Mapping and Pruning: An Approach to Prosodification

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1 Introduction

This paper introduces an approach to the phonology-syntax interface, here called the Mapping and Pruning (MaP) model. The aim of this approach is to provide a model of prosody in which prosodic constituents at the word-level and above are defined in a deterministic fashion by the syntax, by cross-linguistically invariant Mapping principles. At the same time, the model attempts to account for the observed variability in prosodic structures, even among closely related languages – the tools used to implement this are Pruning rules, which enforce constraints on phonological well-formedness. The main focus here will be on the Mapping component proper, but Pruning rules will be touched upon at various points.

This yields two sources of variation in prosody – syntactic variation, and variation in the phonological configurations which induce the repairs implemented by Pruning rules. If variation cannot be accounted for by structural well-formedness, it must be attributed to the syntax. This not only sharply constrains our theory of prosodification, but also offers up the possibility of using prosody as a precision tool to probe syntactic structure.

This model must have a way of accounting for the fact that syntactic and phonological domains often fail to coincide. To this end, we adopt the auxiliary hypotheses in (1).

(1)
  a) The phonological spellout of a *phase* applies in a bipartite fashion – the first part (preceding Vocabulary Insertion) applies to the *whole* phase, while the second part (following VI) applies only to the *complement* of the phase head.
  b) Prosodification applies early, *before* VI.
  c) The modification of prosodic objects is subject to *visibility* conditions, preventing modification of edges associated with fully spelt out phonological material.

These auxiliary hypotheses will be explained more explicitly later on. When combined with relatively simple Mapping principles, the resulting model readily reproduces the correct prosodification in a variety of languages.

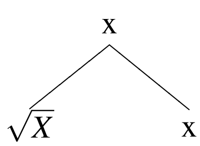
1.1 Background Assumptions

This paper will be couched in a framework of the phonology-syntax interface making use of standard assumptions in Minimalist Syntax and Distributed Morphology. The most important will be discussed briefly here.

1.1.1 The Marantz-Borer Conception

Following Marantz (1997 et seq.) and Borer (2005 et seq.), lexical categories (nouns, verbs, adjectives, adverbs, and possibly others) are supposed to be universally introduced as acategorial *roots*. I take roots to be devoid of all syntactic features, and to be distinguished from one another only through an arbitrary *index* (cf. Harley 2014). These are provided with some category by a syntactic process, here assumed to be the insertion of a categorising functional head (represented as *n*, *v*, *a*, etc.). A typical lexical category item, then, will have the following structure:

(2)



Where *x* is an arbitrary categoriser and *X* is some index compatible with categoriser *x*. I will typically represent the index of a root using the English translation of the word it represents (so that the root of English *cat* and French *chat* will be represented alike as $\sqrt{cat}$).

1.1.2 Late Insertion

It is assumed, following Halle and Marantz (1993) et seq. that elements in the syntactic lexicon does not contain any phonological features. Instead, phonological features are associated with syntactic features by the process of *Vocabulary Insertion*, which applies as the syntactic structure is spelled out. Phonological exponents of syntactic objects are assumed to be drawn from a list known as the *Vocabulary*. Multiple Vocabulary entries may compete with one another to apply to a given syntactic object, with the the more specific item being preferred (by the *Subset Principle* (Halle 1997)). For example, the English plural marker may be realised as *-s* or *-en*, depending on the root it attaches to.

(3) a) [+pl] $\leftrightarrow$ *-s*

b) [+pl] $\leftrightarrow$ *-en* / $\sqrt{ox}$ __

Here (3b) applies in a more specific context, and so is inserted in preference to (3a).

Contra e.g. Embick (2000), I assume that roots are likewise subject to Late Insertion (for some arguments to this effect, see Haugen and Siddiqi 2013, Harley 2014).

1.1.3 Cyclic Spellout

Following Uriagereka (1999), Chomsky (2000, 2001 et seq.), I take syntactic *Spellout* to apply piecewise, delimited by a domain generally known as the *phase*. Phases are defined by certain syntactic heads, including at a minimum the heads C and *v** (the subset of *v* heads which introduce an external argument). Here, the set of phase heads is taken to be somewhat larger, consisting of categorising heads (*n*, *v*, *a*, etc.) as well as the heads of their maximal *extended projections*, such as the C head in the case of verbs, or the case projection K in the case of nouns (cf. Bošković 2014). The phase constitutes the maximal projection of a phase head.

In general, phases are taken to be divided into a *phase domain* (the complement of a phase head) and a *phase edge* (the phase head and its specifiers). Typically, it is assumed that only the phase *domain* undergoes Spellout when the phase is complete, with Spellout of the phase edge delayed until the next phase.[1] When a phase is complete, the phase domain is generally taken to be interpreted by the LF and PF components of grammar, and rendered inaccessible to further syntactic operations (this is the *Phase Impenetrability Condition* (PIC)). The notion that the syntactic phase plays a role in (morpho)phonology after Spellout is well-established (to give a small selection: Seidl 2001, Marvin 2002, Pak 2008, Newell 2008, Kahnemuyipour 2009, Dobashi 2010, Embick 2010, Scheer 2012, Newell and Piggott 2014, D'Alessandro and Scheer 2015, Cheng and Downing 2016, 2021, Kilbourn-Ceron et al. 2016, Guekguezian 2021). It is in this function that the phase will be of interest to us here.

As outlined in (1a), I make a slight adjustment to this model. In particular, I suppose that a *whole* phase undergoes certain operations associated with Spellout, such as linearisation (discussed further in the next subsection) and prosodification. These are operations which *precede* Vocabulary Insertion. Operations which follow VI, importantly including those which remove syntactic features from the derivation (and consequently make the domain inaccessible for further morphosyntactic processes), apply only to the phase domain. The phase edge, while linearised and prosodified, remains accessible to later syntactic operations– see Martinović 2019 for some additional evidence (from Wolof) that at least some parts of a phase must remain syntactically accessible, even when partially spelt out in this way. Some independent motivation for this is given in the next subsection when we come to discuss linearisation, and this bipartite model of the phase is key to the functioning of the MaP model.

[1] This is what Müller (2004) refers to as PIC1 (Chomsky 2000). Chomsky (2001) adopts a slightly different hypothesis (PIC2), whereby the spellout of a phase domain is delayed until the completion of an additional phase, so that the complement of *v* is not spelled out until the CP phase is complete. Similar proposals are adopted by Embick (2010) in his account of suppletive allomorphy. I do not follow them here.

1.1.4 Movement and Linearisation

Throughout this paper it is assumed that syntactic structure does not contain information concerning linear order. Linear order is instead imposed post-syntactically, by a *linearisation algorithm*. I assume that the linearisation algorithm can vary among languages, and do not adopt proposals along the lines of Kayne (1994), where linearisation is wholly determined by syntactic structure. Variations on Kayne's model which allow parametrisation of some aspects of linearisation, such as that of Sheehan (2013) are compatible with the model presented here.

Following Chomsky (2004), syntactic *movement* has often been conceptualised as a special instance of the structure-building Merge operation, specifically *Internal* Merge, whereby an element is merged which is already present in the derivation. The presence of the same element in two positions renders the structure unlinearisable, and the linearisation algorithm consequently permits the internally-merged object to appear only in one position.

The conception of movement as Internal Merge works well for *phrasal* movement, but is less clearly appropriate for *head* movement. I adopt the proposal of Roberts (2010), that Head Movement is a consequence of the features of the moved head constituting a subset of the features of the target, generally as a consequence of some sort of Agreement operation. I assume that this is likewise driven by linearisation, though in this case it is the linearisation of a set of features which is at issue, rather than a complete syntactic object.

If all apparent movement is driven by linearisation (that is to say, by considerations of phonological realisation), then it follows that certain phonological operations apply to a whole phase. To see why, consider the role of a phase edge as an *escape hatch* for moved items. Because a phase domain is rendered inaccessible to syntactic operations when a phase is complete, it is not possible for an item to be moved outside the phase unless it is generated in, or moved to, the phase edge first. For example, if a *wh*-phrase in the object position is moved to SpecCP, it must first move through Spec*v*P. Evidence for this can be seen, for example, in languages such as Irish, where a progressive marker (normally *ag*), which can presumably be placed in the *v* domain, takes on a special form *a* when wh-movement takes place (McCloskey 2001, Clements et al. 1983):[2]

(4) *Irish Aspect Markers under* wh-*movement* (adapted from Clements et al. 1983)

a) *Tá sé ag ceannach teach*
be 3SG.M PROG buy.VN house
'He is buying a house'

b) *Cén teach a-tá sé a cheannach*
which house COMP.WH-be 3SG.M PROG.WH buy.VN
'Which house is he buying?'

[2]The alternation in form is optional under *wh*-movement, but ungrammatical elsewhere. Note that the form triggered by *wh*-movement causes *lenition* on the verb.

In (4a), the object remains *in situ*, and the progressive marker is realised in its usual form, as *ag*. In (4b), we take the object to move to SpecCP, using Spec*v*P as an escape hatch. The form of the progressive marker in *v* is sensitive to the *wh*-phrase in its specifier, and is accordingly realised as *a*.

Under the Internal Merge account of movement, the object in (4b) is initially merged in the complement of the main verb, then merged again in the specifier of *v*P, and then finally in the specifier of CP. At PF, the linearisation algorithm causes the lower two copies to be unrealised, because it is impossible to linearise an object which occupies two positions. But note, for this to work, the linearisation algorithm must have access to the *whole* phase, as well as just the phase domain. If the linearisation algorithm had access only to the phase domain, the object would only appear in one position in that domain, and the linearisation algorithm would consequently fail to remove it. After this, the phase domain will be rendered inaccessible to subsequent operations, and initial merge position of the object would no longer be visible, permitting the internally merged object in the specifier of *v*P to be linearised unproblematically. What we would expect to see, then, is a copy of the object overtly realised in every position in which it is merged, rather than only in the highest position. Since this is not what we see, it seems plausible that some early PF operations such as linearisation have access to the entire phase, as assumed in (1a).

1.2 Mapping Principles

In this paper I will focus on the behaviour of the *phonological phrase* (ϕ). I will adopt a very simple algorithm to define its distribution. Syntactic elements are exhaustively associated with an existing phonological phrase if this is possible, failing which a new ϕ constituent will be inserted, until every syntactic object is mapped onto a phonological phrase.

(5) *Phrase Mapping Algorithm*

a) If possible, associate a syntactic object with a ϕ constituent at a visible edge.

b) Otherwise, insert a new ϕ constituent.

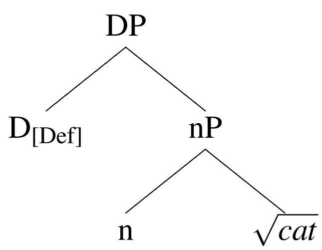
c) Repeat steps a) and b) until all syntactic objects (or subconstituents thereof) are associated with some ϕ constituent.

The notion of a visible edge is the same as the one referred to in (1c), and will be defined more sharply later on. One of the results of this paper is that, if combined with an appropriate theory of syntax and the hypotheses in (1), the very simple algorithm in (5) reproduces many of the results of an edge-alignment model of prosodification such as that of Selkirk (1986) without any further stipulation.

At this stage it will be helpful to define some notations used to represent the notion of 'association' used in (5). I do not assume any *containment* of syntactic objects within phonological constituents such as ϕ. Rather I suppose that association of the sort referred to in (5) adds to a list of *mapping statements* relating syntactic and phonological objects. These mapping statements, I suppose, condition Vocabulary Insertion – an exponent of a syntactic object is inserted under the smallest prosodic constituent to which the syntactic object in question is mapped.

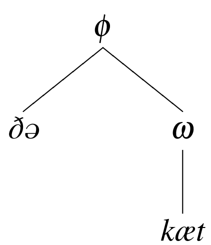
Consider, for example, the phrase ‘the cat’, which can be taken to have the following syntactic structure:

(6)



I assume (following Selkirk 1995) that this consists of a single phonological phrase and a single phonological word (ω), with the exponent ‘the’ as an immediate daughter of phonological phrase, and the exponent ‘cat’ as a daughter of the phonological word, which is itself contained the the phonological phrase in question. That is, we have the following prosodic structure:

(7)



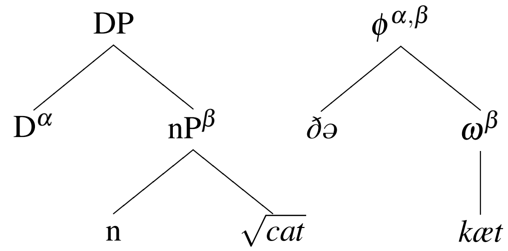
To link these two representations, we can assume the existence of three mapping statements:[3]

(8) $\mathrm{D} \leftrightarrow \phi$
$\mathrm{nP} \leftrightarrow \phi$
$\mathrm{nP} \leftrightarrow \omega$

In general, I will not present mapping statements explicitly in this way. Instead I will indicate a mapping statement through a Greek letter superscript shared by a syntactic constituent and a prosodic constituent.

[3]Here adopting the convention that a mapping statement which refers to a syntactic object implicitly refers to all subconstituents of that object for the purposes of VI and clause (5c).

(9)



The first mapping statement in (8) is implicitly represented by the α superscript, shared between D and ϕ. The other two mapping statements are both indicated by the β superscript, shared by *n*P with ϕ and ω, respectively. In general, I will provide at most one superscript on a syntactic object, while allowing multiple superscripts on prosodic objects.

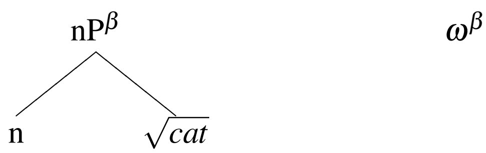
Let us consider how the phonological representation in (9) might be derived, given the Phrase Mapping Algorithm in (5) and the hypotheses in (1). To ensure that (5) proceeds in a fully deterministic manner, we should place further constraints on possible sets of mapping statements and on the operation of mapping algorithms such as (5).

(10) *Mapping Statement Constraint*:
A set of mapping statements may not contain two statements $\alpha \leftrightarrow \pi$ and $\beta \leftrightarrow \pi$, where α, β are syntactic objects and π is a prosodic constituent, where β is a subconstituent of α.

(11) *Mapping Procedure Constraint*:
Mapping algorithms such as (5) search for an available syntactic object top-down, first attempting to associate the largest syntactic object in a domain to a prosodic constituent, and only then applying to its subconstituents.

Recall from section 1.1.3 that we assume *n* to be a phase head. The nP consequently constitutes a *phase*, and, following (1a, b), triggers a cycle of prosodification operations, which apply over the entire nP phase. I will not discuss the algorithm which maps syntactic objects to phonological *words* (ω) here, but assume that there is some mapping algorithm which maps nP to ω.[4] At this point, we have the following representation:

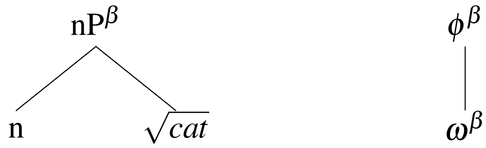
(12)



The Phrase Mapping Algorithm (5) then applies. Since there are no ϕ constituents in the representation, (5a) cannot apply, and so (5b) applies. (5a) then applies in a top-down fashion, following (11). After this, the syntactic domain is exhaustively associated with the inserted ϕ constituent, and the prosodification process in this cycle is complete.

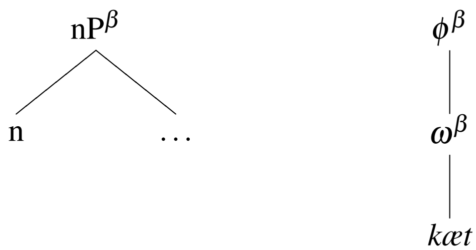
[4]One possible algorithm which would produce this result would be one which associates projections of functional heads in general to phonological words. This obviously encounters the problem that many functional projections, cross-linguistically, do not define a phonological word. This might be parametrised using Pruning Rules, as discussed in the next section.

(13)



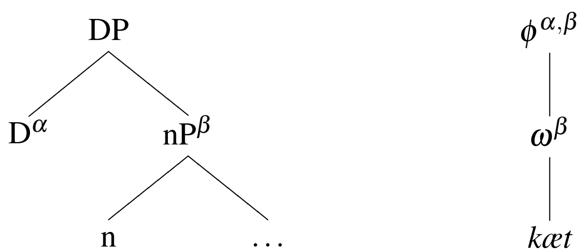
After prosodification is complete Vocabulary Insertion applies, as does *Feature Stripping*, the operation which removes syntactic information from the derivation. Both these operations, by (1b), apply only to the phase *domain*, inserting the exponent of $\sqrt{cat}$ into the phonological representation before removing the root from the syntactic representation.[5]

(14)



In the next phase, the D head (for whatever reason) does not map to an independent ω constituent, which we will simply take here as a fact. The Phrase Mapping Algorithm applies as normal. By (11), the mapping algorithm searches for an available syntactic constituent, beginning with DP. But (10) states that the DP cannot be mapped to the same prosodic element as one of its subconstituents. Since the nP is already mapped to the ϕ constituent, and because it is a subconstituent of the DP, the DP cannot be mapped to the existing ϕ constituent. No such issue exists for the D *head*, however, and so it is associated with ϕ, exhaustively parsing the domain.

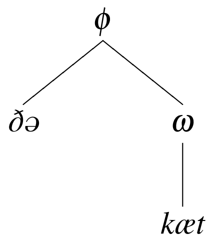
(15)



Assuming that DP is in the phase domain of some higher head, Vocabulary Insertion then applies, and Feature Stripping removes the remaining syntactic features from the domain.

[5]Here I am assuming that the root $\sqrt{cat}$ does not raise to its categoriser, thereby escaping Vocabulary Insertion and Feature Stripping. This makes no difference in this toy example, and so I omit the relevant stage for simplicity, which may well not be the correct assumption.

(16)



Since feature stripping has applied, the mapping statements relating syntactic and phonological structure are no longer relevant, and are not shown here. This obtains the correct prosodification.

This is of course a very trivial example, but illustrates some key features of (5) and its interaction with the hypotheses in (1). That this algorithm obtains the correct results in more complex cases will be the topic of sections 2 and 3.

1.3 Pruning Rules

In addition to mapping algorithms of the sort discussed above, we require an additional set of rules to account for the fact that prosodic representations are subject to phonological well-formedness conditions. In an Optimality-Theoretic framework, the interaction between contraints on the phonology-syntax mapping and phonological well-formedness constraints is considered by Truckenbrodt (1999), and within the *Match Theory* framework (Selkirk 2009, 2011, see also e.g. Elfner 2012, 2015, Ito and Mester 2013, Bennett et al. 2016, 2019, Kratzer and Selkirk 2020, Weber 2022, papers in Kubozono et al. 2022, among many others: see Ishihara and Kalivoda 2022 for a review and additional references). In the model I adopt here, I suppose well-formedness constraints of the sort proposed by the aforementioned authors to be repaired by rules, where both the activation of the well-formedness constraint and the repair are parametrised (cf. Calabrese 2005). One way in which the model here differs from the original proposal of Selkirk is that mapping and enforcement of phonological well-formedness constraints are strictly separated. The reasons for this are conceptual – under Selkirk's model, the phonological computation may have direct access to syntactic information: this is how mapping is determined. This leaves us with no clear motivation for prosodic constituents – phonological processes in general could presumably make direct reference to syntax. This is especially problematic in Selkirk's model, where prosodic and syntactic structure are taken to be closely isomorphic (hence the name *Match* Theory). Given that domains for phonological processes are often non-isomorphic to syntactic domains, it would seem that we require some additional theoretical machinery. Under the MaP model, the mapping from syntactic to phonological structure strictly precedes the phonological computation, including pruning rules. Note that this approach is also adopted in more recent versions of Match Theory, e.g. as presented in Kratzer and Selkirk (2020).

Examples of the sorts of constraints proposed by Selkirk which may require a pruning rule to apply as a repair include those listed in the following table:[6]

(17) *Constraints and Repairs*

Constraint	**Definition**	**Possible Repair**
BINMIN	Prosodic constituents must have at least two daughters.	$(_{\pi_i}\ \pi_j) \rightarrow \pi_j$
BINMAX	Prosodic constituents must have at most two daughters.	$\pi_j \pi_k \rightarrow (_{\pi_i}\ \pi_j \pi_k)$ / $(_{\pi_i} \ldots \pi_l, \_\_ \ldots)$
STRONG-START	The initial daughter of π_i must be $\pi_{\geq i-1}$.	$\pi_{i-2} \rightarrow (_{\pi_{i-1}}\ \pi_{i-2})$ /$(_{\pi_i}\ \_\_ \ldots)$
EQUAL-SISTERS	Sister prosodic constituents must have equal rank	$\pi_i \rightarrow (_{\pi_{i+1}}\ \pi_i)$ / $\_\_ \pi_{i+1}$
NORECURSION	Prosodic constituents may not be recursive.	$\pi_i \rightarrow \varnothing$ / $(_{\pi_i} \ldots \_\_ \ldots)$

This model of pruning is only preliminary, and other models can be imagined quite easily. For instance, one could plausibly assume that, while the prosodification algorithm makes use of mapping principles of the sort outlined above, pruning takes place in an optimality-theoretic computation (cf. Kratzer and Selkirk 2020). The MaP model predicts that where two languages are syntactically identical, all differences in prosodification should be accountable for in terms of well-formedness conditions enforced by pruning rules.

2 Edge Alignment and the Phase

Selkirk (1986) proposes what she calls an *end-based* theory, where *edges* of prosodic constituents are aligned to *edges* of syntactic constituents. This model has been defended more recently by Cheng and Downing (2016).

The aim of this section is to show that given the MaP model, many of the predictions of the edge-alignment model are recovered. Although edges are never specifically *aligned* with one another, the interaction between a mapping algorithm like (5) and the syntactic cycle mean that they appear to be.

In particular, making use of what Truckenbrodt (1999) later called the *lexical category condition*, Selkirk (1986) supposes that the edges of prosodic constituents are aligned

[6] Here π_i means a prosodic constituent of rank i, where it is assumed (following Nespor and Vogel 1986, Selkirk 1986) that prosodic constituents fall into a strictly ordered hierarchy. Generally in this paper I adopt Ito and Mester's (2013) reduced prosodic hierarchy, whereby the only prosodic constituents which interface with syntax are the phonological word (ω), the phonological phrase (ϕ) and the intonational phrase (ι), which, by convention, I will take to have ranks 1, 2 and 3, respectively.

with those of *lexical* categories and their maximal projections, whereas functional categories are invisible to the mapping algorithm. In the model adopted here, this condition (or a close analogue thereof) emerges directly from the fact that we take categorisers, and the heads of extended projections to be phase heads.

2.1 A Toy Example from English

As an illustrative example, consider a phrase like 'The cat miaows'. In the model of syntax used by Selkirk (1986) this would presumably have a structure along the lines of [$_{S}$ [$_{NP}$ the cat][$_{VP}$ miaows]]. If we assume that, in English, the right edge of the maximal projection of a lexical category must align with a right edge of a phonological phrase, then we obtain the result that 'the cat' and 'miaows' constitute separate phonological phrases, which seems to be correct.

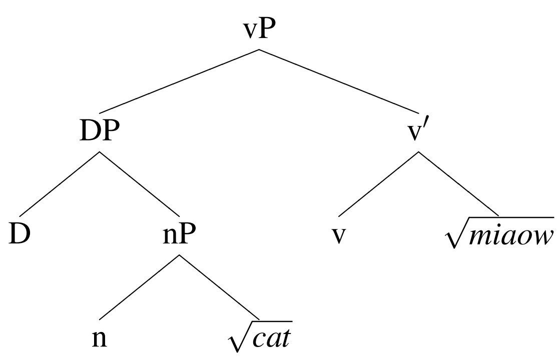
(18) *Edge-Alignment in English*:

Syntactic Structure:	[$_{S}$[$_{NP}$	the cat]	[$_{VP}$	miaows]]
Aligned Edges:		$_{\phi}$)		$_{\phi}$)
Prosodic Structure:	($_{\phi}$	$_{\phi}$)	($_{\phi}$	$_{\phi}$)

Recasting this sentence into the syntactic model adopted here, we obtain the structure [$_{CP}$ C [$_{TP}$ [$_{DP}$ the [$_{nP}$ cat]] T [$_{vP}$ ~~the cat~~ miaows]]]. It will be seen that Selkirk's model still produces the correct phrasing here, replacing the edges of NP and VP for those of nP and vP. Let us briefly show that this is also the case for the MaP model as presented so far.

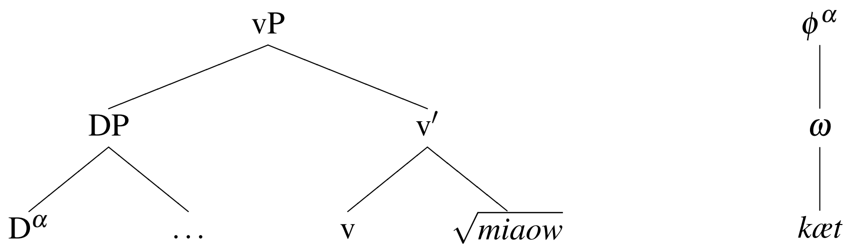
When the vP is complete, we can take the sentence to have the following syntactic structure, neglecting the result of Spellout operations:

(19)



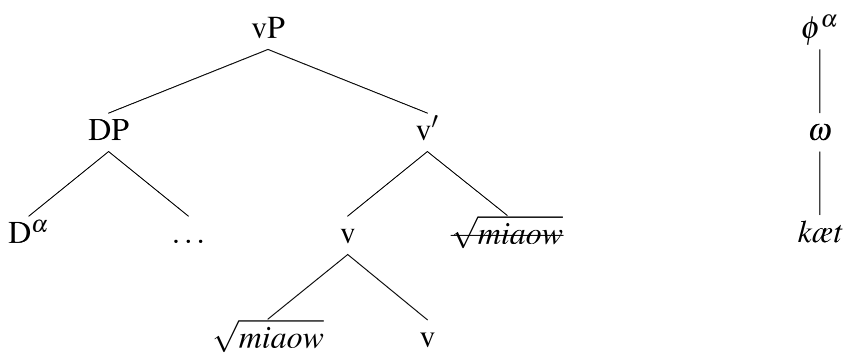
Let us take the DP to be the maximal extended projection of nominals in English. It is prosodified along the lines discussed in section 1.2. However, since we take D to be a phase head here (as the head of a maximal extended projection), the head is not fully spelt out until the vP is complete. Once Spellout has applied at the DP phase and the rest of the vP has been merged, we have the following representation:

(20)



As stated above, *v* is a phase head, and so the domain presented here constitutes a phase. It is consequently subject to Spellout operations. First, I assume, the linearisation algorithm implements head movement of the root to *v*.

(21)



This rescues the root from being fully spelled out in the vP phase – necessary to account for instances of tense-conditioned root allomorphy in English. After this, prosodification applies to the phase. This is where the condition in (1c) comes into play: the spelled out material contained in the ϕ constituent is aligned with the *right* edge of ϕ, with the D head being linearised to the left of that material. Consequently, we say that the *right* edge of the ϕ constituent is *invisible*. Visibility is defined informally below:

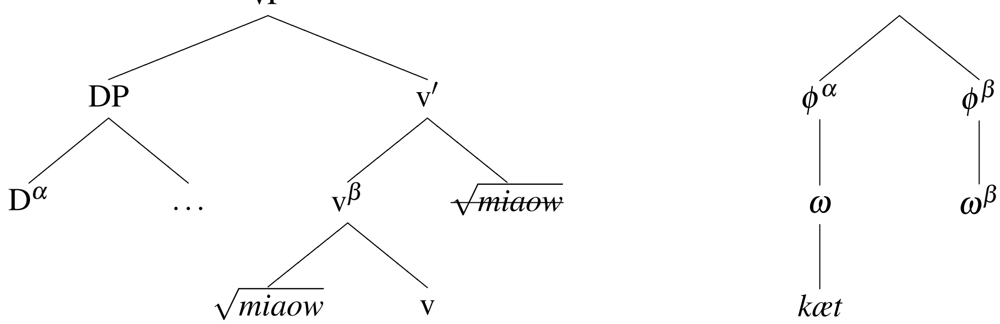
(22) *Visibility*
An edge of a prosodic constituent π is *invisible* if it is aligned with phonological material not associated with an accessible syntactic object. Otherwise, the edge is *visible*.

Visibility is taken to constrain modification of syntactic constituents, along the following lines:

(23) *Constraint on Modification*
If the edge of a prosodic constituent π is invisible, it must remain invisible throughout the derivation.

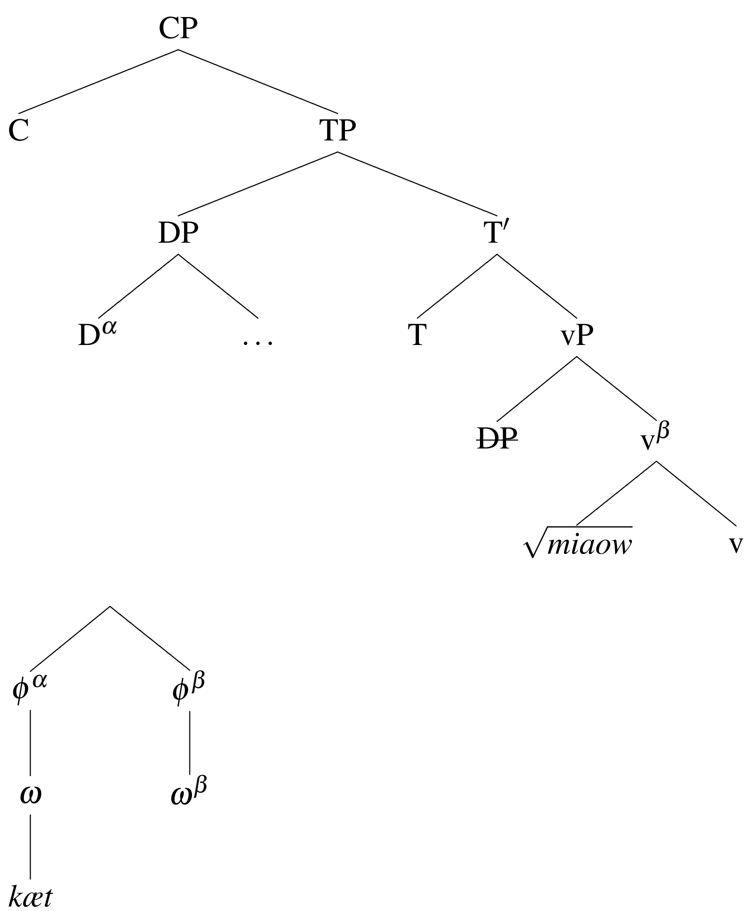
More formal definitions are given in the Appendix. Since the right edge of the relevant ϕ constituent is invisible, it is not possible to associate further material at that edge. A new ϕ constituent must be inserted (by 5b) and the verb is associated to it, resulting in the following structure (assuming here that the verb is mapped to a phonological word by some other process):

(24)



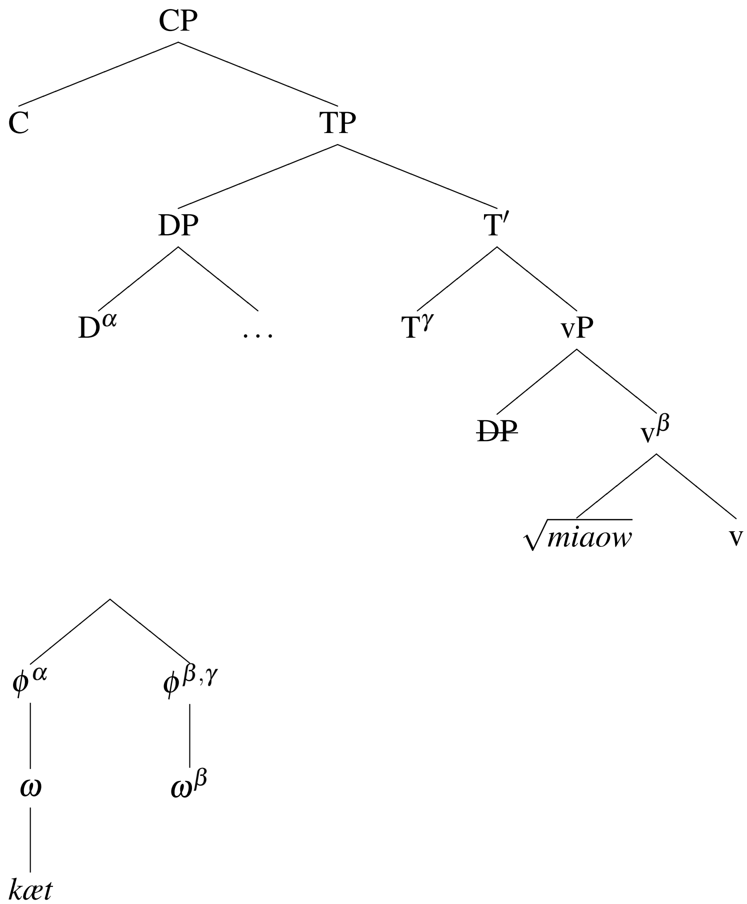
Finally, the phase domain is full spelt out – but since there is no remaining material in the complement of the phase head, the processes are vacuous. In the next phase, the CP, the DP is internally merged to TP before being removed from its original position by linearisation processes. Since the object now in TP is, in fact, the same syntactic object as the original DP, mapping statements referring to it remain unchanged. That is, we have the following structure, before prosodification applies in this phase:

(25)



As prosodification applies in this phase, the T head is mapped to the ϕ constituent associated with the *v* head, since the ϕ associated with the DP has an invisible right edge.[7] I suppose that the exponent of the T head, like that of the D head, adjoins to the ϕ constituent rather than forming its own phonological word.

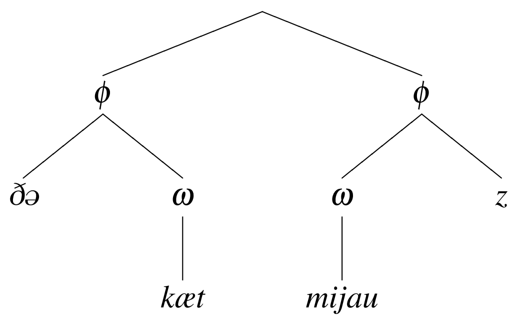
(26)



Other spellout operations then apply to the phase domain, including VI, which inserts exponents of D (*the*) and T (-*s*). I assume that some sort of morphological affix lowering operation relinearises the exponent of T with respect to the verb, yielding the form that we observe. Feature Stripping removes syntactic features from the phase domain, leaving only the prosodic representation.

[7] Since the C head is null, I will neglect it here. There is reason to treat the DP as having two invisible edges, in which case the C should map to its own ϕ, at least initially. This follows from the formalisation offered in the appendix. (see also Perry 2016)

(27)



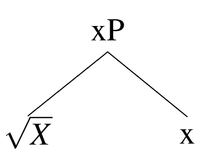
As we can see, this procedure obtains the same distribution of ϕ constituents as Selkirk's model. Note, however, that no parametrisation of the prosodification operation is involved, at least as far as mapping to ϕ is concerned – instead the resulting prosodic structure is entirely determined by the syntactic structure.

2.2 Recovering the Lexical Category Condition

One aspect of Selkirk's analysis that we might hope to reproduce is the fact that lexical categories define edges of prosodic constituents, but that functional categories generally speaking do not – Truckenbrodt (1999) calls this the *lexical category condition*. In our model, this fact emerges as a consequence of the fact that lexical categories (and maximal extended projections thereof) constitute a phase, while functional categories generally do not. Spellout operations which apply at the phase level, and in particular Feature Stripping, provide an invisible (and consequently unmodifiable) edge to a prosodic constituent with a phase domain at one of its edges. This typically results in the alignment of lexical material with the edge of some prosodic constituent. This is what causes the DP constituent in the example above to be parsed separately from the following verb, so that the lexical item *cat* stands at a ϕ edge.

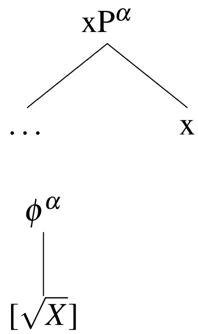
Let us show this, in the abstract, a little more explicitly – suppose for example we have the configuration below, taken in the introduction to be the structure of some lexical category item, where $\sqrt{X}$ is an acategorial root and x a categoriser.

(28)



As we have assumed, x is a phase head. This means that if $\sqrt{X}$ does not raise to its categoriser through head-movement, it will be contained in the phase domain. Spellout operations such as VI and Feature Stripping will apply. Assuming categorisers are linearised to the right of roots in this language, the left edge of ϕ will then be aligned with phonological material (namely the exponent of $\sqrt{X}$, here represented as [$\sqrt{X}$]), and consequently invisible. The left edge of this ϕ will then be aligned with lexical material (the exponent of the root) throughout the derivation.

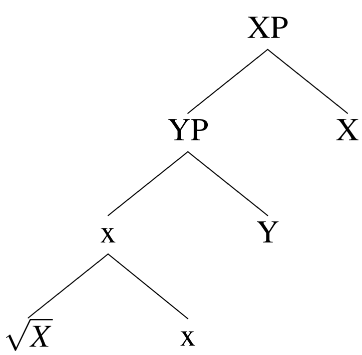
(29)



This is the simplest case – in general, however, there will be evidence of some kind or another that the root raises to its categoriser, and is not spelt out in the phase headed by its categoriser. For example, a root may display suppletive allomorphy indicating that Vocabulary Insertion applies after material higher than the categoriser is introduced. In this case the root will not define an invisible edge of a prosodic constituent, and the prosodic constituent will consequently remain modifiable. How, then, are we to reproduce the lexical category condition?

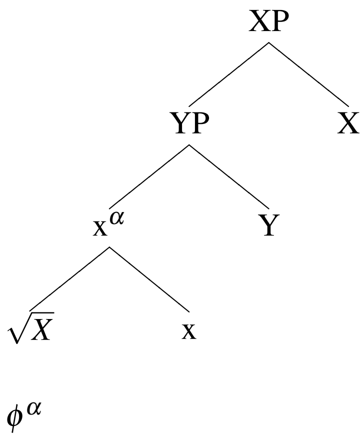
The answer comes when we recall the assumption that not only categorising heads are phase heads, but that heads of *maximal extended projections* of lexical categories are phase heads. Again keeping discussion in the abstract for the time being, consider the structure below:

(30)



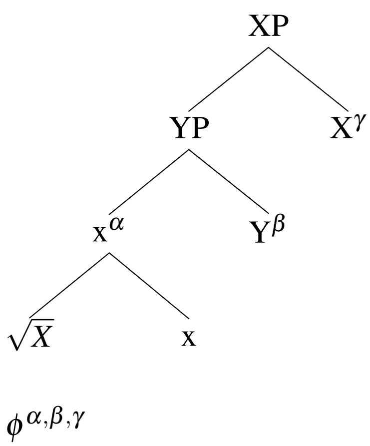
Here XP represents the maximal extended projection associated with the category x. By assumption, the head X of this projection is a phase head. Here Y is some a non-phasal head intervening between the categoriser x and the extended projection head X. Let us assume that the Root $\sqrt{X}$ has undergone head movement to its categoriser x, thereby escaping Vocabulary Insertion and Feature Stripping in the xP phase. It will, however, have undergone prosodification, which by hypothesis applies to the phase head as well as the phase domain, and we expect a prosodic structure along the following lines:

(31)



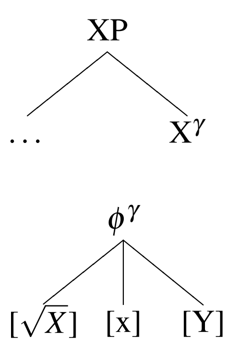
In the next phase, as XP is spelled out, another prosodification cycle takes place. This maps Y and X heads to the phonological phrase initially associated with the xP.

(32)



VI and feature stripping apply, inserting the exponents of $\sqrt{X}$, x and Y (but not X).

(33)



This defines an invisible left edge of ϕ, again aligned with the exponent of the lexical root $\sqrt{X}$. The lexical category condition will consequently appear to apply even though $\sqrt{X}$ has undergone raising to its categoriser. This particular example demonstrates the point for a consistently *head-final* language, where all heads branch to the right. In a consistently head-initial language, much the same facts will be observable, except that the root will stand at the *right* edge of the phonological phrase rather than the left.

This accounts for a correlation between branching direction in the syntax and alignment in prosodic structure noted by e.g. Nespor and Vogel (1986). For Nespor and Vogel, a phonological phrase is defined as follows:

(34) *Phonological Phrase* (Nespor and Vogel 1986: 168)
The Domain of ϕ consists of a *C*[litic group] which contains a lexical head and all *C*s on its non-recursive side up to the Clitic Group that contains another head outside of the maximal projection of X.

The term *non-recursive side* here indicates that branching direction is expected to play a role in the definition of the phonological phrase. I will call the requirement of a correlation between branching direction and prosodification the *Branching Directionality Condition* (BDC). Both the BDC and LCC must be stipulated by traditional approaches to prosodification, but emerge naturally from the MaP model.

To see more concretely how this works, let us consider an example from head-initial Chimwiini, discussed by Selkirk (1986), contrasting it with the head-final Gyalsumdo language (Hildebrandt and Perry 2011, Perry 2016, Dhakal et al. 2016). Both languages appear (for the most part) to conform to the BDC and the LCC, and it will be shown that this is in agreement with the MaP model.

2.3 Prosodification in Chimwiini and Gyalsumdo

The phonological phrase in Chimwiini, as discussed by Selkirk (1986), may be identified by the application of a vowel-shortening process which is sensitive to phrasal stress.[8] In particular, underlying long vowels which appear in a pre-antepenultimate position within a phonological phrase (i.e. outside the position of phrasal stress) are shortened, leading to alternations such as the following:

(35) *Vowel Shortening in Chimwiini* (adapted from Selkirk 1986: 377)

a) *ma:limu* 'teacher' + *-we* 'his' $\rightarrow$ *malimuwe* 'his teacher'

b) *mta:na* 'room' + *-we* $\rightarrow$ *mta:nawe* 'his room'

Here we see that the underlyingly long vowel in (35a) is shortened in *malimuwe* because it falls in pre-antepenultimate position, while in (35b), the long vowel appears in antepenultimate position and is consequently not shortened. The phrases which condition

[8] Kisseberth and Abasheikh (2011) suggest that phonological phrasing in Chimwiini is in fact recursive, along lines similar to Kimatuumbi, as discussed by Truckenbrodt (1999). A full system of this type will be discussed in Section 3.3, but we will not deal with recursive phrasing in Chimwiini here.

shortening may span multiple words – for example, we see shortening in the phrase *malimu wa sitta* ‘the sixth teacher’, where the long vowel of *maːlimu* is again pre-antepenultimate in the phrase.

Selkirk analyses the distribution of phonological phrases in Chimwiini using edge-alignment parameters. In particular, she proposes that in Chimwiini, the *right* edge of a *lexical* head aligns with the right edge of a phonological phrase. To see how this works, consider the expression *kamaː mp*^{h}*aka naː mp*^{h}*ana* ‘like a rat and a cat’.

(36)	*kamaː*	*mp*^{h}*aka*	*naː*	*mp*^{h}*ana*
	like	rat	and	cat
	‘like a rat and a cat’			

As we can see, this expression includes two long vowels, and consequently two phrasal stresses. We must consequently analyse this expression as being made up of two phrases ($_\phi$ kamaː mp^{h}aka)($_\phi$ naː mp^{h}ana). *mphaka* ‘rat’ and *mphana* ‘cat’ belong to lexical categories – we consequently expect the right edges of phonological phrases to align with their right edges, which is precisely what we see. This is illustrated, with the syntactic structure that Selkirk assumes, in (37).

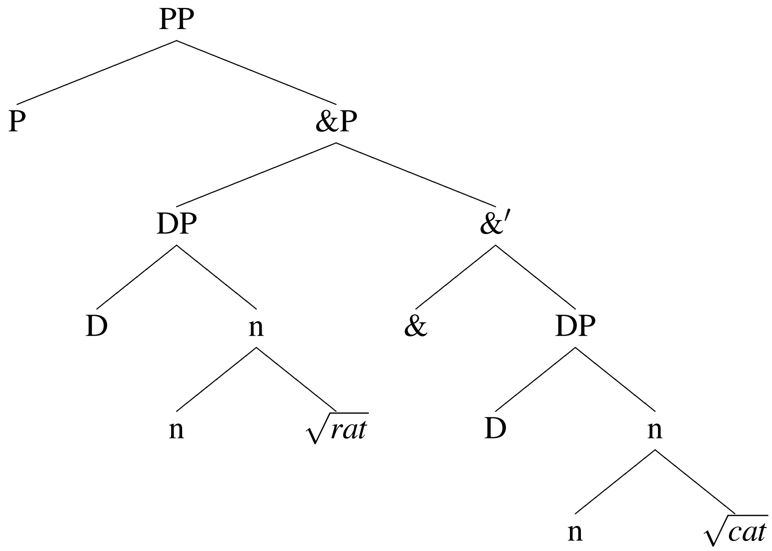
(37) *Prosodic Structure in Chimwiini*

Syntactic Structure:	[$_{PP}$ kamaː	[$_{NP}$[$_{NP}$ mphaka]	naː	[$_{NP}$ mphana]]]	
Aligned Edges:		$_\phi$)		$_\phi$)	
Prosodic Structure:	($_\phi$	$_\phi$)	($_\phi$	$_\phi$)	

The edge alignments observed here follow from both the LCC – which accounts for the particular alignment of phrases with *lexical* categories, and the BDC, which predicts that a generally head-initial language like Chimwiini will have prosodic constituents which extend to the right of their lexical categories.

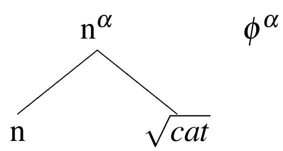
Now let us see how this structure follows naturally from the procedures adopted in the MaP model. First of all, however, we must revise the syntactic structure offered by Selkirk here. In particular, as conventional in a Minimalist framework, we will adopt the model of coordination developed by Johannessen (1998), where coordinate constructions are taken to be headed by an & head, with coordinands forming complement and specifier of the head in question. We will also adopt the DP hypothesis, taking the head of the maximal extended nominal projection to be D. That is, we assume the phrase to have the syntactic structure in (38).

(38)



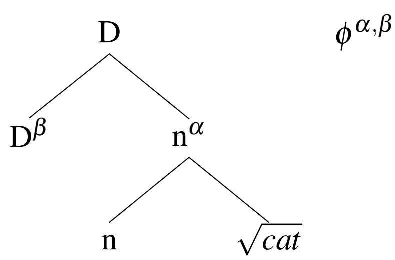
For illustrative purposes, I assume that the root has raised to *n* here, but nothing hinges on this. Spellout operations in an nP phase prosodify the n head, but because the phase domain is empty, VI and feature stripping are vacuous, producing the representation below, with the complex *n* head mapping to a phonological phrase (neglecting the phonological word here).

(39)



The ϕ constituent here, being associated entirely with a syntactic constituent which has not been spelt out, has two visible edges. At the DP phase, then, the ϕ constituent may be expanded to be associated with the D head.

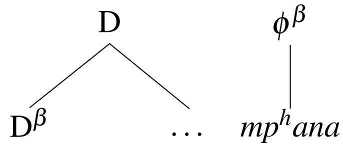
(40)



VI and feature stripping apply to the phase domain, here taken to be identical with the complex n head.[9]

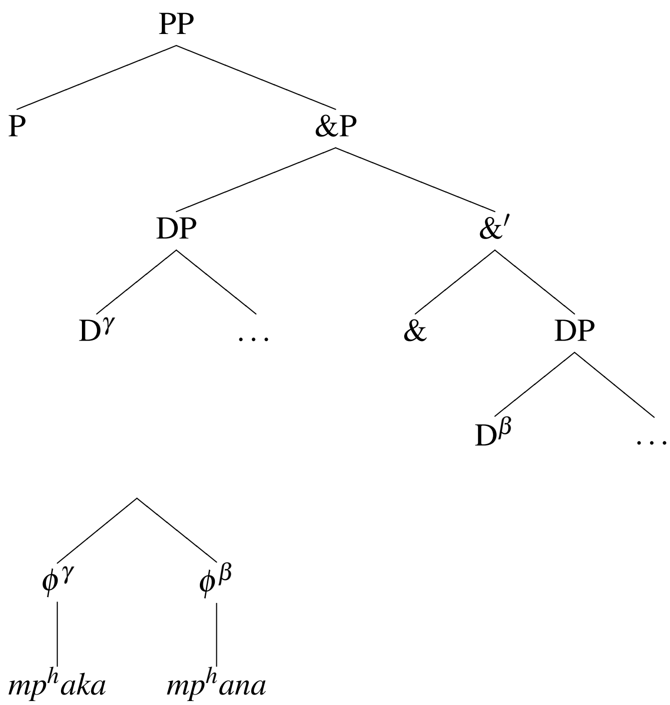
[9] I assume here that the noun class marker *m-* in these examples is an exponent of the *n* head, though it could easily be the exponent of a head intermediate between *n* and D. The choice made here is for no reason other than representational simplicity.

(41)



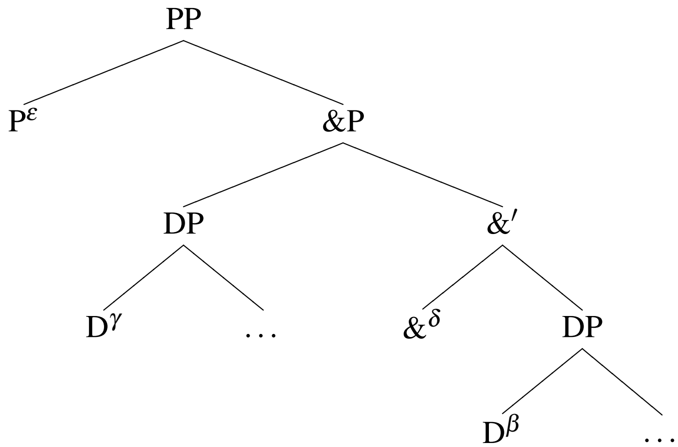
Note that the ϕ constituent here has a visible *left* edge, but no visible right edge. The two DPs are each assembled in this way before being incorporated into the PP structure, which before Spellout consequently has the structure in (43).

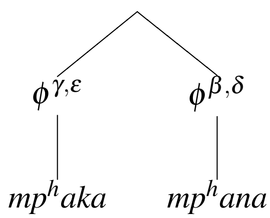
(42)



Both ϕ constituents here have visible left edges, and may consequently be associated with syntactic objects which are linearised to their left – the ϕ containing *mp^h aka* ‘rat’ is consequently associated with the P head, and that containing *mp^h ana* ‘cat’ is associated with the & head.

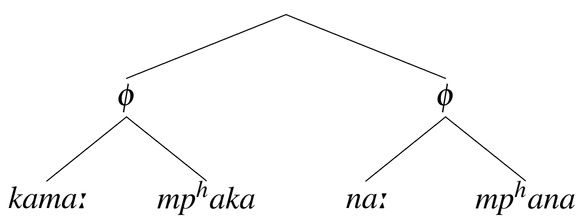
(43)





As VI and Feature Stripping apply, the exponents of P and & are inserted into the relevant ϕ constituents. VI applies vacuously to the null D heads. This results in the prosodic structure shown below:

(44)



As we can see, this corresponds exactly to the structure (37) produced by Selkirk's edge-alignment model, without the need to independently stipulate either the LCC or the BDC. Next we will consider Gyalsumdo, a head-final language, showing how the results of the BDC are correctly reproduced in this language.

Gyalsumdo is a Tibetic language spoken by about 500 speakers in Nepal's Manang district. Like most Tibetic languages, it possesses a simple tonal system, with contrast for high and low tone. The phonological phrase in Gyalsumdo, as analysed by Perry (2016) may be identified by two properties – firstly, contrastive tone is forbidden on all syllables in the phonological phrase other than the initial syllable: the pitch of other syllables receives a default realisation. Secondly, elements which do not form part of an initial p-word in a phonological phrase do not display metrical structure. Metrical structure may be identified by a final high tone on the initial (maximally disyllabic) foot of a word. This is shown for a number of cases in (45)

(45) a) /sàŋ/ [sàŋ́] ‘copper’

b) /bòmo/ [bòmó] ‘girl’

c) /ɖèmenjoŋ/ [ɖèmèńjôŋ̀] ‘elbow’

d) /káŋgari/ [káŋ́gârì] ‘bicycle’

As (45) illustrates, the foot-final high tone is realised on the final mora of the foot in question. The simplest case is (45b), where the second syllable of a disyllabic word, exhaustively metrified in a single foot, receives a default high tone. In (45a), we have a monosyllabic word, likewise metrified into a single foot, where the high pitch is realised on the final moraic nasal. In (45c), the word is no longer parsed into a single foot – rather the initial foot includes only the first two syllables, and the foot-final high appears on the final moraic nasal of the second syllable. In (45d), the morphological structure of the word means that the initial foot is monosyllabic, and the foot-final high is realised on the final mora of the first syllable. In both (45c) and (45d) syllables outside the initial foot show pitch interpolation from the foot-final high to a word-final low. Unmetrified elements in the phonological phrase are neither footed nor show this interpolation.

Now consider the phrase below:

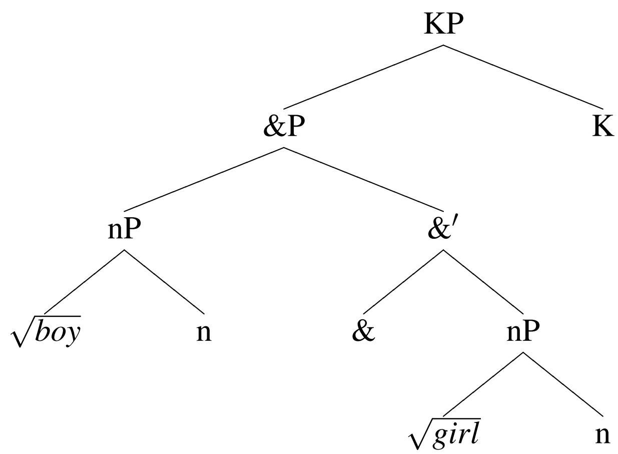
(46) *bìdza=daŋ bòmo=la*
[bìdzá dàŋ̀ bòmó là]
boy=and girl=DAT
‘To the boy and girl’

As we can see, (46) shows only two contrastive tone marks, and only two foot-final high tones, indicating that there are two ϕ constituents here, each initiated by the lexical category items *bìdza* ‘boy’ and *bomó* ‘girl’. This could be readily accounted for in Selkirk’s edge-alignment model by taking the right edges of phonological phrases to be aligned with the right edges of lexical categories in the syntax. Again, however, the correlation between the direction of branching and must be independently stipulated, as must the restriction to *lexical* categories.

This has a syntactic structure broadly parallel to the Chimwiini example above, with the exception that we will (following Perry 2016) take the maximal projection here to be K(ase) rather than P, and we will take the coordinator to conjoin nP constituents rather than DPs. There is reason to believe that roots in Gyalsumdo do not undergo head-movement to their categorisers (see Perry 2016 for further details). We assume K to be the maximal nominal extended projection, and consequently a phase head. None of these assumptions alter the outcome of the procedure used here. The structure assumed is given in (47). Gyalsumdo is, for the most part, a rigidly head-final language, but the placement of the coordinator indicates that it should be taken to precede its complement.[10]

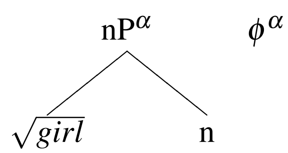
[10]If it followed its complement, we would expect the ungrammatical **bìdza bòmo=daŋ=la*.

(47)



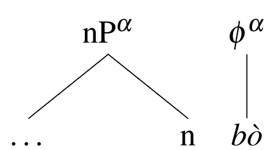
Let us see how this derives a representation consistent with the LCC and BDP. The first step of the derivation begins with the nP phases. Our procedure maps the whole nP phase to a single ϕ.

(48)



VI and Feature Stripping apply – since the root does not raise to its categoriser, it lies within the phase domain at this point and is subject to VI.[11]

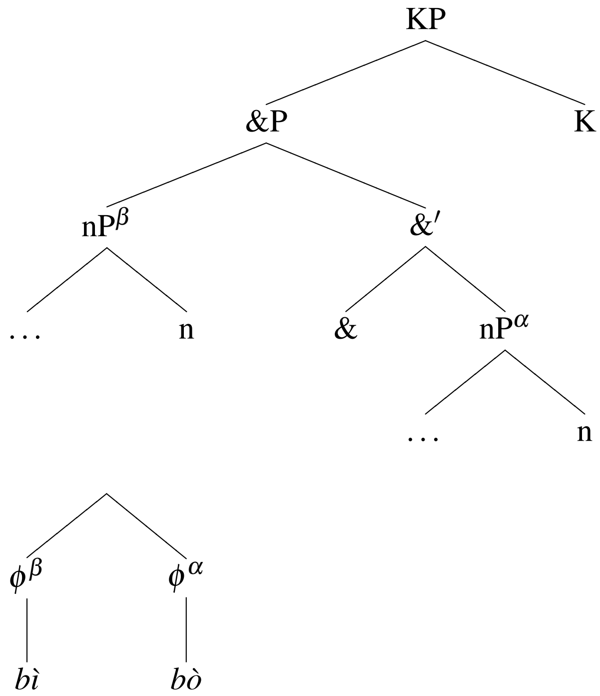
(49)



This application of VI and Feature Stripping defines an invisible left edge of the phonological phrase in question. At the beginning of the KP phase two nPs have been prosodified in this way.

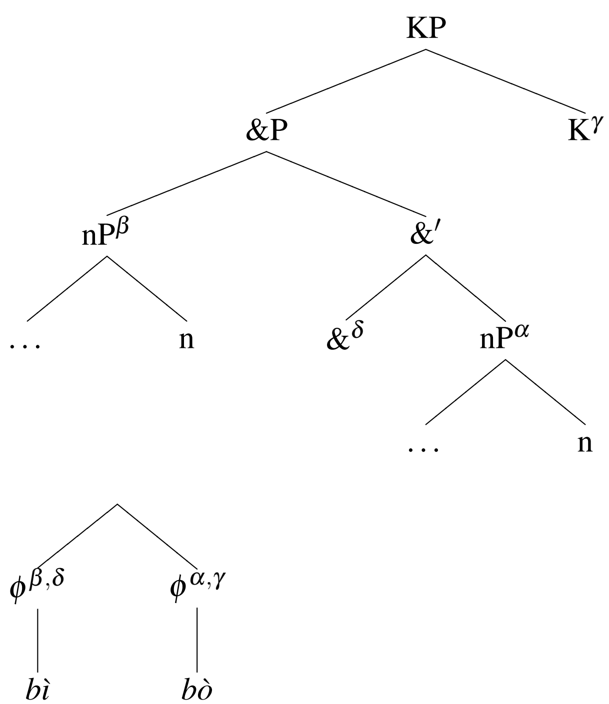
[11] There is reason to believe that only the first syllable of a word like *bòmo* is the root. The categoriser then (*-mo*) forms a single ω constituent with this root – we will not be concerned with this here, however.

(50)



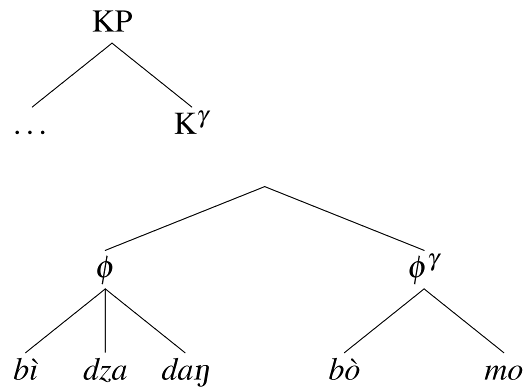
Each of the nPs are associated with a ϕ constituent with a visible right edge – this means that syntactic material linearised to the right of these ϕ constituents (the & head and the K head, respectively) may be associated with them.

(51)



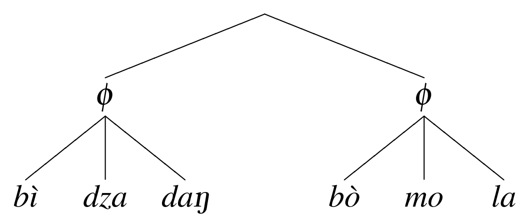
The KP phase then undergoes VI and feature stripping, inserting exponents of the & and *n* heads while removing them and their projections from the syntactic representation.

(52)



The final trivial step is the complete spellout of the K head, giving the prosodification we expect from the surface representation.

(53)



As we can see, the correlation between head directionality and prosodic constituency follows without further stipulation, as does the fact that lexical categories define prosodic constituent edges. In the next section, we turn to cases where the interaction between prosody and syntax is more complicated, showing that it is possible for the MaP model to account for these in a natural way.

3 Recursive Constituents and Pruning

In this section I will illustrate an interesting, and perhaps slightly unexpected, side-effect of the MaP model, namely that it produces *recursive* constituents in a natural way. I discuss two case studies, namely Kimatuumbi, drawing on work by Truckenbrodt (1999), and Irish, drawing in particular on work by Elfner (2012, 2015).[12]

As suggested by the name of the MaP model (Mapping *and* Pruning), the mapping produced by the procedure above on the basis of an input syntactic structure do not always correspond to the prosodifications we observe. The prosodifications proposed by

[12] Although these cases are standardly assumed to involve recursion, as will be assumed in what follows, this is not without controversy: see in particular Cheng and Downing (2021) for a reanalysis of these cases which does not use recursion.

Elfner and Truckenbrodt are somewhat different from those reached by the Mapping component of our model – but we can observe that the proposed representations can be reached through the application of pruning processes.

Dealing first with the question of recursion, we will consider how recursive constituents may emerge in the abstract given our model, before showing how this can be applied to Kimatuumbi and Irish.

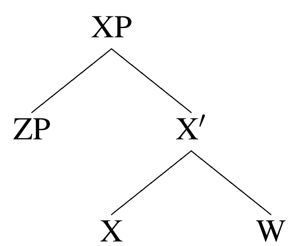
3.1 Movement and Recursion

In the previous section, we took linearisation operations to precede prosodification within a phrase. This included, for example, the operations which linearise multiply-merged objects to a single position ('chain reduction' - cf. Nunes 2004). We have also assumed that prosodification and operations which precede it at the phase level apply not just to the phase domain, but to the whole phase, including the phase edge, which remains accessible in subsequent phases.

This latter assumption allows linearisation operations such as chain reduction to apply to material that has already been prosodified. This allows for a complex interaction between movement and prosodification, and it is that which will be discussed in this section.

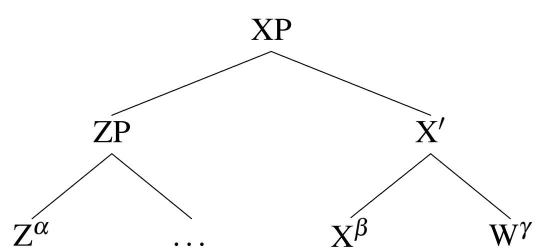
Suppose that we have two phases XP and YP, such that XP is contained within YP, and each phase is head-initial. Let us also suppose that XP has in its specifier a phasal constituent ZP, also head-initial, along with a complement W, the internal structure of which is immaterial here. That is to say, XP has the structure below:

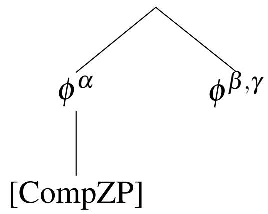
(54)



Because ZP is head-initial, it will be associated with a phonological phrase containing an invisible right edge. When the XP phase is prosodified, then, the XP will contain two ϕ constituents – one associated with X and W, the other with the contents of ZP (the only remaining mapping statement at this point referring to the Z head, assuming that ZP has no specifier).

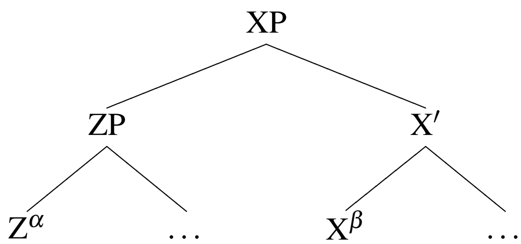
(55)

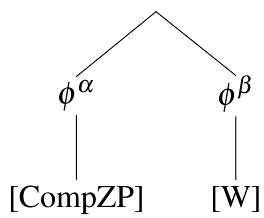




VI and Feature Stripping insert the exponent(s) of W and remove it from the syntactic representation.

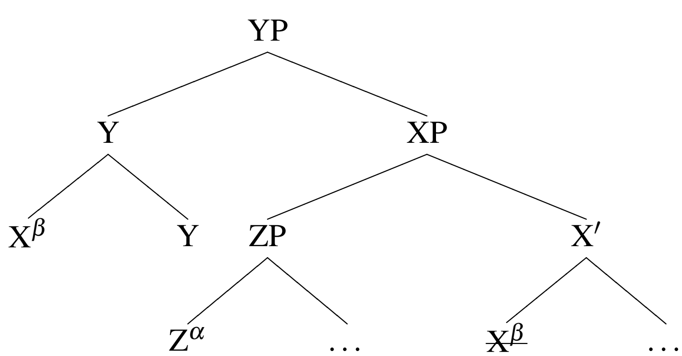
(56)





Now let us move to the YP phase, and crucially assume that X undergoes movement to Y. That is to say, it is relinearised so that it appears in a position adjoined to Y. Note that this relinearisation does nothing to the mapping statements in which X plays a part, since the object X itself is unmodified except for its linear precedence relations.

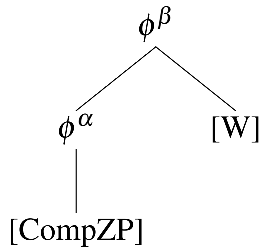
(57)



When it comes to projecting the linearisation of these syntactic objects into the prosodic structure (see Appendix for further details), this presents us with something of a problem.

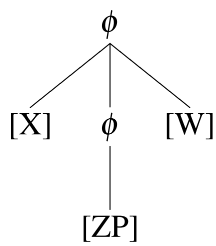
The ϕ constituent to which X is mapped contains the phonological exponent of W, which is linearised to the right of ZP. But X is now linearised to the left of ZP, and remains associated with the ϕ constituent in question. This seems to present a linearisation paradox. How are we to resolve this? Given that discontinuous prosodic constituents are not readily phonologically interpretable, the least invasive modification would seem to be to have the ϕ constituent which is associated with X *dominate* that which contains ZP. That is to say, we have the structure in (58).

(58)



When VI has applied to all the heads of interest (assuming Y to be null for the time being), we arrive at the following structure:

(59)



This is of course only the initial prosodic representation of the domain: subsequent pruning rules may apply and modify the structure quite substantially – but in the default case, we expect the representation containing a recursion of ϕ arrived at in (59). Recursive constituents in this model therefore emerge naturally as a consequence of the interaction between prosodification, linearisation, and the structure of the syntactic phase.

This is not to imply that this is the *only* way in which recursive constituents may emerge. In particular, recursion may appear in the course of pruning as a means of satisfying well-formedness conditions on prosodic structure. Indeed, the model here can be shown to imply that this *must* be the case when we see recursive constituency in head-final languages, as in Ito and Mester's (2013) analysis of Japanese prosodic structure.[13]

3.2 Irish

The configuration discussed in section 3.1 can be shown to appear in Irish. Irish is a relatively consistent verb-initial (VSO) language – this means that, in most cases, the verb

[13] It does indeed seem to be the case that recursion in Ito and Mester's analysis is exclusively driven by considerations of prosodic well-formedness.

head must be taken to have moved past the subject on its way to a higher head.[14] A typical VSO sentence in Irish is shown in (60).

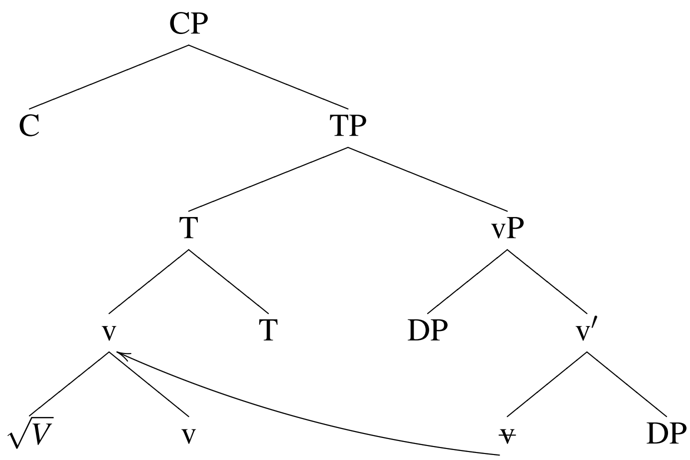
(60)

Cheannaigh	*an*	*fear*	*teach*
buy(PST)	the	man	house

‘The man bought a house’

The assumed structure of a simple VSO sentence such as (60) is shown in (61).

(61)



Because Irish is a head-initial language, this precisely reflects the configuration in section 3.1, with the subject DP fulfilling the role of ZP, the verb head the role of the X head, and the object DP the role of W. This means that the MaP model predicts a recursive structure, whereby the prosodic phrase containing the exponent of the subject is included within another prosodic phrase containing the exponents of object and verb.

In fact, Elfner (2012) offers evidence for precisely this kind of recursive structure. The evidence comes from the default intonation of Connemara Irish declarative sentences. This type of intonation in Connemara Irish is characterised by two pitch specifications – a fall (H-L) which appears phrase-finally, and a rise (L-H) which appears phrase-initially.[15] Consider a phrase like (62), shown together with the pitches which Elfner observes.

(62)

Díolfaidh	*rúnaí*	*dathúil*	*blathanna*	*áille*
L-H	L-H	H-L		H-L
will.sell	secretary	colourful	flowers	beautiful

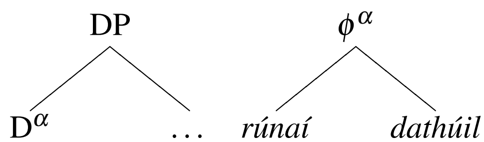
‘An attractive secretary will sell beautiful flowers’

[14]The identity of the higher head in question is not altogether clear – McCloskey 2017 takes it to be a high polarity head Σ. For simplicity of representation (since the identity makes no material difference to the prosodification algorithm), I will assume it to be the tense head T.

[15]The distribution Elfner proposes is, in fact, a little more complicated than this – we will return to this point later on.

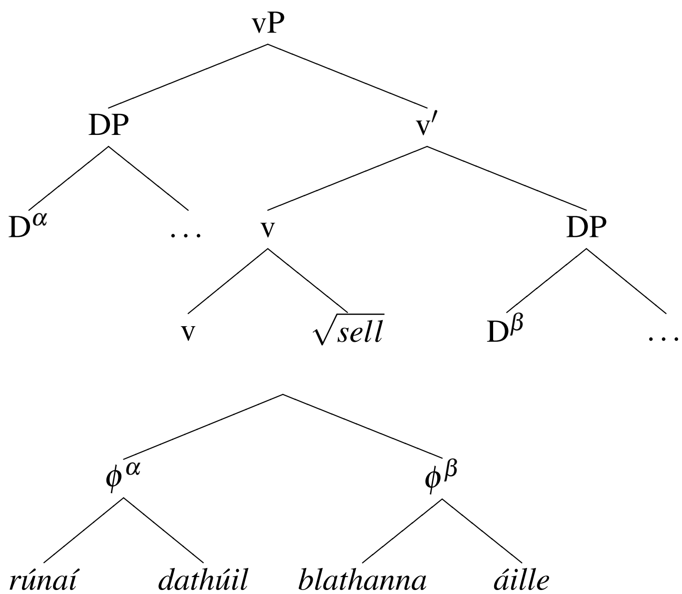
The configuration produced by the MaP model gives us the correct distribution of pitches in this sentence without any additional stipulation – we would simply need to state that an L-H tone is associated with the first (phonological) word of a ϕ constituent, and an H-L tone with the last. Let us see explicitly how the derivation of (62) proceeds (assuming, for the time being, that no pruning rules apply – an assumption that will be revised). We will not concern oursleves too much with the internal structures of the DP here, simply assuming that they form a single phonological phrase with (as expected for a head-initial language) an invisible (and consequently unmodifiable) right edge. We can assume that D heads are initial in Irish, whether they are null (as they are here) or overt (e.g. the definite article in ***an*** *rúnaí dathúil* 'the attractive secretary'). At the point of Spellout, then, the subject DP phase has the structure below (with a parallel structure for the object):

(63)



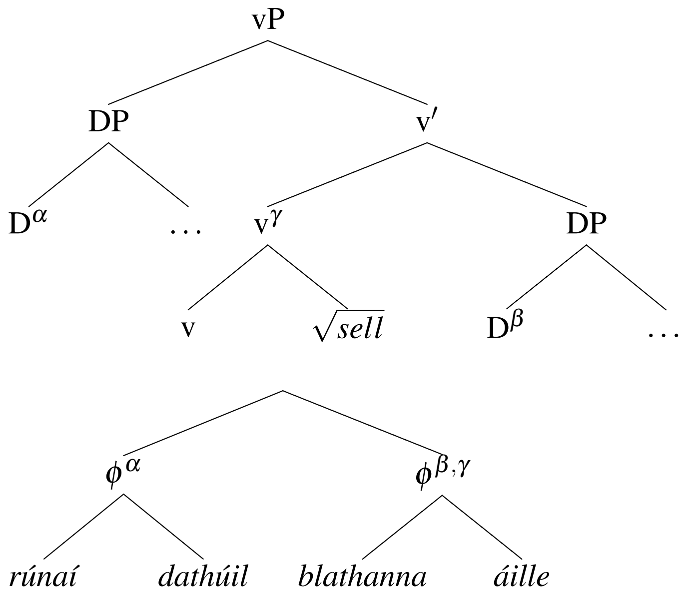
The structure of the vP phase immediately before Spellout, then, is as follows.

(64)



In the process of prosodification, since the object DP has a visible (i.e. open) edge at its left, while the subject has an invisible (i.e. closed) edge at its right, the verb is prosodified together with the object.

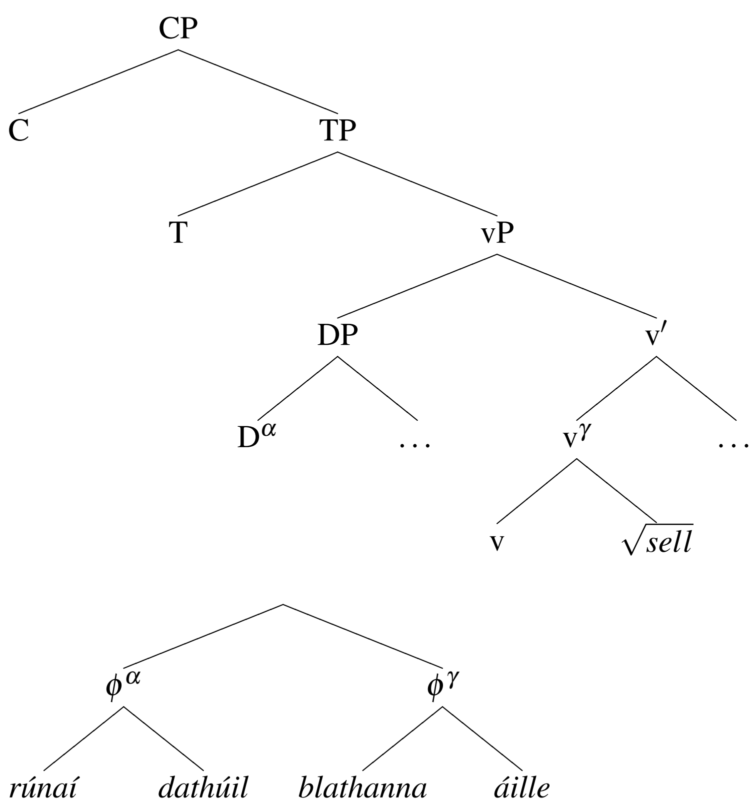
(65)



The object DP then undergoes (vacuous) VI and feature stripping – since the verb and subject lie in the phase edge, VI and feature stripping do not apply to them.

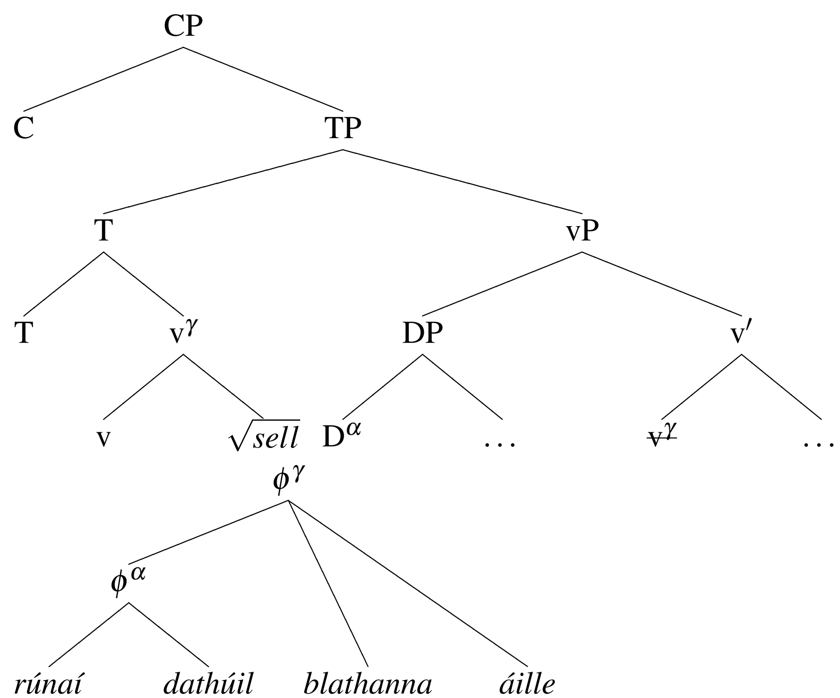
Let us now turn to the CP phase. The initial state of this phase before Spellout is as follows:

(66)



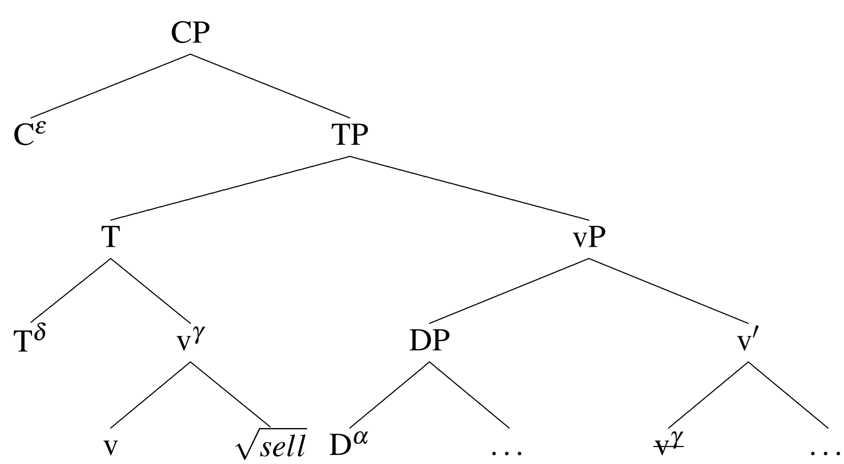
As Spellout begins, the verb undergoes head-movement (a species of relinearisation, as discussed above) to T. This results in a configuration whereby the *v* head is linearised before the subject D head, while the ϕ constituent associated with the *v* head contains overt phonological material (i.e. the exponent of the object) which is linearised *after* the exponent of the subject. This leaves us with the ordering paradox which is only resolvable by having the ϕ associated with the verb and object *dominate* the ϕ associated with the subject, as follows:

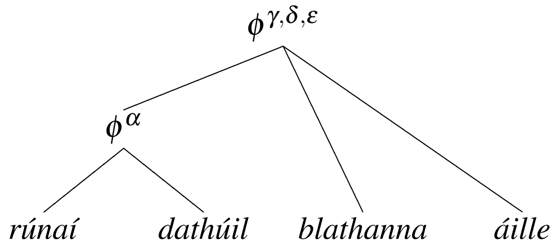
(67)



Prosodification operations then incorporate C and T into the prosodic representation, associating them with the ϕ already associated with the verb.

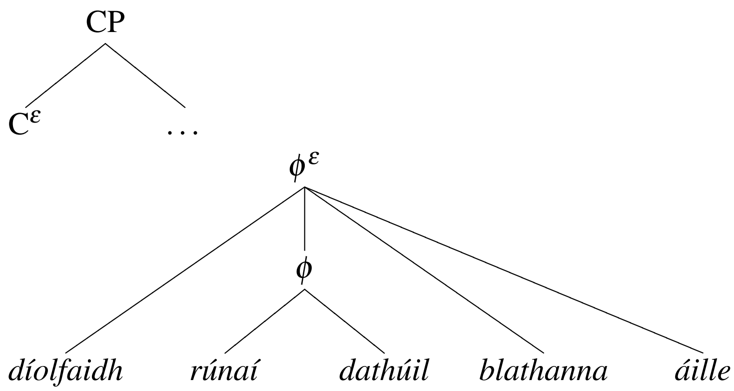
(68)





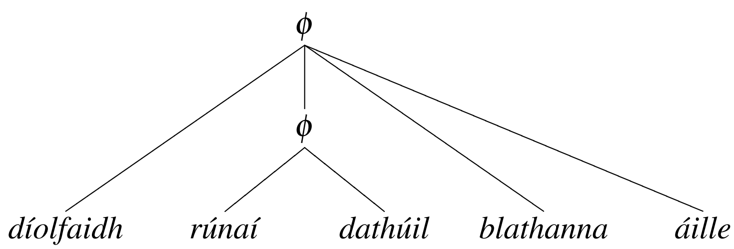
The remaining Spellout operations apply to the phase domain of the CP, inserting the exponent of the verb and removing the TP from the syntactic representation.

(69)



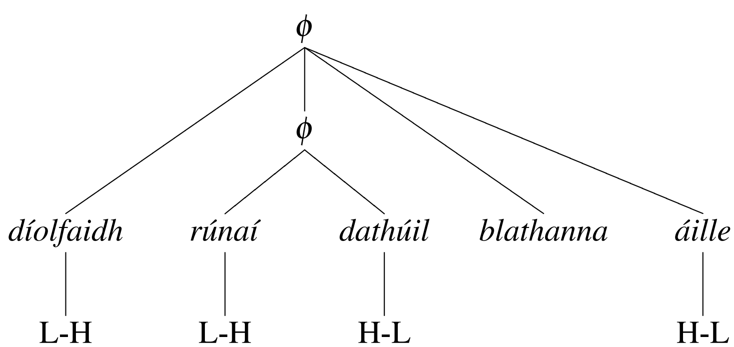
In this instance the Spellout of C is null and we obtain the final prosodic representation:

(70)



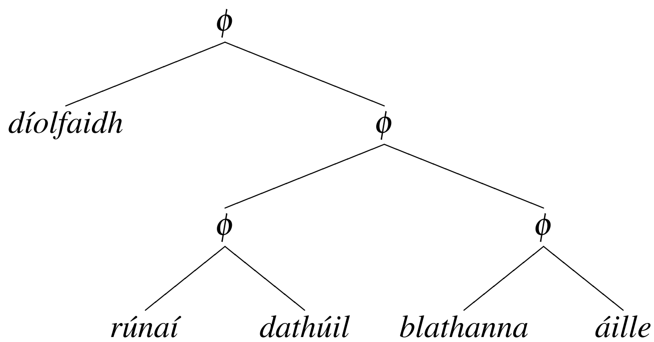
A simple phonological rule inserting an L-H tone on the initial member of a phonological phrase and an H-L tone on the final member then obtains the observed intonation patterns:

(71)



Note that the prosodic representation in (71) is not the representation Elfner adopts for Irish. The representation she adopts is somewhat more complex, containing an additional layer of recursive structure, and grouping the elements of the object into a ϕ constituent of their own:

(72)



Elfner then supposes that *non-minimal* ϕ receives an initial L-H tone, with H-L assigned to the final element of all ϕ constituents. This gives the same distribution of tonal elements as our model above produced. If we suppose that the prosodification that Elfner gives is indeed correct, we can attribute this to a preference for binary constituents (enforced by constraints BINMIN and BINMAX, discussed in the introduction). These, we can assume, are implemented by pruning operations as follows:[16]

(73)

Constraint	**Pruning Operation**	**Description**
BINMAX	$\pi_i\pi_i \rightarrow (_\phi\ \pi_i\pi_i)$ / $(_\phi \ldots \pi, \_\_ \ldots)$	Group constituents of same rank into a new ϕ within ϕ with more than two branches.
BINMIN	$(_\phi\ \pi) \rightarrow \pi$	Remove non-branching ϕ.

These pruning operations can be taken to apply until the constraints are satisfied, yielding the representation in (72).[17] Given that simply taking the output of our mapping procedure allows us to describe the distribution of tonal elements more simply, however, we might wonder whether pruning rules such as these are indeed necessary. One reason we might suspect that they are comes from the behaviour of sentences with simple one-word subjects, such as the following (taken from Elfner 2015: 1197–1199):

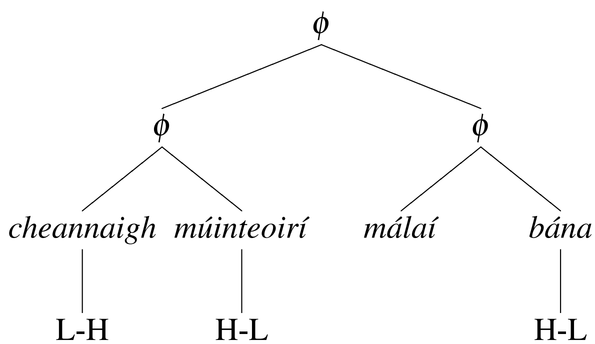
[16]Where π is any prosodic constituent, and π_i is any prosodic constituent of a particular rank.

[17]Or, as noted above, the relevant constraints could be taken to participate in an optimality-theoretic computation of which (71) is the input.

(74) *Cheannaigh* *múinteoirí* *málaí* *bána*
L-H H-L H-L
bought teachers bags white
'Teachers bought white bags'

Here we see the phrase-final H-L, but not the phrase initial L-H tone on the subject, suggesting that it is final within a larger phonological phrase. The MaP model, on the other hand, in the absence of pruning rules, predicts that the subject should form a phrase of its own. If we adopt Elfner's account of the distribution of tone, and assume that the binarity constraints in (73) do indeed hold and apply the relevant pruning rules, we correctly predict the representation in (75).

(75)



It should be mentioned, however, that the correct tonal pattern can be captured without pruning rules if we assume that a single p-word can only bear a single tonal specification, and that H-L tones pre-empt L-H tones.

Whether the approach with or without pruning is correct will depend on other facts of the language, but it should be clear that the model adopted here has sufficient power to reproduce either analysis. If Elfner's description of the distribution of tones is indeed correct, the MaP model still has a small explanatory advantage over the Match Theory- based model she adopts, as it allows an acquisition based account of how this rather marked distribution of tones might arise historically. We can suppose that, at some stage in the history of the language, the prosodic structure of Irish was indeed simply the output of the mapping procedure, with no pruning rules applying. At this stage, we would have the simple distribution of tones we adopted above, with L-H appearing ϕ-initially and H-L appearing ϕ-finally. Since these prosodic structures are phonologically marked, it is not unreasonable to suggest that a learner might initially hypothesise relatively unmarked structures along the lines of the binary structures in (72, 75). This learner would have to account for the distribution of tones in the input, however, and this would lead to the generalisations relating Elfner gives. Match Theory does not allow an account along these lines, and the distribution of tones must simply be stipulated.

3.3 Kimatuumbi

That recursion in Irish is predicted by the MaP model follows relatively transparently from the fact that the verb must move over the subject. Analyses involving recursive ϕ constituents are not limited to verb-initial languages, however, and it may be instructive to explore how recursion can arise given the Mapping Procedure adopted here in languages of other types. In particular, I show how the MaP model can reproduce the prosodic recursion observed by Truckenbrodt (1999) in Kimatuumbi.

Truckenbrodt (1999) highlights two phonological processes in Kimatuumbi, drawing on data from Odden (1987, 1996). In particular, he identifies a *shortening* process which is blocked at the right edge of a phonological phrase, and a tone-insertion process (PTI) which is triggered on the syllable before the left edge of a phonological phrase.

(76) *Processes in Kimatuumbi* (formulation mine)

a) *Shortening*
Shorten long vowels, except in a word at the right edge of a phonological phrase.

b) *Phrasal Tone Insertion* (PTI)
Assign a high tone to the syllable before the left edge of a phonological phrase.

The fact that there are separate processes which allow us to identify each edge of a phonological phrase allows us to identify cases in which a right edge of one phrase is not followed by the left edge of another, or a left edge is not preceded by a right edge. That is to say, as Truckenbrodt notes, it allows us to detect nested or recursive phonological phrases.

Consider, for example, the three expressions below (where elements subject to the relevant processes are **bolded**):

(77) a) *m-p**u**nga* *wa* *báa-ndu*
CL14-rice LNK.CL14 CL2-person
'The people's rice'

b) *m-puung**á*** *w-aa-bó-i*
CL14-rice CL14.SUBJ-REM-rot-PST
'The rice rotted'

c) *n-aa-m-pé-i* *ki-kóloombe* *Mambóondo*
1SG.SUBJ-REM-CL1.OBJ-give-PST CL7-shell M.
'I gave the shell to Mamboondo'

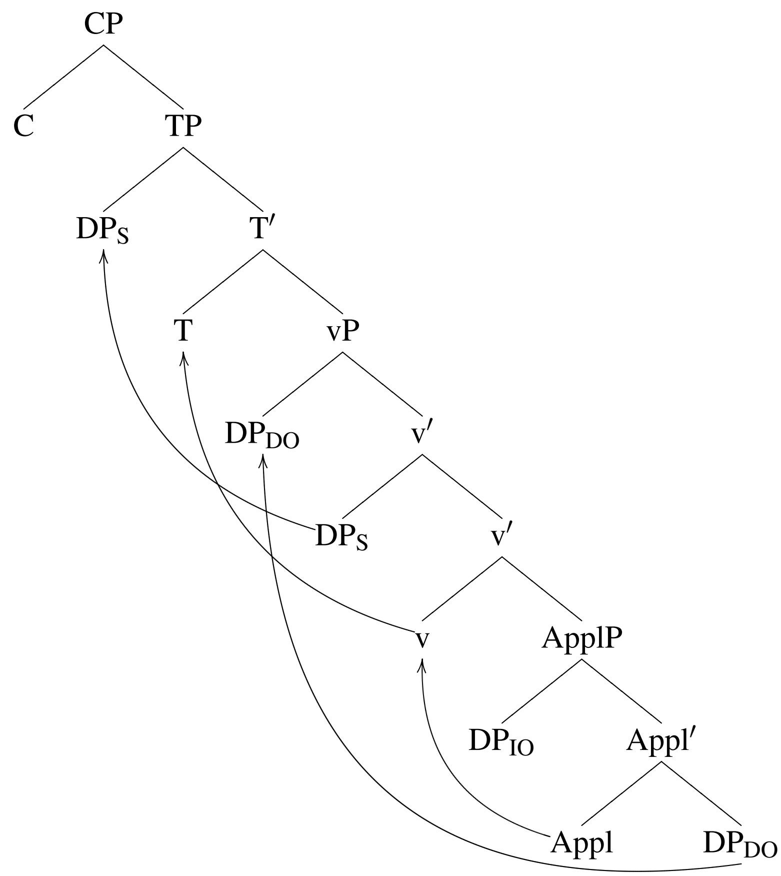
In example (77a), the word *m-puunga* 'rice' undergoes shortening, surfacing as *m-p**u**nga*. This implies that it is not at the right edge of a phonological phrase. This contrasts with (77b), where the same item surfaces as *m-puung**á***: it fails to undergo shortening (indicating that it stands at the right edge of ϕ), and also undergoes PTI, indicating that it is followed by the left edge of another phonological phrase. Finally, in (77c) the item *ki-kóloombe* 'shell' undergoes neither shortening nor PTI, indicating that it stands at the right edge of a p-phrase (blocking shortening), but is not followed by the left edge of another – this indicates that the phonological phrase of which it is a part is nested within another, larger phonological phrase. In other words, the forms in (77) are compatible with the following prosodic structures:

(78) a) ($_\phi$ mpunga wa báandu)
b) ($_\phi$ mpuungá) ($_\phi$ waabói)
c) ($_\phi$ ($_\phi$ naampéi kikóloombe) Mambóondo)

These are the prosodic representations which Truckenbrodt adopts. What this section attempts to show is that the MaP model is capable of reproducing a recursive representation of the sort seen in (78c). To do this, we need to assume that the *object* in this sort of construction plays a similar role to that of the *subject* in Irish. For this to be the case, the verb must be taken to *follow* the object in one phase and then move so that it *precedes* the object in another phase. Given that Kimatuumbi (like most Bantu languages) is quite consistently head-initial (i.e. object-final), this would seem to require that the object raises to the edge of the vP phase, before the verb itself moves over the object to a higher position in the next phase. That is to say, we have something the following structure:[18]

[18]This is the structure showing as little movement and structure as possible – it is quite possible that the final position of the verb is a head above T, and that the object DP moves outside the vP (albeit to a position lower than the verb). On the other hand, it is also possible that the verb moves to a position below T, but above Neg and v (this is implied by the model adopted by Julien 2002). Since this is not required to obtain the correct prosodification, however, we will not assume either of these alternatives here.

(79)



To show that this is the case, we need to demonstrate that both that the verb moves outside the vP, and that the object moves to the vP edge. That the verb in Kimatuumbi moves high is clear from the position of the verb relative to negation – a finite verb precedes its negator, even though negators (following Pollock 1989) are generally taken to be generated above the verb.

(80) *Position of Negation* (from Odden 1996: 243)

n-aa-m-pé-i	*lí*	*Mamboondo*	*ki-wɪkɪlyo*	*iijuma*
1SG.SUBJ-REM-CL1.OBJ-give-PST	NEG	M.	CL7-cover	Friday

'I gave Mamboondo a cover on Friday'

Another reason to believe that the verb moves high is that the verbal complex contains markers for information generally taken to be provided in T or above, including tense/aspect (and agreement) morphology, as well as morphology relating to clause type (such as relativisers) which might even be taken to be generated in the C domain.

(81)

mu-ndu	*ywa-n-áa-m-pe-íi*	*m-puungá*
CL1-person	CL1.REL-1SG.SUBJ-REM-CL1.OBJ-PST	CL14-rice

a-a-bʊʊ-i
CL1.SUBJ-REM-leave-PST

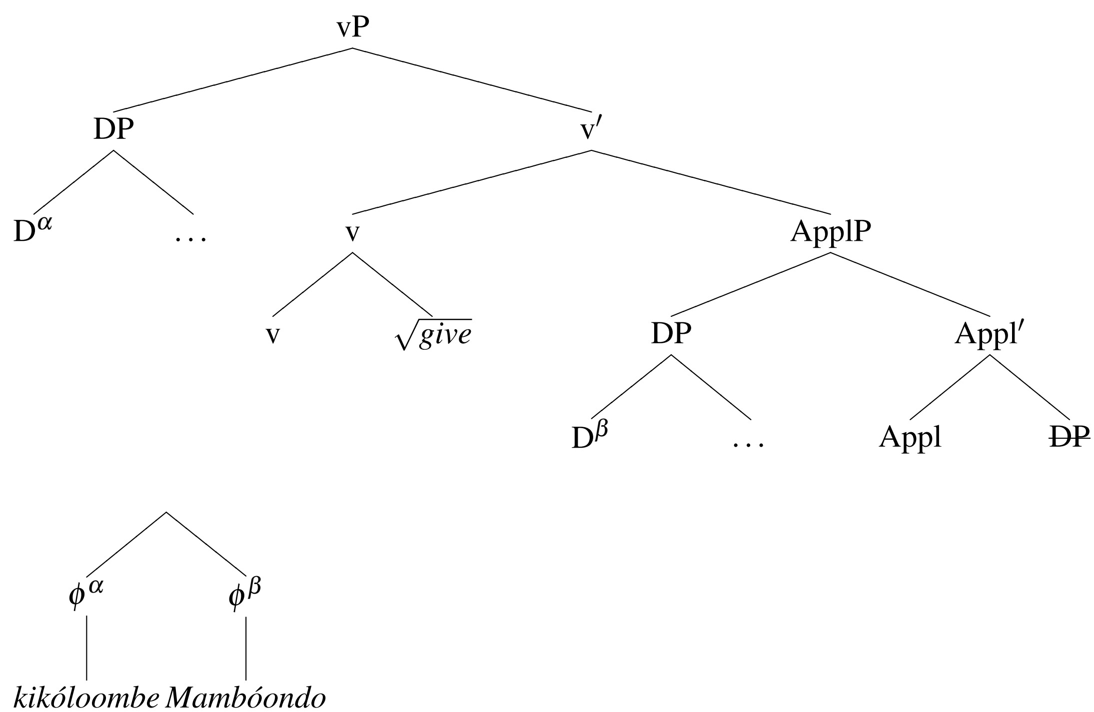
‘The person who I gave rice to left’

As for the object, we can note that both V IO DO and V DO IO orders are possible in Kimatuumbi. These orders are illustrated in (80) and (77c), respectively. If we assume that UTAH (Baker 1988) or some variant holds in the language (so that the same thematic roles are assigned to DPs in the same first-merged position), this must imply that one or both of these orders involves movement of an object to a higher position. That this position is at (or above) the phase edge of vP is not indisputable, of course, but it seems plausible at the very least.

Given that both verb and object raising are independently desirable in Kimatuumbi, there is good reason to assume that some representation similar to (79) holds, and we consequently *expect* recursive prosodic phrasing. Let us now see how the structure of (77c) is derived explicitly.

Again neglecting the internal derivation of the DPs, we will assume them to be straightforwardly parsed as phonological phrases, with a visible edge on their left-hand side, associated with the D head. This means that the initial structure of the vP phase is as follows:[19]

(82)

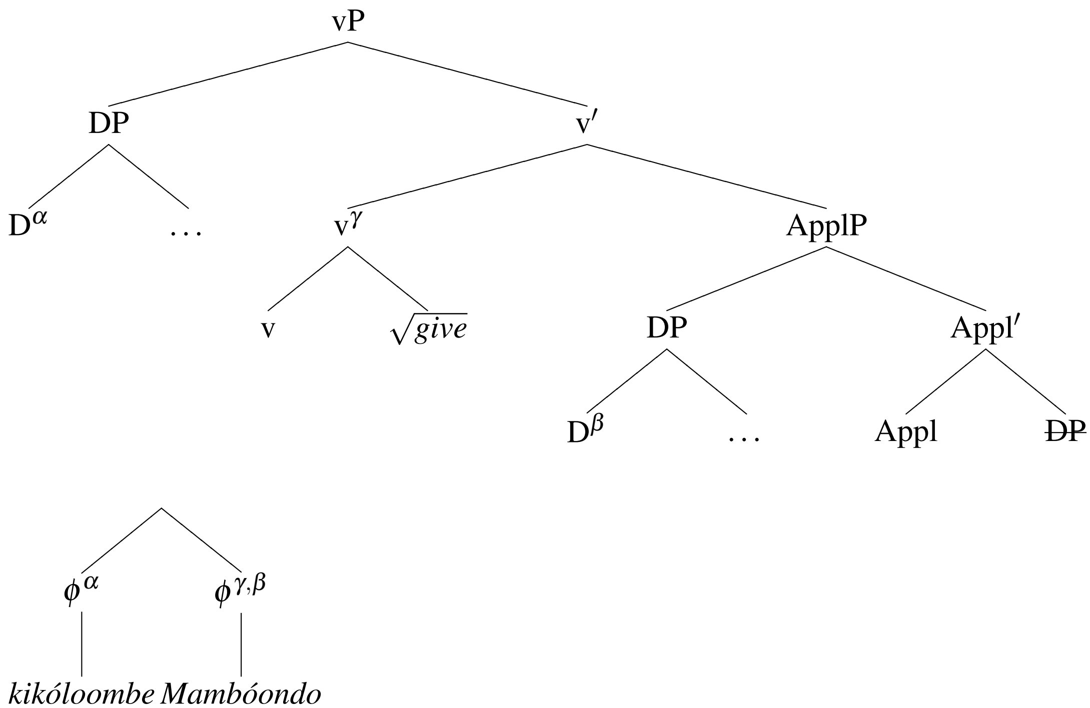


Note that the direct object has already moved as vP is spelled out – chain reduction ensures that the direct object DP unambiguously precedes the verb and the indirect object

[19] I neglect the external argument here – it is null in (77c) and plays no role in the emergence of recursive prosodification in any case. I also show the verb root as already incorporated into its categoriser: this does not make any difference to the analysis.

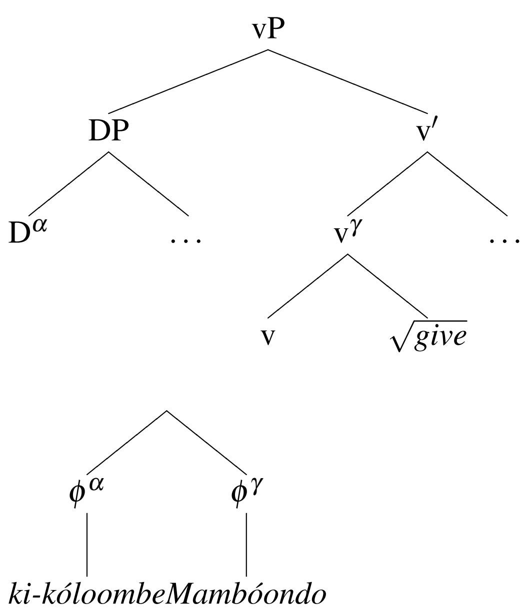
DP. Because the IO has a visible prosodic edge on the same side as the verb, the the DO does not, the verb phrases with the IO rather than the DO in the course of prosodification.

(83)



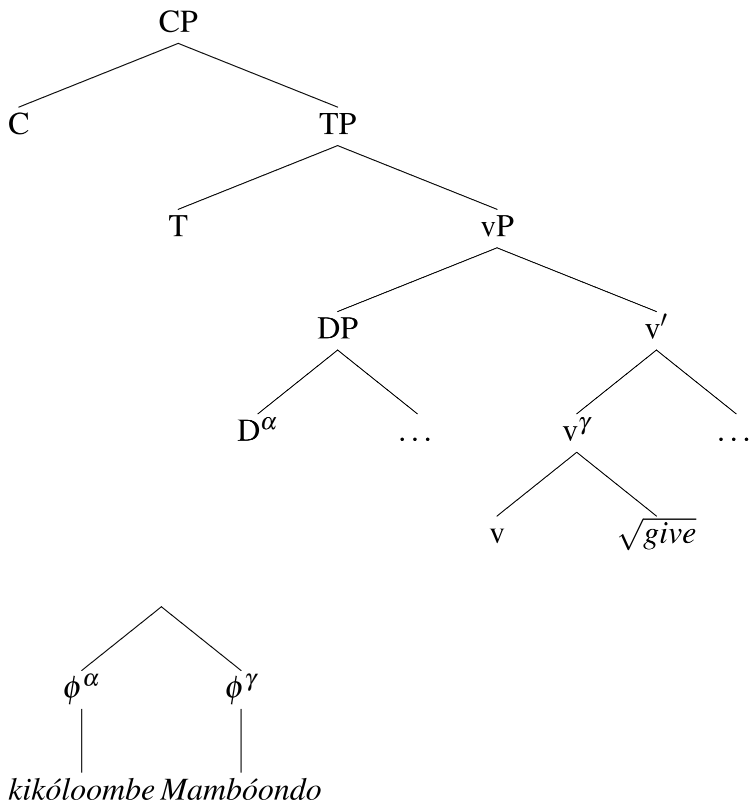
VI and feature stripping apply, removing the complement of *v* from the syntactic representation.

(84)



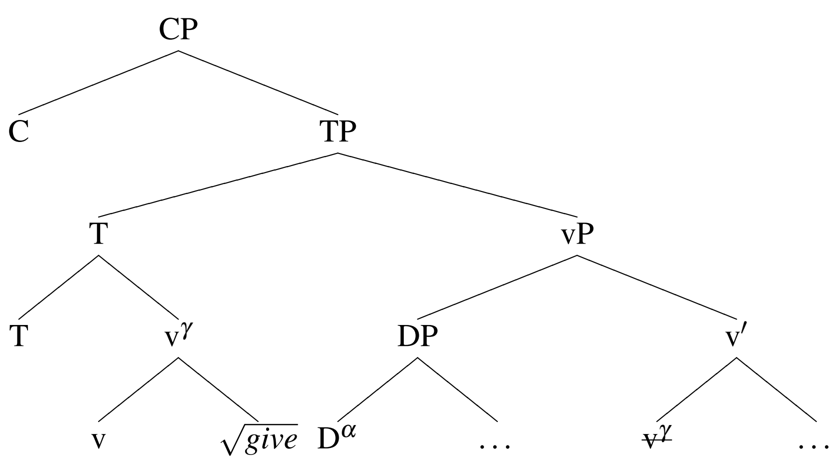
At the beginning of the CP phase, then, we have the following structure:

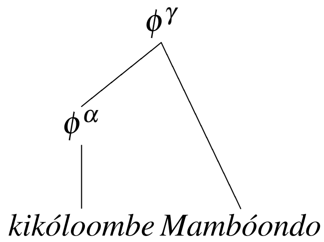
(85)



The verb undergoes incorporation to T and is consequently relinearised: the prosodic structure is also altered to reflect the new linear ordering, with the phonological phrase associated with the verb dominating the phonological phrase associated with the direct object, as in the Irish example above. Again, this is necessary because the ϕ associated with the verb includes, or is associated with, material which precedes the DO as well as material that follows. The only well-linearised structure compatible with this is a structure containing nested ϕ constituents.

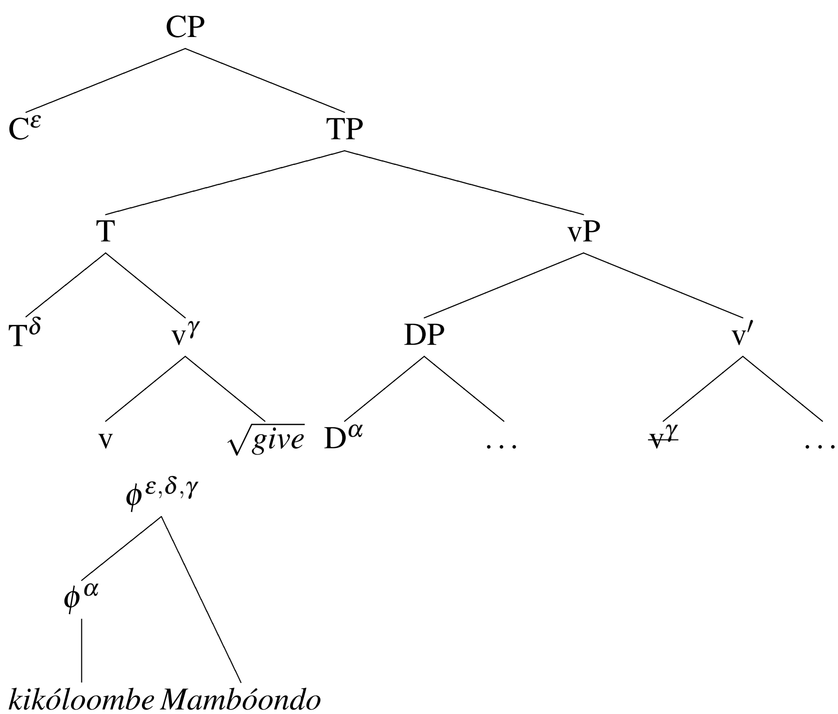
(86)





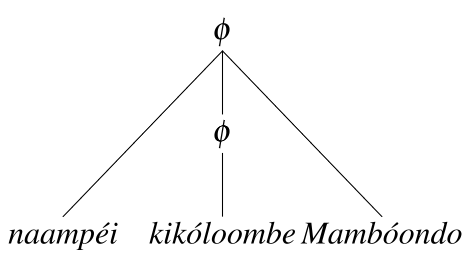
The ϕ associated with the verb is then extended at its visible edge, to include T and C.

(87)



VI and feature stripping apply, inserting exponents of the verbal complex and removing the TP from the syntactic representation. C is eventually spelt out vacuously, giving the prosodic representation below:

(88)



This places *kikóloombe* at the right edge of a phonological phrase, without a following left edge, and consequently correctly predicts the failure of shortening and the absence of

PTI. This is not, however, quite the same as the representation in (78c). In particular, the verb is not included in the lower ϕ constituent. This is problematic because if it is not included it precedes the left edge of a phonological phrase, and we expect PTI, which we do not see. As such we would seem to require a pruning rule which reparses the verb so that it is located in the lower ϕ together with the direct object. This could be motivated by a constraint such as STRONGSTART, which demands that the initial element of a prosodic constituent have a rank at least as high as the following constituent. The repair to this constraint with the least amount of additional structure would simply parse the verb with the object, not adding any additional prosodic constituents.

There is an alternative to this pruning rule – we could adopt a slightly different description of the environment in which PTI applies

(89) *Phrasal Tone Insertion* (alternative)
Insert a phrase-final high tone to the syllable before the right edge of a ϕ, iff a left ϕ edge follows.

Here (unlike the Irish case), the pruning rule allows us to adopt the simpler description, making use of the less involved PTI process in (76b). This means that pruning may be well-motivated in this case, although it is still not clear whether a complication of the prosodic mapping algorithm is indeed preferable to a complication of the phonological derivation.

It is of some interest to compare the model discussed here to Truckenbrodt's model, which makes use of a constraint WRAP-XP, which states that maximal projections of lexical heads (e.g. NP, VP, AP, etc.) must be parsed in a single phonological phrase – this supplements a constraint (ALIGNR) on Alignment of the sort we discussed above with respect to e.g. Chimwiini, such that the right edge of maximal projections of lexical categories must coincide with the right edge of a phonological phrase. For him, the recursive phrasing we see emerges from the interaction between these two constraints. If we assume a structure of the sort $[_{VP}$ V NP_1 $NP_2]$ for ditransitives (as Truckenbrodt does, following Odden), the two constraints can only be satisfied simultaneously if we have two phonological phrases, one containing the whole VP, with a right edge aligned with the right edge of VP and NP_2, and another, nested phrase whose right edge is aligned with NP_1 – that is, the structure in (78c).

The main issue with this approach, at least for those adopting a Minimalist syntactic framework, is that it does not seem to accurately reflect the observed syntactic properties of Kimatuumbi, where the verb appears to occupy quite a high position, outside the initial verb phrase. The approach taken here not only captures this fact, but actually relies on it in order to recover the correct prosodification. In general, a condition along the lines of the LCC, as adopted by Truckenbrodt and implicitly by Selkirk (1986), which singles out *lexical* projections to the exclusion of *functional* projections runs into trouble in Minimalist models adopting the Marantz-Borer conception, where elements which were traditionally considered lexical are now generally considered to be headed by functional items. This is not an issue in the MaP model, where the analogue of the LCC emerges naturally from relatively well-established syntactic assumptions regarding the phasal status of categorisers (and their extended projections).

4 Conclusion

This paper has introduced the MaP model of prosodification, shown that it reproduces some key generalisations concerning the correlation between prosody and syntax, and illustrated its application to a number of different languages of quite different syntactic types, showing that it recovers the results we expect, in some cases more readily than other existing models.

This is, of course, only a starting point: it has not been shown that the model here can account for the full diversity of interactions between prosody and syntax. One particular point of interest might concern languages where the BDC (based on 34) appears not to hold, e.g. head-initial languages where lexical categories appear to define the *left* edge of a prosodic constituent rather than the expected *right* edge.

One such example might be seen in Selkirk and Shen's (1990) analysis of Shanghai Chinese, where functional heads such as prepositions phrase not with a following noun (as in head-initial Chimwiini above), but with *preceding* lexical material. To quickly sketch a possible analysis of languages of this type: it is of some interest to note that Chinese varieties such as Shanghai Chinese are not straightforwardly head-initial – they are almost unique among head-initial languages in ordering a relative clause before its head noun, for example. The correlation between branching direction and prosodification which the model here predicts in fact relates only to the branching direction of *phase heads*. What we require, then, is that phase heads in Sinitic varieties such as Shanghainese are head-final. In fact, Erlewine (2017) independently requires this in order to account for apparent violations of the Final-over-Final Condition (Biberauer, Holmberg and Roberts 2014, Sheehan et al. 2017) in Chinese. Examples like this, then, would seem not to be intractable in the model concerned, and are in fact predicted if Erlewine is correct.

Discussion here has been limited to the distribution of only one prosodic constituent – the phonological phrase constituent ϕ. Even if we adopt a fairly minimal prosodic inventory along the lines of Ito and Mester (2013), we must still account for the distribution of intonational phrase (ι) and phonological word (ω) constituents. Any complete account of the interaction between prosody and syntax must account for these constituents – Perry (2016) explores some possibilities regarding the ω constituent. Describing the distribution of ι in particular must take place in the context of the wider project of investigating how prosodic structures of the type generated by the MaP model interact with *information structure* (cf. Truckenbrodt 1995, Ishihara 2003, Kratzer and Selkirk 2007, 2020, Kahnemuyipour 2009, among many others), which has not been touched upon here.

The treatment of the 'pruning' portion of the model has also been rather cursory – limits on possible pruning rules, or the constraints which motivate them, have not been given. Establishing these limits must be the result of careful empirical work on a wide range of languages. It seems likely that pruning rules, depending as they do on phonological well-formedness, must be motivated on the basis of more general principles of phonological structure.

These and other directions must be explored if the model presented here is to serve as a full theory of the interaction between syntactic and prosodic structure. It is to be hoped, however, that the examples presented here provide enough initial plausibility to the model to motivate further work along these lines.

5 Appendix: Some Formal Issues

For ease of exposition and for reasons of space, some of the principles of the MaP model have not been spelt out in their most precise forms. This appendix constitutes an attempt to rectify certain ambiguities in the presentation above.

The most important point to disambiguate is the functioning of the *linearisation* operation. I assume two sets of statements of linear precedence, one holding between syntactic objects, the other holding between phonological constituents. The syntactic precedence statements are the statements where *chain reduction* applies, implementing relinearisation due to movement. We assume that a relation of *projection* applies to realise these syntactic linearisation statements in the phonological component.

We assume that projection initially applies by mapping immediate precedence in the syntax into immediate precedence in phonology. We define immediate precedence in syntax as follows, where $A >> B$ is read 'A immediately precedes B'. We assume the basic precedence relation in syntax (as opposed to immediate precedence) is derived by a relatively simple algorithm such as Sheehan's (2013) revised LCA:

(90) *Revised LCA* (adapted from Sheehan 2013):

a. If a category A c-selects a category B, then A precedes/follows B.[20]

b. If no order is specified between A and B by the sum of all precedence pairs defined by (a), then A precedes B if A asymmetrically c-commands B.

Other possible algorithms can, of course, be imagined. The requirement is simply is that a relation *precedes* is established among syntactic objects. It is assumed that *chain reduction* applies at this stage in order to ensure that the relation is irreflexive.. The definition of immediate precedence is derived from this relation.

(91) *Immediate Precedence of Syntactic Constituents*
For syntactic objects α, β:
$\alpha >> \beta$ iff α precedes β and there is no syntactic object γ such that α precedes γ and γ precedes β.

[20] Precedence here is parametrised.

This syntactic relation is realised in the phonology through a very simple projection relationship:

(92) *Projection of Immediate Precedence*
If a pair of syntactic elements α, β maps onto pair of phonological sister elements a, b, insert the statement $a >> b$ iff $\alpha >> \beta$.

We make no modification to the notion of mapping introduced in the body of this paper. Now we are in a position to formalise the notion of a constituent edge. Suppose a phonological element x is dominated by a prosodic constituent c. Then we may insert one of a pair of special immediate precedence statements. We assume this follows the establishment of other immediate precedence relations:

(93) *Edge Statements*:

a) If x is dominated by a prosodic constituent c, and there is no constituent y such that c dominates y and $x >> y$, insert a statement $x >> \#_c$.

b) If x is dominated by a prosodic constituent c, and there is no constituent y such that c dominates y and $y >> x$, insert a statement ${}_c\# >> x$.

The statement established by (93a) can be read as *x is aligned with the right edge of c* and the statement established by (93b) can be read *x is aligned with the left edge of c*.

We then suppose that a more general phonological precedence relation $\mathrm{Prec}(a,b)$ among phonological constituents is derived from these immediate precedence statements.

(94) *Phonological precedence relation*:
Insert a phonological precedence statement $\mathrm{Prec}(a,b)$ iff one of the following holds:

a) $a >> b$

b) $\mathrm{Prec}(x,y)$, where x dominates a and y dominates b.

c) $\mathrm{Prec}(a,z)$ and $\mathrm{Prec}(z,b)$

We assume that sets of phonological precedence statements have certain interface-driven wellformedness conditions, failing which the derivation will crash:

(95) *Wellformedness Conditions*:

a) There are no elements a,b,c such that $a >> b$, $a >> c$, $b >> c$ (Immediacy Condition)

b) There are no elements a,b such that $\mathrm{Prec}(a,b)$ and $\mathrm{Prec}(b,a)$ (No-Loop Condition)

c) If a constituent a does not dominate b or vice versa, either $\mathrm{Prec}(a,b)$ or $\mathrm{Prec}(b,a)$ (Completeness condition)

The final issue to clarify concerns the behaviour of operations which alter the mapping between the syntax and phonology. First, we define the operation of *Vocabulary Insertion*:

(96) *Vocabulary Insertion*:
Insert a phonological exponent *e* such that:

a) *e* maps to a syntactic terminal σ contained within a given phase domain.

b) *e* is dominated by the smallest prosodic constituent which either maps to σ or maps to a syntactic constituent containing σ.

We further have an operation of *reprojection* – this ensures that exponents are correctly linearised relative to one another, as well as implementing relinearisation of phonological elements which map to moved syntactic objects.

(97) *Reprojection*:
If there is any change to the mapping or linearisation of syntactic objects (unless triggered by Feature Stripping, below), delete all linearisation statements referring to phonological objects which map to syntactic objects and reapply the projection of precedence relations from the syntax to phonology.

This applies automatically with VI, which adds a new mapping statement referring to the exponent *e* and syntactic object σ.

Finally, we have an operation *Feature Stripping* on the syntactic representation, which we suppose implements phase impenetrability, and which follows VI (and, we can suppose, morphophonological rules).

(98) *Feature Stripping*:
Remove all syntactic objects, as well as associated mapping and syntactic linearisation statements, contained in a given phase domain from the syntactic derivation.

This is all the formal machinery needed to reproduce the claims above, including the constraint on modification in (23). Much of it is necessary in any model which attempts to relate syntactic structure to prosodic structure in a principled way.

Let us show how (23), reproduced here in (99), emerges from this formal machinery.

(99) *Constraint on Modification*
If the edge of a prosodic constituent π is invisible, it must remain invisible throughout the derivation.

Recall that an invisible edge is defined as an edge aligned with phonological material which does not map to a syntactic constituent. Following definitions given above, for a phonological object x to be aligned with an edge of a given constituent c, it must be associated with an immediate precedence statement $x >> \#_c$ or $_c\# >> x$. Note if x is not mapped to a syntactic object, then there is no mechanism provided to eliminate this statement – *Reprojection* cannot apply since it only applies to elements which are mapped to syntactic objects. Let us suppose that we attach a new phonological object y to c at the edge aligned with x. Then $x >> y$ (assuming for concreteness that we are dealing with the right edge – exactly the same holds at the left edge, *mutatis mutandis*). (93) implies that we must insert a statement $y >> \#_c$. But this violates the Immediacy Condition (95a), and so the derivation will crash. If a phonological object not mapped to a syntactic element stands at a constituent edge (i.e. the edge is invisible), it must remain so throughout the derivation – a restatement of (99).

Now let us see how the recursion facts emerge from this model – in this case the key condition is (95c). Suppose we have three syntactic constituents, A, B, C mapping to phonological constituents x, y, z. Suppose at first that $A >> B >> C$ and that y, z are dominated by another constituent c, of the same type as x. Projection of syntactic precedence relations establishes the ordering $x >> y >> z$.[21] Now suppose a movement operation modifies the linearisation of the syntactic constituents so that $B >> A >> C$. Reprojection applies, eliminating the linearisation statements relating to the phonological objects of interest, and establishing the linear order $y >> x >> z$. But y, z are still dominated by c, while x is not. The condition (95c) demands that x either have a precedence relation with c or be dominated by it. If it has a precedence relation with c, then (94b) implies that it will have the same relation with both y and z. But given the projection of immediate precedence from the syntax, this would create a violation of (95b), since (assuming for concreteness that x precedes c) we would have Prec(x, c), and consequently Prec(x, y) and $y >> x$, and consequently Prec(y, x). For (95c) to be satisfied, then, x must be dominated by c. If, as assumed, x is of the same type as c, this creates a recursive structure.

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[21] A combination of (95b, c) and (94b) also ensures that x precedes c, though this is not relevant here. It is worth noting that the modification of this relation below requires that c is mapped to some syntactic material, in order for reprojection to apply.

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