tone span] in the output must (not) align with the left edge of a HTS in the input" (Bickmore 1996: 16)

To evaluate this constraint, the grammar must compare the leftmost TBU of a tone in the input to the leftmost TBU of its corresponding tone in the output. Since both lexical and surface structure are involved in the evaluation, this is a two-level constraint.

Two-level constraints go against a core principle of OT: its output orientation. Consider the following criticism of these constraints from Kager (1999):

> "[Two-level constraints] function as rules, combining a structural condition (the input structure) and a repair. A theory allowing for two-level well-formedness constraints may stipulate any type of relation between the input and output, being equivalent in this respect to rule-based theory (Lakoff 1993). This power undermines standard OT's solutions to problems inherent to rule-based serialism, in particular *conspiracies* and the *Duplication Problem.* [emphasis in original]" (Kager 1999: 381)

In conclusion, it is desirable to avoid the use of two-level constraints.[15] However, past approaches needed such constraints to account for opaque processes in standard OT. The handling of opacity in the present framework is relegated to Harmonic Serialism. Consequently, it no longer needs to be encoded in the constraint set. As a result, the present framework does not make use of two-level constraints.

5.3 Analyses with binary or flat ternary feet

Although the previous section has accomplished a descriptively adequate analysis of Saghala using layered ternary feet, it has not been shown that analyses with alternative conceptions of foot structure are infeasible. The most immediate alternatives are analyses using binary feet or flat ternary feet (Halle & Vergnaud 1987; Rice 2007; Buckley 2009). A full investigation of these alternatives is beyond the scope of this paper, but some challenges can be pointed out. In both cases, the major challenge is finding an approach that fits all subpatterns, particularly finding a trigger for the Adjacent Sponsors context to deviate from the default pattern.

A binary feet analysis could enforce foot placement to the right of the sponsor, so that the two tones of the default pattern are the two footed syllables, i.e. /σ́σσ/ → [σ(σ́σ́)]. One issue here is finding constraints that drive this footing, especially if the analysis is to abstain from using two-level constraints.

This footing also raises questions for the analysis of the Adjacent Sponsors context. In the present layered feet analysis, licensing drives foot placement over both of the sponsor syllables, e.g. /$\acute{\sigma}_1$#$\acute{\sigma}_2$σσ/ maps to the intermediate form ($\acute{\sigma}_1$#$\acute{\sigma}_2$)σσ. This takes the derivation in a different direction from the default pattern and eventually allows tone to settle solely on the second sponsor syllable. However, if the binary analysis places feet next to sponsors rather than on them, /$\acute{\sigma}_1$#$\acute{\sigma}_2$σσ/ would map to $\acute{\sigma}_1$#($\acute{\sigma}_2$σ)σ or even $\acute{\sigma}_1$#$\acute{\sigma}_2$(σσ). Hence, an open challenge is motivating why either of these forms would deviate from the default pattern, which incorrectly predicts the forms to surface as *[σ#(σ́σ́)σ] or *[σ#σ(σ́σ́)], respectively.

[15] This argument against two-level constraints leans on the assumption that the adoption of any such constraint implies that all two-level constraints could plausibly be part of a grammar. However, it may be possible to motivate the adoption of a more strictly defined subclass of two-level constraints. Further research is needed on this issue. The author thanks Marc van Oostendorp and Jochen Trommer for independently pointing this out.

An analysis with flat ternary feet can capture the entire bounding domain of the default pattern with one foot, giving /σ́σσ/ → [(σσ́σ́)]. However, some new constraints will be needed to accomplish correct tone association; with the constraint set presented here, there is no way to target the middle syllable for spreading.

Furthermore, like the binary feet analysis, the flat ternary analysis seems to have no means of distinguishing the spreading targets in the Adjacent Sponsors pattern from that of the default pattern. Presumably, /σ$\acute{\sigma}_1$#$\acute{\sigma}_2$σ/ should map to either (σ$\acute{\sigma}_1$#$\acute{\sigma}_2$)σ or σ($\acute{\sigma}_1$#$\acute{\sigma}_2$σ). Again, an open question is how a flat ternary analysis now avoids application of the default tone pattern, which would yield *[(σσ́#σ́)σ] or *[σ(σ#σ́σ́)].

5.4 Tone-foot constraints and headedness

A previous OT proposal for relating tone and feet is De Lacy (2002). The constraint set centers around a tendency for H tones to avoid non-heads, and for L tones to avoid heads. The constraints are expressed in terms of markedness. For example, *L/HD militates against foot heads with a low tone. In languages with two tone levels, this can help to drive association of a H tone to the head of a foot. This type of constraint behaves similarly to the foot-licensing constraints of the present paper. Both constraint types enforce high-toned footed syllables, but only to suit the needs of the foot; the constraints are indifferent to unfooted high tones. The remainder of this section discusses whether Saghala could be analyzed with De Lacy-style constraints and headed feet.

A first issue when considering a headedness-based approach for the present foot-based analysis is that the status of prominence in the layered foot needs to be clarified. The layered foot has a head syllable, which is the head of the internal foot. In addition, the syllable in the higher foot layer, called the satellite syllable, could also be interpreted as a prominent position.[16] Consequently, a structure such as in (28), with stress on the right syllable of the internal foot and with the satellite syllable on the right of the layered foot, would yield H tone on the last two syllables of the layered foot, as desired.

(28) ((σˈσ)σ)

Several problems remain. Firstly, the headedness in the structure above is based only on the fact that it is needed for an interpretation in terms of a headedness-based constraint set. Ideally, independent evidence should be adduced to support the left-branching amphibrach, ((σˈσ)σ), in favor of the dactyl, ((ˈσσ)σ).

Secondly, the constraint set also raises issues for the analysis. Notably, the present analysis relies crucially on licensing constraints to derive the correct foot placement for tone shift, as can be gleaned from Table 4. A markedness-only constraint set will have to ensure that feet are properly positioned for tone association in some other way. Furthermore, under the naive assumption that all foot structures are the same as in the present analysis, there are still counterexamples to the generalizations proposed above. This will be demonstrated using a schematized form from the SWIS context, shown in (29).

(29) (σ(σ#σ́))(σ́σ)

Firstly, if every head syllable should receive a H tone, the form in (29) should surface as *[(σ(σ#σ́))(σ́σ́)], assuming head syllables are always rightmost in the minimal foot. Secondly, the form in (29) surfaces with a tone linked to the non-head syllable of the second

[16] MPK do not suggest that satellite syllables should universally carry prominence. Hence, satellite prominence might be best thought of as a language-specific property that Saghala happens to carry.

foot, which is not motivated under De Lacy's constraint set, where non-heads are preferably low-toned.

In summary, the present analysis cannot swap out edge-based constraints for headedness-based ones without issue. However, an analysis of Saghala that posits different foot structures might successfully use headedness-based constraints. If such an analysis can be found, the question remains whether it is more desirable to refer to feet edges or headedness. Foot edge constraints may differ from headedness constraints in that they allow for direction reversals, e.g. left-edge orientation in flat binary feet, but right-edge orientation in layered ternary feet. Consequently, future typological research may provide insight into the optimal formulation of a feet-and-tone constraint set.

6 Conclusion

This paper has introduced a foot-based approach to account for bounded tone shift and spread. Key elements are the adoption of a layered foot to delimit the bounding domain, the use of Harmonic Serialism to derive local effects, and the proposal of a licensing/structural markedness constraint family to relate tone and feet to each other.

The approach was demonstrated on Saghala. It successfully accounted for all six patterns. This involved dealing with the interplay of tone spread, tone shift, various cases of tonal proximity, and sensitivity to word-initial syllables. Furthermore, Saghala tonology took place in a trisyllabic domain size and with no discernible role for morphology.

The ability of the framework to deal with the Saghala patterns shows promise for its applicability to a range of Bantu bounded tone systems. Furthermore, the framework improved on previous OT proposals in two aspects: it does not stipulate the size of the bounding domain, and it does not use markedness constraints that make reference to input structure.

Future work will explore the full typological predictions of the framework. In addition to bounded tone patterns, the foot-based nature of the framework may allow the typology to include edge-based tone and rhythmic tone with minimal adaptations.

The paper also warrants further research on Saghala. Firstly, it can be tested if the proposed foot structures are acoustically detectable in speaker productions. Secondly, further data collection can determine if the foot-based generalization of Saghala tone has applications beyond the noun phrase domain, and if the layered foot plays a more general role in Saghala phonology. At a more general level, it is hoped that the present analysis can inspire a new foot-based perspective on the analysis of bounded tone phenomena.

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Competing Interests

The author has no competing interests to declare.

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