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RESEARCH

Moraic Domains between feet and syllables: An argument from vowel reduction typology

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In this paper, I propose a separate prosodic domain that regulates mora assignment in syllables: the Moraic Domain, a domain between the foot and the syllable in which only the head syllable may be moraic (see also van der Hulst & Moortgat 1980; LeSourd 1993; and Hermans & Torres-Tamarit 2014, among others, for other proposals of metrical domains between the foot and the syllable). I argue that this domain is necessary to account for the combination of two typological generalizations about vowel reduction. The first is the Ambiselectivity Generalization, according to which vowel reduction that decreases sonority (Crosswhite 1999; 2001; de Lacy 2002) may be restricted to foot-internal unstressed syllables, or to unfooted (minimal foot-external) syllables (see Martínez-Paricio 2013 for evidence). The second is the Sonority Requirement Generalization, which is derived from typological facts discovered by Crosswhite (1999; 2001); according to this generalization, a language may have at most one vowel reduction process that forces underlying low vowels to reduce to mid or high vowels.

While accounts for each individual generalization may be derived from existing proposals without a Moraic Domain (Crosswhite 1999; 2001; Martínez-Paricio 2013), I show that no such account can derive both generalizations at once. In contrast, I argue that a Moraic Domain can account for both generalizations when embedded into Crosswhite's (1999; 2001) account. This is demonstrated with a case study of Dutch semi-informal vowel reduction (Kager 1989), which cannot be derived in Crosswhite's (1999; 2001) original approach without Moraic Domains.

Keywords: phonological theory; metrical phonology; vowel reduction; Dutch; phonological representations

1 Introduction

In this paper, I propose a unified account of two typological facts about vowel reduction. First, vowel reduction processes may systematically apply to some unstressed syllables to the exclusion of others, as illustrated by Dutch semi-informal reduction in (1a) and Old English in (1b). Second, if a language has two distinct vowel reduction processes, only one of these processes reduces low vowels to non-low vowels (Crosswhite 1999; 2001), as illustrated by the contrast between Russian in (2a) and a corresponding unattested language type in (2b).

(1) *Reduction in select unstressed syllables only*

a. Dutch semi-informal reduction (Kager 1989; Booij 1995)
/fonoloɣi/ → (ˌfo.nə)lo(ˈɣi)
(unstressed, unfooted syllable [lo] remains unreduced)

b. *Old English high vowel deletion (Dresher & Lahiri 1991)*
/heafudes/ → (ˈhea)fu(ˈdes) → heafdes
(high vowel deleted in unfooted syllable)
/werudu/ → (ˈwe.ru)du → werud
(high vowel retained footed syllable)

(2) *At most one sonority-reducing vowel reduction process in one language*

a. *Attested: Russian (two reduction processes, only one of them raising low vowels; cf. Crosswhite 2001: 52, ex. (38))*

Stressed: no reduction[1]

/kam(e)n^j/ →	(ˈka)m^j**i**n^j
Immediately pre-tonic:	/e/ → [i], /a/ → [a]
/kam(e)n^j-ej/ →	(k**a**m.ˈn^{j}ej)
All other unstressed syllables:	/e/ → [i], /a/ → [ə]
/kam(e)n^j-ist-oj/ →	k**ə**(m^j**i**.ˈn^{j}is)təj
/za-kal^{j}i-l-a/ →	z**ə**(k**a**.ˈl^{j}i)l**ə**

The immediately pre-tonic reduction process does not turn /a/ into a non-low vowel. The other reduction process turns /a/ into [ə], a non-low vowel.

b. *Unattested: Pseudo-Russian (two reduction processes, both raising low vowels)*

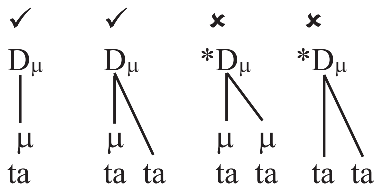
Stressed: no reduction

/kam(e)n^j/ →	(ˈka)m**ɨ**n^j
Immediately pre-tonic:	/e/ → [i], /a/ → [ə]
/kam(e)n^j-ej/ →	(k**ə**m.ˈn^{j}ej)
All other unstressed syllables:	/e/ → [ɨ], /a/ → [ɨ]
/kam(e)n^j-ist-oj/ →	k**ɨ**(m^j**i**.ˈn^{j}is)t**ɨ**j
/za-kal^{j}i-l-a/ →	z**ɨ**(k**ə**.ˈl^{j}i)l**ɨ**

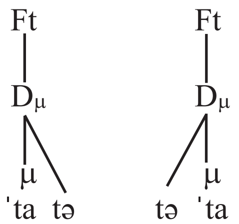
The immediately pre-tonic reduction process turns /a/ into [ə], a non-low vowel. The other reduction process turns /a/ into [ɨ], a non-low vowel.

To create an account of both typological facts, I propose the Moraic Domain, a level of metrical structure between the foot and the syllable that parses one moraic syllable as its head, and a non-moraic syllable as its dependent, as shown in (3a). This Moraic Domain account is based on Crosswhite's (1999; 2001) account of vowel reduction. However, as demonstrated in Section 3.3, the latter approach does not permit a satisfying account for languages like Dutch[2] unless Moraic Domains are assumed, which allow for the motivation of foot-internal non-moraic syllables, as in (3b).

(3) a. *Illustration of Moraic Domains*



b. *Foot-internal non-moraic syllable with D_μ*



[1] The (e) in parentheses signifies a yer (see Gouskova 2012 and references therein), which is an underlying mid vowel that surfaces in some environments only.

[2] Crosswhite does provide a partial account for Dutch, just for the case when all unstressed vowels become schwa (see Section 4.1). However, she does not account for the full range of facts, which will be discussed in Section 4.1.

An account for the typological facts in (1) had previously been proposed by Martínez-Paricio (2013). However, as I will show in Section 3.5, this approach cannot capture the typological facts in (2): there is nothing that prevents the occurrence of languages like (2b).

However, because a Moraic Domains account maintains a difference between moraic and non-moraic unstressed nuclei, such an account can use the mechanisms built into Crosswhite's framework to eliminate languages that have two separate sonority-reducing vowel reduction processes, like Pseudo-Russian – see (2b) at the beginning of this introduction. The mechanism that excludes such languages will be shown in Section 5.2.

The rest of this paper is structured as follows. Section 2 will review the typological facts. Section 3 will then present the novel proposal of Moraic Domains to the background of Crosswhite's (2001) account, in which it is rooted. After this, section 4 will present, as a case study, a Moraic Domains analysis of Dutch vowel reduction, which makes this type of reduction consistent with a Crosswhite-style account. Section 5 will then show how Moraic Domains allow us to account for the rest of the typological facts laid out in this paper. It will also show how an approach with recursive footing but no Moraic Domains (Martínez-Paricio 2013) does not derive the same facts. Finally, Section 6 will offer some concluding remarks.

2 Typology of vowel reduction processes

Crosswhite (1999; 2001) introduced a distinction between sonority-reducing and contrast-enhancing vowel reduction processes, which will be defined below. This paper focuses on two typological properties of the former type of reduction: sonority-reducing reduction. First, as I will show in Section 2.1, such reduction processes may be restricted either to foot-internal position, or to foot-external position. Second, as I will show in Section 2.2, a language may only have one sonority-reducing vowel reduction process (even when it does have additional vowel reduction processes of the other kind).

Sonority-reducing reduction, under Crosswhite's (1999; 2001) classification, only involves mappings that lower the sonority of a vowel. In this paper, I will define a vowel's sonority along the scale [low vowels > mid (non-schwa-like) vowels > high vowels > schwa-like vowels] (see de Lacy 2002). This means that a sonority-reducing process may not map an underlying mid vowel to a surface low vowel, or an underlying high vowel to a surface low or mid vowel, as illustrated in (4).

(4) a. *well-formed sonority-reducing vowel reduction process (Standard Bulgarian, Crosswhite 1999; 2001)*
/i,u/ → [i,u]
/e,o/ → [i,u] (mid vowels become high vowels – reduction in sonority)
/a/ → [ə] (low vowel becomes schwa – reduction in sonority)

b. *ill-formed sonority-reduction vowel reduction process*
/i,u/ → [e,o] (high vowels become mid vowels – **increase** in sonority)
/e,o/ → [e,o]
/a/ → [ə] (same as in a.)

In their studies of sonority-reducing vowel reduction, de Lacy (2002) and Martínez-Paricio (2013), among others, have shown that such processes may apply to all unstressed vowels, or to certain unstressed prosodic positions in the word only (I will call this "selective reduction"). In Dutch (see Section 4.1), both options are possible:

(5) /fonoloɣi/ → (ˌfo.nə)lo(ˈɣi) ~ (ˌfo.nə)lə(ˈɣi)

Existing work, to be reviewed in Section 2.1, has found that sonority-reducing reduction is conditioned by foot structure. Three possible options are attested, as indicated in (6). The fact that all three possibilities are possible will be called the "Ambiselectivity Generalization".

(6) *The three cross-linguistically possible contexts for application of sonority-reducing reduction processes (following Martínez-Paricio 2013 and Crosswhite 2001)*
 i. Process applies in all unstressed syllables ((ˈσ **σ**) **σ**)
 ii. Process applies in footed* unstressed syllables only ((ˈσ **σ**) σ)
 iii. Process applies in unfooted* syllables only ((ˈσ σ) **σ**)
 *(if footing is recursive, e.g., Martínez-Paricio 2013, a "footed" syllable can be defined as "part of a minimal foot")

Contrast-enhancing reduction differs from such processes in considering low vowels as desirable end points of reduction (since low vowels provide maximal contrast with high vowels), while sonority-reducing processes consider these to be the most undesirable end points of reduction (because of low vowels' high degree of sonority). Mid vowels may reduce to low vowels by contrast-enhancing reduction, while low vowels remain unaffected by contrast-enhancing reduction. For this reason, I will focus specifically on low vowels: if a low vowel reduces to a non-low vowel, this must be the effect of sonority-reducing reduction.

As will be reviewed in Section 3.1, Crosswhite (1999; 2001) observes that a language has at most one sonority-reducing reduction process. If a language has different vowel reduction processes in different positions, only one of these is a sonority-reducing reduction process, and the other must be a contrast-enhancing process. Since the difference between the two types of reduction processes lies in the treatment of low vowels, I will call this generalization the "Sonority Requirement Generalization".

2.1 Contexts for sonority-reducing vowel reduction (Ambiselectivity Generalization)

Selective vowel reduction (i.e., application of reduction processes to some, but not all unstressed vowels) has not been studied extensively from a typological perspective, but the literature does provide existence proofs of at least two types: reduction inside a (minimal) foot, and reduction outside a (minimal) foot.[3] I will only consider sonority-reducing reduction processes here.

The first type (reduction inside a (minimal) foot) is exemplified by Dutch "semi-informal" reduction (Booij 1995), in which directly post-tonic syllables reduce their vowels to schwa, to the exclusion of all other unstressed syllables, as illustrated in (7). Works like van der Hulst (1984); Kager (1989); Gussenhoven (1993); and Booij (1995) provide evidence that the foot in Dutch is left-headed (trochaic), and not right-headed (iambic). If this evidence is accepted, then "semi-informal" reduction applies only in unstressed syllables inside a (minimal) foot.

(7) *Semi-informal reduction of /o/ in Dutch (cf. Booij 1995)*
 /tomat/ → to(ˈmat)
 /filosof/ → (ˌfi.lə)(ˈsof)
 /fonoloɣi/ → (ˌfo.nə)lo(ˈɣi)

[3] The provision, "minimal foot", is given to include analyses that assume recursive footing (Kager & Martínez-Paricio 2012; Martínez-Paricio 2013; Bennett 2013, and work cited therein; see also Section 3.5). In other frameworks, all feet are minimal feet.

The second type (reduction outside a (minimal) foot only) is exemplified by Russian, and, according to Martínez-Paricio (2013), Old English. In Russian, sonority-reducing reduction (/o,a/ go to schwa, /e/ goes to [i], /i,u/ remain faithful) applies in all unstressed syllables except the directly pre-tonic syllable (in which contrast-enhancing reduction applies). The special status of the pre-tonic syllable has been taken by Suzuki (1998) and Crosswhite (1999; 2001) as evidence for an iambic foot. Since there is no other evidence for feet in Russian (stress placement is driven by morpho-lexical factors, see Zaliznjak 1977, Revithiadou 1999), I will adopt the iambic foot for Russian after these sources.

(8) *Directly pre-tonic vs. other reduction in Russian; see (2a) in Section 1*

/kam(e)n^j/ → (ˈka)m^{j}in^j	‘rock (nom.)’
/kam(e)n^j-ej/ → (kam.ˈn^{j}ej)	‘rocks (gen.)’
/kam(e)n^j-ist-oj/ → kə(m^{j}i.ˈn^{j}is)təj	‘rocky’
/za-kal^{j}i-l-a/ → zə(ka.ˈl^{j}i)lə	‘(she) hardened, steeled’

In Old English (Dresher & Lahiri 1991), high vowels reduce to zero in syllables that are not stressed and do not directly follow another stressed syllable, as in (9) (although see Hogg 2000 for more nuanced conditions on vowel deletion, including closed vs. open syllable status). Since there is evidence for trochaic feet (Dresher & Lahiri 1991), this means that reduction takes place in unfooted syllables only. The trochaic foot hypothesis is strengthened by Fulk’s (2001) observation that fricative voicing fails to apply in the same set of environments, suggesting that both high vowel deletion and fricative voicing are sensitive to (minimal) foot boundaries: high vowel deletion occurs only outside of (minimal) feet, while fricative voicing only occurs inside (minimal) feet. The examples of high vowel deletion in (9) are taken from Martínez-Paricio (2013), who cites Dresher & Lahiri (1991).

(9) *(based on Martínez-Paricio 2013:238 (26); non-minimal feet omitted)*

a.	/werudu/ → (ˈwe.ru)du → werud (high vowel deleted in unfooted syllable only)	‘troops’
b.	/niitenu/ → (ˈnii)te(ˈnu) → niitenu ([e] not deleted because it is not a high vowel)	‘animals’
c.	/heafudes/ → (ˈhea)fu(ˈdes) → heafdes (high vowel deleted in unfooted syllable)	‘head, GEN. SG.’
d.	/singende/ → (ˈsin)(ˈgen)de → singende (no unstressed high vowels)	‘sing, PRES. PART.’

Crosswhite (1999; 2001) identifies some patterns of selective reduction that, at first sight, appear to be counterexamples to these two types. For instance, in some dialects of Brazilian Portuguese, sonority-reducing reduction only applies in the first and last syllables of a word. In Lucanian Italian (Maiden 1995), sonority-reducing reduction only applies after the (main and only) stress of a word (pretonic syllables undergo contrast-enhancing reduction). However, Crosswhite interprets these patterns as sonority-reducing reduction in unfooted syllables, assuming a somewhat unorthodox footing schema for each language: for Brazilian Portuguese, feet that parse all but the first and last syllable of the word, as illustrated in (10a), and for Lucanian Italian, a foot that encompasses the stressed syllable and everything before it, as in (10b). In these illustrations, non-moraic (potentially reducing) syllables are indicated as σ, whereas moraic (non-reducing) ones are indicated as σ_μ.

(10) a. Brazilian Portuguese: # σ ($_{\text{ˌ}}$σ$_{\mu}$ σ$_{\mu}$) … (ˈσ$_{\mu}$ σ$_{\mu}$) σ #
b. Lucanian Italian: # (σ$_{\mu}$ σ$_{\mu}$ … ˈσ$_{\mu}$) σ σ #

I will not advance any specific alternative hypothesis with regard to footing in such languages, choosing instead to follow Crosswhite's analysis for lack of a better alternative. Setting these cases aside, however, the other languages discussed in this subsection provide evidence for the existence of selective reduction in unstressed syllables within a minimal foot (as in (7)), as well as in those outside a minimal foot (as in (8)). In addition, when reduction is non-selective, all unstressed syllables (both within and outside a (minimal) foot) are reduced alike. Thus, we have the cross-linguistic generalization in (11):

(11) *Ambiselectivity Generalization*
A sonority-reducing reduction process may select as its environment of application: unstressed syllables within a (minimal) foot, syllables outside a (minimal) foot, or both.

The Ambiselectivity Generalization, in other words, states that languages may choose whether it is a foot-internal or a foot-external unstressed syllable that is the weakest type of syllable, or whether these two types of syllable are equally weak. Therefore, it is not possible to predict the relative weakness of syllables from a universally determined foot structure alone: there must be some other factor. Hypotheses as to what this other factor is will be discussed in Sections 3.1, 3.3, and 3.5. However, before this, I will introduce the other empirical generalization crucial for this paper: the Sonority Requirement Generalization.

2.2 At most one sonority-reducing process (Sonority Requirement Generalization)

In her sample of 32 languages, Crosswhite (1999; 2001) finds 15 languages with more than one distinct vowel reduction process: all unstressed syllables undergo reduction, but the type of reduction depends on the type of unstressed position. For example, in Standard Russian, all unstressed vowels undergo reduction, but /o,a/ are realized as [a] directly before stress, but as [ə] in all other unstressed positions (as in (12a)). In Neapolitan Italian (Bafile 1995), as in Russian, all unstressed positions undergo reduction of some sort, but /a/ is only (optionally) reduced to [ə] post-tonically except at the end of a Phonological Phrase, and not in any other unstressed positions (as in (12b)).[4]

(12) *Examples of multiple reduction processes*
a. *Russian, see (8) in Section 2.1*
/kam(e)nʲ/ → ˈkamʲinʲ
/kam(e)nʲ-ej/ → k**a**mˈnʲej
/kam(e)nʲ-ist-oj/ → k**ə**mʲiˈnʲistəj
/za-kalʲi-l-a/ → z**ə**(k**a**.ˈlʲi)l**ə**

Immediately pre-tonic	Default/elsewhere
/i,u/ → [i,u] /e/ → [i] /o/ → [a] /a/ → [a]	/i,u/ → [i,u] /e/ → [i] /o/ → [ə] /a/ → [ə]

[4] This pattern is presented here in a somewhat simplified form. See Bafile (1997) for more details. Standard Italian vowels are used in the underlying form.

b. *Neapolitan Italian (Bafile 1997: 129–131)*
/… kel:a/ → (…ˈkel:**a**)$_{PP}$ ~ (…ˈkel:**ə**)$_{PP}$ ‘this (f.) …’
/kel:a …/ → (ˈkel:**a** …)$_{PP}$ ‘this (f.) …’
/kwat:oʃjento/ → kw**a**t:uˈʃjentə ‘four hundred’
/man:olel:a/ → m**a**n:uˈlel:**a** (~ m**a**n:uˈlel:**ə**)[5] ‘little almond’

Pre-tonic & post-tonic non-PP-final	Post-tonic & PP-final
/i,u/ → [i,u] /e/ → [i~ə] /o/→ [u] /e/ → [i~ə] /ɔ/ → [u] /a/ → [ə]	/i,u/ → [i,u] /e/ → [i~ə] /o/→ [u] /e/ → [i~ə] /ɔ/ → [u] /a/ → [a]

The crucial observation that Crosswhite makes is that at most one vowel reduction process is a sonority-reducing process. As explained at the beginning of Section 2, sonority-reducing vowel reduction processes differ from Crosswhite’s contrast-enhancing vowel reduction processes in their treatment of low vowels. Sonority-reducing reduction may reduce low vowels to non-low vowels (since they have highest sonority), while contrast-enhancing reduction never reduces low vowels by turning them into non-low vowels. In other words, Crosswhite’s contrast-enhancing reduction processes do not place sonority requirements on reduced vowels, whereas sonority-reducing reduction processes do.

Crosswhite’s definition of contrast-enhancing reduction does allow for reduction of non-low vowels to either [ɨ] or [ə]. Therefore, if a mid vowel reduces to [ɨ] in one position, and to [ə] in another, this could mean that reducing to [ɨ] is a sonority-reducing process and reducing to [ə] is a contrast-enhancing process or *vice versa*.

For these reasons, if we want to restate the generalization above in terms of the phenomena that may (not) occur, we can say that there is at most one process that places a sonority requirement on the reduced vowels:

(13) *Sonority Requirement Generalization*
If a language has different vowel reduction processes by prosodic position, then there is at most one such process that puts a sonority requirement on reduced vowels. (At most one process reduces low vowels to non-low vowels.)[6]

Crosswhite establishes her generalization based on 9 patterns in the 15 languages in her survey that have more than one reduction pattern. Even though Crosswhite’s typological sample is small and not designed to be genetically or areally balanced, the Sonority Requirement Generalization that arises from it is robust. There is not much literature specifically on languages with more than one reduction process, but my search of papers that mentioned distinct vowel reduction processes (e.g., Zuraw 2003; Harris 2004; Sen 2012; Delucchi 2013; Kenstowicz & Sandalo 2016; Nadeu 2016; Huang 2018) and Mielke’s (2008) P-base did not produce any counterexamples.

The latter is remarkable, since counterexamples to the Sonority Requirement Generalization are easy to construct. For instance, Standard Russian can be minimally modified to be such a counterexample, as had already been shown in (2b) in Section 1. In the Pseudo-Russian that arises, /a/ goes to [ə] in some unstressed syllables, and to [ɨ] in others. There are sonority requirements on the reduced vowels in both processes

[5] The second variant with reduction of word-final /a/ was inferred based on the statement regarding phrase-final /a/-reduction in Bafile (1997: 131).
[6] I would like to thank an anonymous reviewer for suggesting this name and formulation of the generalization.

(pre-tonic: at most a high full vowel; elsewhere: at most [ɨ]), which means that this system violates the Sonority Requirement Generalization.

(14) *Russian, modified to violate the Sonority Requirement Generalization; see also (2b) in Section 1*

Stressed: no reduction
/kam(e)nʲ/ → (ˈka)mɨnʲ
Immediately pretonic: /a/ → [ə]
/kam(e)nʲ-ej/ → (kəm.ˈnʲej)
All other unstressed syllables: /V/ → [ɨ]
/kam(e)nʲ-ist-oj/ → kɨ(mi.ˈnʲis)tɨj
/za-kalʲi-l-a/ → zɨ(kə.ˈlʲi)lɨ

Immediately pre-tonic	Default/elsewhere
/i,u/ → [i,u] /e/ → [i] /o/ → [ə] /a/ → [ə]	/i,u/ → [ɨ] /e/ → [ɨ] /o/ → [ɨ] /a/ → [ɨ]

Another imaginable counterexample is a counterpart to Neapolitan Italian (see (12b) in section 2.2), in which all phrase-final unstressed vowels (not just the non-low vowels) reduce to [ə]. Here, there are two types of reduction, but both types change low vowels to schwa. This violates the Sonority Requirement Generalization: the left column in (15) requires sonority to be at most that of a high full vowel, while the right column requires that sonority be at most that of [ə].

(15) *Neapolitan Italian, modified to violate the Sonority Requirement Generalization*

/… kel:a/ → (…ˈkel:ə)$_{PP}$
/kel:a …/ → (ˈkel:ə …)$_{PP}$
/kwat:oʃjentə/ → kwət:uˈʃjentə
/man:olel:a/ → mən:uˈlel:ə

Pre-tonic & post-tonic non-PP-final	Post-tonic & PP-final
/i,u/ → [i,u] /e/ → [i~ə] /o/→ [u] /ɛ/ → [i~ə] /ɔ/ → [u] /a/ → [ə]	/i,u/ → [ə] /e,o/ → [ə] /ɛ, ɔ/ → [ə] /a/ → [ə]

One important remark about this Pseudo-Neapolitan Italian case is that it violates the Sonority Requirement Generalization without low vowels' showing different behavior between the two types of positions. Both processes in (15) reduce /a/ to [ə], but they do have different outcomes for non-low vowels in the different positions. Thus, the violation of the Sonority Requirement Generalization comes from the fact that two distinct processes both reduce /a/ to a non-low vowel.

This precludes a representational explanation of the Sonority Requirement Generalization (e.g., stipulating a representation of low vowels that would prevent them from reducing to anything but low vowels). A representational solution could restrict low vowels to reducing to [ə] instead of [ɨ], thus prohibiting /a/ from reducing in two different ways. However, such a solution will not prevent /a/ from participating in two distinct vowel reduction processes.[7]

[7] Many thanks to an anonymous reviewer for raising this point.

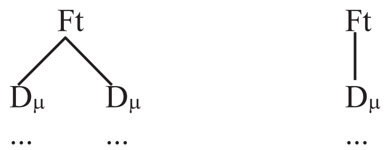
To conclude, while future research might yield a revised typological picture, current evidence supports the Sonority Requirement Generalization as cross-linguistically real, and, pending a learning or historical explanation, this generalization must be explained in the grammar. In Section 3, I will propose the first theoretical account that predicts both the Ambiselectivity Generalization and the Sonority Requirement Generalization.

3 Proposal: Moraic Domains

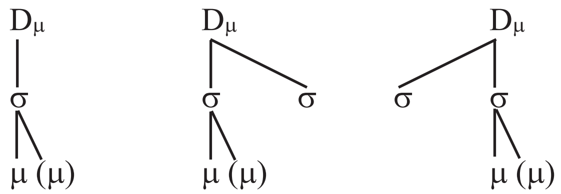
In this paper, I propose to account for both generalizations described in Section 2 by introducing a novel prosodic level, the Moraic Domain (D_μ), that is smaller than the foot but larger than the syllable. Moraic Domain do not directly dominate the level of the mora. Instead, they regulate which syllables have morae, and which do not: moraic (stressable) syllables are Moraic Domain heads, while non-moraic syllables are never Moraic Domain heads, but may be included as a non-head constituent in a Moraic Domain.

(16) *Properties of Moraic Domains*

a. *Directly dominated by the foot*

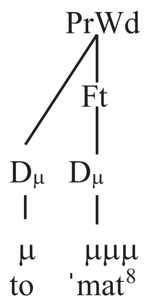


b. *Moraic syllables as heads, non-moraic syllables as optional non-head constituents*



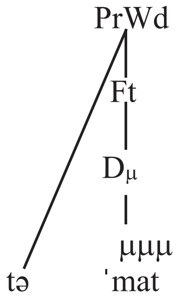
The consequences of the properties in (16) for parsing are illustrated in (17), based on two words from Dutch: 'tomato' (unreduced in (17a), reduced in (17b)) and 'philosopher' (unreduced in (17c), reduced in (17d)). These examples will be repeated in (30) in Section 4. The representations in (17) are based on the assumption that Dutch schwa is non-moraic (see Van Oostendorp 1995; 2000). In the reduced examples – (17bd) – unstressed syllables and reduced syllables coincide, and therefore Moraic Domains and feet coincide, as well. However, in the unreduced examples – (17ac) – there are unstressed full vowels, which are heads of Moraic Domains but dependents of feet.

(17) a.

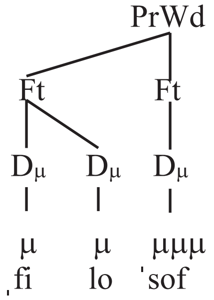


[8] See Kager (1989) on the superheaviness and, hence, trimoraicity of closed syllables with tense vowels in Dutch.

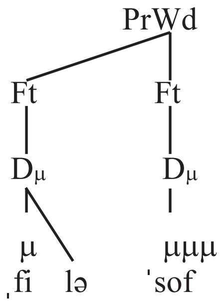
b.



c.



d.



In the remainder of this paper, I will indicate foot boundaries with parentheses ( ), while Moraic Domain boundaries will be indicated with angled brackets < >. Thus, the parses in (17) can be rendered as <to>(<ˈmat>), tə(<ˈmat>), (<ˌfi.lo>)(<ˈsof>), and (<ˌfi.lə>)(<ˈsof>), respectively.

The current account is intended as an extension of Crosswhite's (1999; 2001) account of vowel reduction, and Section 3.1 will provide the necessary background on Crosswhite's account, before my own proposal is explained in Section 3.2.

3.1 Background on Crosswhite's approach

3.1.1 Reduction in non-moraic syllables

Crosswhite (1999; 2001) hypothesizes that, when only a subset of unstressed syllables undergoes sonority-reducing vowel reduction, those syllables that do undergo this type of reduction are non-moraic. This is formalized by a series of sonority-minimizing constraints on non-moraic syllables (*NONMORAIC/X), as exemplified in (18):

(18) a. *NONMORAIC/X: One violation mark for every X vowel that is non-moraic.
b. *NONMORAIC/NON-HIGH: One violation mark for every non-high non-moraic vowel.
c. *NONMORAIC/FULL VOWEL: One violation mark for every non-moraic non-schwa.[9]

[9] This specific constraint is not proposed by Crosswhite, but I have added it based on de Lacy's work, specifically, his reduction constraint series, as laid out in Section 3.5.1.

I will depart from Crosswhite's original proposal in two ways. First, I will hypothesize that, even when all unstressed syllables undergo the same reduction process, sonority-reducing vowel reduction may only apply in non-moraic syllables;[10] I will still assume with Crosswhite that vowel reduction applies equally in all non-moraic syllables. Second, as laid out at the beginning of Section 2, I will follow de Lacy (2002) in classifying reduction to schwa as sonority-reducing reduction, with schwa having a lower sonority than all full vowels (including high vowels); this alternative is also represented in (18), and will be followed in my own adaptation of Crosswhite's proposal.

Table 1 below shows how Crosswhite derives (actual) Russian vowel reduction (as opposed to the Pseudo-Russian explored in Section 2.2) from the interaction of *NONMORAIC/NON-HIGH (non-moraic full vowels must be high) with Faithfulness; MAX(FEATURE) is used here, in accordance with Crosswhite's analysis. It is assumed for now that syllables are moraic unless they are outside a (minimal) foot, and constraints on contrast-enhancing reduction are omitted. Crosswhite's account of mora-to-syllable assignment will be discussed in Section 3.1.2.

The tableau in Table 1 gives several possibilities of reducing moraic and non-moraic /a/: no reduction, reduction to schwa, or reduction to [ɨ]. All candidates with a non-moraic full vowel that is mid or low – like candidate a. – are ruled out by top-ranked *NONMORAIC/NON-HIGH. The remaining candidates all have schwa or a high vowel in non-moraic positions, like candidates b.-d. Of, these, the candidates with moraic low vowel reduction to schwa, as in candidate c., are ruled out because of their excessive violation of MAX([+LOW]). Reduction of non-moraic /a/ to a high vowel rather than schwa is ruled out by excessive Faithfulness violations compared to candidate b., leaving b. itself as the winner.

3.1.2 Location of non-moraic syllables

Crosswhite proposes that non-moraic syllables may occur outside of a foot, but that not all foot-external syllables must be non-moraic. To model this, she assumes the interaction between two constraints: "some … constraint … requir[ing] footed syllables to be moraic" (Crosswhite 1999: 145), and a constraint *STRUC-μ that disprefers morae across the board.

Table 1: Selective reduction outside the foot according to Crosswhite (1999; 2001).

/za-kalʲi-l-a/	*NONMORAIC/ NON-HIGH	MAX ([+LOW])	MAX ([–HIGH])
a. μ μ z**a**(k**a**.ˈli)l**a**	*!*		
☞ b. μ μ zə(k**a**.ˈli)lə		**	
c. μ μ zə(kə.ˈli)lə		***!	
d. μ μ z**ɨ**(k**a**.ˈli)l**ɨ**		**	*!*

[10] Because Crosswhite does not have a mechanism for making all unstressed syllables non-moraic, her account provides for the possibility of sonority-reducing reduction taking place in unstressed moraic syllables. She posits a series of constraints that motivates sonority-reducing reduction in non-moraic syllables (*NONMORAIC/X), and a separate series that motivates the same type of reduction in unstressed syllables (*UNSTRESSED/X). Since I do propose a mechanism to make all unstressed syllables non-moraic, I hypothesize that it is always non-moraic syllables that undergo sonority-reducing reduction, and the *UNSTRESSED/X series is unnecessary.

To instantiate Crosswhite's unspecified constraint in favor of moraic syllables in a foot, I will follow Van Oostendorp (1995; 2000) in adopting a family of PROJECT constraints, which enforce the co-occurrence of particular pieces of segmental and autosegmental/metrical material. This family will plausibly include constraints like the ones in (19), of which (19b) plays the role of Crosswhite's unspecified constraint:

(19) a. PROJECT(V,μ): Assign one violation mark for each vowel that has no mora.
b. PROJECT(V,μ)/FT: Assign one violation mark for each vowel in a foot that has no mora.

The constraint *STRUC-μ may be defined as in (20).

(20) *STRUC-μ: Assign one violation mark for every mora.

Together, these constraints can motivate the absence of morae foot-externally but cannot motivate the absence of morae in unstressed syllables within a foot only, as illustrated in Table 2. Candidates c. and d. in this tableau, which have non-moraic unstressed foot-internal syllables, are collectively harmonically bounded by candidate a. (which has no violations of the PROJECT constraints), and candidate e. (which has no violation of *STRUC-μ).

Whereas this setup does motivate sonority-reducing reduction outside of the foot, it alone cannot account for the Ambiselectivity Generalization: if sonority-reducing reduction takes place in non-moraic syllables, and foot-internal syllables must be moraic, then sonority-reducing reduction in foot-internal unstressed syllables is not possible. Throughout the rest of Section 3, I will argue that, in order to account for the Ambiselectivity Generalization, Moraic Domains are necessary to motivate sonority-reducing reduction foot-internally.

3.2 Motivating reduction within feet: Stress-to-Weight for Moraic Domains

Since Crosswhite's original proposal does not admit the possibility of foot-internal non-moraic syllables, some addition to this original proposal is needed. In this subsection, I will introduce the current proposal in terms of Moraic Domains, while Sections 3.3 and 3.5 will discuss alternative proposals without Moraic Domains, and why these are insufficient.

Non-moraic unstressed syllables in a binary foot can be achieved by building a single, binary Moraic Domain in that foot rather than two separate, unary Moraic Domains: (<kəˈli$_{\mu}$>) vs. (<ka$_{\mu}$><ˈli$_{\mu}$>); (<ˈta$_{\mu}$.kə>) vs. (<ˈta$_{\mu}$><ka$_{\mu}$>).

Table 2: Motivating the absence of morae in foot-internal unstressed syllables.

/za-kalʲi-l-a/	PROJECT(V,μ)	PROJECT(V,μ)/FT	*STRUC-μ
a. μ μ μ μ z**a**(k**a**.ˈli)l**a**			****
b. μ μ z**ə**(k**a**.ˈli)l**ə**	**		**
☞ c. μ μ μ z**a**(k**ə**.ˈli)l**a**	*	*	***
☞ d. μ z**ə**(k**ə**.ˈli)l**ə**	***	*	*
e. z**ə**(k**ə**.ˈli)l**ə**	****	*	

A binary Moraic Domain within a foot can be motivated by a version of the Stress-to-Weight Principle (SWP – see Prince 1990; Gouskova 2003: 90, and references found there). Specifically, this is a Stress-to-Weight principle for Moraic Domains, as in (21). The connection between the SWP for syllables and the SWP for Moraic Domains is that, when the head of the domain (the nucleus of the syllable and the head syllable of the D_μ, respectively) contains a stressed element, the domain must branch (into several morae and into several syllables, respectively).

(21) SWP(D_μ): One violation mark for every stressed syllable that is contained in a monosyllabic Moraic Domain (i.e., for every “stressed” monosyllabic Moraic Domain).

SWP(D_μ) would prefer (<ˌfi$_\mu$.lə>)(<ˈsof$_{\mu\mu\mu}$>) over (<ˌfi$_\mu$><lo$_\mu$>)(<ˈsof$_{\mu\mu\mu}$>), since the former has the stressed syllable [ˌfi$_\mu$] in a disyllabic Moraic Domain, while the latter has it in a monosyllabic Moraic Domain. Because of the disyllabic Moraic Domain in (<ˌfi$_\mu$.lə>)(<ˈsof$_{\mu\mu\mu}$>), the vowel of the second syllable, /o/, becomes non-moraic. This non-moraic syllable may be subject to various degrees of sonority-reducing reduction through the activity of Crosswhite’s *NONMORAIC/X constraints (see Section 3.1.1).

SWP(D_μ) can be seen as a type of binarity condition, which likens Moraic Domains to feet (cf. the widespread tendency towards foot binarity). However, the tendency towards binarity exhibited by feet is also observed at other levels of the prosodic hierarchy (Nespor & Vogel 1986). For instance, Selkirk (2011) summarizes arguments from different languages in favor of binarity constraints on Phonological Phrases. In addition, the tendency for syllables to have onsets could be seen as a binarity tendency for syllables (assuming Onset/Rhyme theory, see Davis 1988 and work cited there): if a syllable has no Onset, it only contains a Rhyme, whereas a syllable with an onset contains two members: an Onset and a Rhyme.

Normally, SWP is used (Gouskova 2003: 89-90) to motivate stress lengthening effects: in certain languages, such as Hixkaryana (Hayes 1995) or Ilokano (Hayes & Abad 1989), underlying short vowels are lengthened or are followed with an epenthetic coda when they are in stressed position, thus expanding a non-branching syllable rhyme into a branching syllable rhyme. In this case, SWP is invoked to motivate the expansion of a non-branching Moraic Domain into a branching Moraic Domain, although, in the cases examined here, this is not accomplished by adding extra segmental material, but by altering the D_μ parsing of existing syllables.

As pointed out by an anonymous reviewer, SWP(D_μ) might hypothetically be satisfied by the insertion of additional syllables. For instance, in a trochaic foot language that prohibits reducing underlying vowels but still has a high ranking for SWP(D_μ), /takata/ may be expected to surface as (<ˌta.ʔə>)(<ˌka.ʔə>)(<ˈta.ʔə>), as illustrated in Table 3.

This problem is not unique to Moraic Domains: it also arises for the domain of feet, as pointed out by Blumenfeld (2006) and Moore-Cantwell (2016). A constraint like FOOT-BINARITY could, in theory, be satisfied by adding syllables to a word, but such effects never surface in attested languages: /bataka/ → (ˌba.ta)(ˈka.ʔə) (Moore-Cantwell 2016: 243).

Table 3: Insertion of syllables to satisfy SWP(D_μ).

/takata/	IDENT(V)	SWP(D_μ)	DEP
☞ (<ˌta.ʔə>)(<ˌka.ʔə>)(<ˈta.ʔə>)			******
<ta>(<ˈka><ta>)		*!	
<ta>(<ˈka.tə>)	*!		

To counteract this problem, Moore-Cantwell proposes a Harmonic Serialism (HS) solution (McCarthy 2008): foot building and segmental epenthesis take place at distinct stages of the derivation, and feet may not be built over empty segments. Given this setup, it is impossible for FOOT-BINARITY to motivate epenthesis (since epenthesizing a segment to make a foot binary would require building a monosyllabic foot first, and FOOT-BINARITY cannot motivate a monosyllabic foot), so that foot form-motivated epenthesis cannot win. A similar HS account would prevent segmental insertion from being motivated by SWP(D_μ): building Moraic Domains and inserting segments would be presumed to take place at distinct stages of the derivation, and building Moraic Domains over empty segments would plausibly not be allowed. Given these ingredients and Moore-Cantwell's (2016) account, this would similarly lead to the impossibility of syllables' being added to the word to satisfy SWP(D_μ). The details of such an account are presently delegated to future work.

SWP(D_μ) also interacts with stress. Since Moraic Domains with a stressed syllable in them are required by this constraint to be binary, this means that the constraint also prefers binary feet. In this respect, SWP(D_μ) interacts with stress in a way that is identical to (syllable-based) FOOT-BINARITY: it disprefers monosyllabic feet; (<ˈta$_\mu$.ʔə>) is preferred over (<ˈta$_\mu$>).

However, SWP(D_μ) interacts with stress in the same way as any other reduction-inducing constraint would. In conjunction with high-ranked Faithfulness, reduction constraints can trigger stress shift to avoid reducing certain vowels, which appears to be unattested. Consider, for instance, a trochaic language in which IDENT(ROUND) is ranked over the reduction constraint (e.g., SWP(D_μ)), but IDENT(LOW) and ALIGN-MAIN-RIGHT are ranked under it. This language will shift stress to avoid reducing a rounded vowel. For example, /tado/ will come out with final stress, as shown in Table 4, because initial stress is blocked by IDENT(ROUND) or ALIGN-MAIN-RIGHT. At the same time, /toda/ will come out with penult stress, as shown in Table 5, because final stress is blocked by SWP(D_μ) or, once again, by IDENT(ROUND).

A similar stress shift effect can be obtained when SWP(D_μ) is replaced by any other vowel reduction-favoring constraint, so that this is not solely a problem for the Reduction Domain approach. However, a HS solution similar to the one suggested for the epenthesis problem in the preceding paragraphs (following Moore-Cantwell's 2016 approach) would also work for the stress shift problem. If Moraic Domain-building operations take place

Table 4: Final stress (default).

/tado/	IDENT(ROUND)	SWP(D_μ)	IDENT(LOW)	ALIGN-MAIN-RIGHT
(<ˈta><do>)		*		*!
(<ˈta.də>)	*!			*
☞ <ta>(<ˈdo>)		*		
tə(<ˈdo>)		*	*!	

Table 5: Penultimate stress to avoid reduction of /o/.

/toda/	IDENT(ROUND)	SWP(D_μ)	IDENT(LOW)	ALIGN-MAIN-RIGHT
(<ˈto><da>)		*!		*
☞ (<ˈto.də>)			*	*
<to>(<ˈda>)		*!		
tə(<ˈda>)	*!	*		

at steps of the derivation distinct from the steps at which vowel reduction takes place, then stress shift cannot be motivated at the Moraic Domain assignment step, since stress shift is crucially motivated by the avoidance of reducing /o/, and reducing /o/ cannot take place at the same step as stress shift. In other words, candidates like (<ˈta.də>) and <ta>(<ˈdo>) in Table 4 will never compete in the same tableau. Because of this, a serial account would make it possible to avoid this problem, as well. The details of such an account, however, will be relegated to future work.

Finally, despite Moraic Domains' being the direct dependents of feet, I still assume, as is traditional, that FOOT-BINARITY is defined in terms of either morae or syllables. Therefore, there is no motivation from the constraint set to build quadrisyllabic feet like (<ˈta.ʔə><ka.ʔə>). For the same reason, ternary feet cannot be emulated using Moraic Domains, unlike Torres-Tamarit & Hermans' (2014) and Den Dikken & van der Hulst's (to appear) proposals, which are able to create units of three syllables. This is another factor that prevents Moraic Domains from interfering with stress placement.[11]

3.3 The necessity of Moraic Domains

3.3.1 An attempt to derive Ambiselectivity without Moraic Domains

Without a representational mechanism like Moraic Domains, the only way to motivate foot-internal non-moraicity would be to assume some constraint that penalizes moraic syllables exclusively in the unstressed syllable of a (minimal) foot, but not in any other unstressed syllable. Table 6 shows that the addition of such a constraint, which I will call FOOTTAIL-NONMORAIC (after Itô & Mester's 2011 FOOTTAIL-ə constraint, which assigns a violation mark for every full vowel in an unstressed foot-internal syllable), makes it possible to derive foot-internal non-moraic syllables. FOOTTAIL-NONMORAIC is defined in (22).

The other constraints in this tableau are the two constraints that Crosswhite invokes for mora assignment – a general constraint against morae: *STRUC-μ (see Section 3.1.2), and a variant of the FOOT-BINARITY constraint family: FT-BINARITY(μ), which requires that the foot contain two morae. To make sure that foot-internal syllables are moraic in languages that have feet larger than two syllables (as noted in Section 2.1, Crosswhite assumes such feet for Lucanian Italian; she also assumes them for Rhodope Bulgarian), there is an unspecified constraint that motivates moraicity within feet, which in Section 3.1 was instantiated as PROJECT(V,μ)/FT (defined in (19) in Section 3.1). I have also included WEIGHT-BY-POSITION, which requires that closed syllables be bimoraic, as well as the general constraint PROJECT(V,μ) (see (19) in Section 3.1).

Table 6: Non-moraicity of foot-internal syllables motivated by FOOTTAIL-NONMORAIC.

/ ta ta tan ta ta /	FOOTTAIL-NONMORAIC	FT-BIN(μ)	PROJECT(V,μ)	*STRUC-μ	WEIGHT-BY-POSITION
a. μ μ μμ μ μ (ˈta ta) tan ta ta	*!			******	
b. μ μ μ μ μ (ˈta ta) tan ta ta	*!			*****	*
c. μ μ (ˈta ta) tan ta ta	*!		***	**	*
d. (ˈta ta) tan ta ta		*	**!***		*
e. μ μμ μ μ ☞ (ˈta ta) tan ta ta		*	*	*****	

[11] Many thanks to an anonymous reviewer for bringing up this point.

(22) FOOTTAIL-NONMORAIC: Assign one violation mark for every moraic syllable that occurs in the non-head position of a minimal foot.

In Table 6, top-ranked FOOTTAIL-NONMORAIC excludes all candidates that have a moraic unstressed syllable within a foot (a.–c.), while PROJECT(V,μ) excludes candidates in which every syllable is non-moraic (in this case, d.). This produces foot-internal non-moraic syllables (as in e.). This result does not depend on the number of unfooted syllables in the word: the violations of FOOTTAIL-NONMORAIC are not influenced by unfooted syllables at all. Also independently of the number of unfooted syllables, a candidate in which the stressed syllable is non-moraic (e.g., candidate d. in Table 6) will always have more violations of PROJECT(V,μ) than a candidate in which the stressed vowel does have a mora (e.g., candidate c. in Table 6).

However, having FOOTTAIL-NONMORAIC in the constraint set predicts languages with obligatory stress clash. If FOOTTAIL-NONMORAIC together with constraints on mora assignment like PROJECT(V,μ) and Faithfulness all outrank FT-BIN(μ), then single-syllable feet are preferred across the board, as shown in Table 7.

In Table 7, candidate a. is ruled out by FOOTTAIL-NONMORAIC (it has moraic foot non-heads), while candidate b. is ruled out by PROJECT(V,μ). Deleting all light syllables, as in candidate c., is ruled out by FAITH. Instead of these options, a parse in which every syllable is a foot head as in candidate d., violates none of the high-ranked constraints and emerges as the winner. This creates subminimal feet on every light syllable and leads to obligatory stress clash.

This is a serious problem, since languages where every syllable is stressed are unattested. Of course, one could argue that the presence of a foot on each syllable simply corresponds to the absence of a stress pattern (or, if the left- or rightmost foot is promoted to main foot status, to an edgemost stress system). However, the interaction of a constraint like NON-FINALITY with this system creates a particularly problematic language: one in which all syllables but the last are stressed. Such a system arises when the ranking in Table 7 is combined with the ranking NON-FINALITY >> PARSE-SYLLABLE >> FT-BIN(μ), as shown in Table 8.

As in Table 7, candidates a. through c. in Table 8 are excluded by violations of top-ranked constraints. However, this time, candidate d. itself is ruled out by top-ranked NON-FINALITY, since it has a word-final stress. As can be seen in candidates e. and f., the ranking PARSE-SYLLABLE >> FT-BIN(μ) ensures that, among all candidates without word-final stress, moraic foot non-heads or deleted syllables, the winning candidate is the one that is maximally parsed out in terms of one-syllable feet, with the result that all syllables but the final syllable receive stress (at least, if the word is longer than one syllable).

Table 7: Monosyllabic feet motivated by FOOTTAIL-NONMORAIC.

/ ta ta tan ta ta /	FOOTTAIL-NONMORAIC	PROJECT(V,μ)	FAITH	FT-BIN(μ)
a. μ μ μμ μ μ ('ta ta)('tan)('ta ta)	*!*			
b. μ μμ μ ('ta ta)('tan)('ta ta)		*!*		
c. μμ ('tan)			*!*******	
d. ☞ μ μ μμ μ μ ('ta)('ta)('tan)('ta)('ta)				****

Table 8: Stress on any syllable but the last one.

/ ta ta tan ta ta /	Foottail-Nonmoraic	Project (V,μ)	Faith	Non-Finality	Parse-syll	Ft-Bin(μ)
a. μ μ μμ μ μ ('ta ta)('tan)('ta ta)	*!*					
b. μ μμ μ ('ta ta)('tan)('ta ta)		*!*				**
c. μμ ('tan)			*!*******	*		
d. μ μ μμ μ μ ('ta)('ta)('tan)('ta)('ta)				*!		****
e. μ μ μμ μ μ ta ta tan ta ta					**!***	
f. μ μ μμ μ μ ☞ ('ta)('ta)('tan)('ta)ta					*	***

As far as I am aware, a language that has stress in all syllables but the last is unattested and highly implausible. There are reports of some languages requiring "obligatory clash" in specific parts of the word (e.g. Schachter & Otanes 1972/1983: Tagalog has secondary stress only directly preceding primary stress), but not throughout the word. I am also unaware of any language that must be analyzed as having stress on all syllables but the last. In this manner, the prediction that languages like this should occur makes the Foottail-Nonmoraic constraint highly problematic and undesirable.[12]

Thus, a foot-only version of Crosswhite's approach cannot account for the Ambiselectivity Generalization without also predicting languages with obligatory adjacent stress. Section 3.3.2 will show how the presence of Moraic Domains improves on this.

3.3.2 A solution with Moraic Domains

To demonstrate that SWP(D_μ) actually solves the typological problem, I provide below equivalents of Tables 6 and 8 from Section 3.3.1 in which Foottail-Nonmoraic is replaced with the constraint SWP(D_μ) and Moraic Domain representations are included (these are Table 9 and Table 10, respectively). As can be seen in these tableaux, SWP(D_μ) can motivate non-moraicity within the minimal foot (see Table 9), but it also penalizes monomoraic feet (see Table 10), so that languages with obligatory stress clash are not generated.

Table 9 works the same as Table 6 in Section 3.3.1 and produces the same output. All candidates that have a unary Moraic Domain in stressed position are ruled out by top-ranked SWP(D_μ), while the moraless candidate, e., is ruled out by superfluous violations of Project(V,μ). This leaves candidate d., which has a non-moraic foot-internal syllable, as the winner.

Note also that the constraint *Struc-μ can motivate the absence of Moraic Domains. For instance, candidate e. in Table 9, which has no Moraic Domains, is the only candidate in that tableau that has no violations of *Struc-μ, and would win if *Struc-μ were undominated.

[12] An anonymous reviewer points out that there are established constraints that may lead to the prediction of monosyllabic feet, such as certain definitions of Trochee and Iamb. However, it seems to me that this does not affect the argument against Foottail-Nonmoraic: any constraint that makes a problematic prediction (in this case, a possible preference for monosyllabic over disyllabic feet) is a problem on its own, independently of whether other constraints make the same problematic prediction.

Table 9: Non-moraicity of foot-internal syllables motivated by SWP(D_μ).

/ ta ta tan ta ta /	SWP(D_μ)	Ft-Bin(μ)	Project(V,μ)	*Struc-μ	Weight-by-Position
a. μ μ μμ μ μ (<ˈta><ta>)<tan><ta><ta>	*!			******	
b. μ μ μ μ μ (<ˈta><ta>)<tan><ta><ta>	*!			*****	*
c. μ μ (<ˈta><ta>)tan.ta.ta	*!		***	**	*
d. ☞ μ μμ μ μ (<ˈta.ta>)<tan><ta><ta>		*	*	*****	
e. (ˈta.ta)tan.ta.ta		*	**!***		*

Table 10: Monosyllabic feet not motivated by SWP(D_μ).

/ ta ta tan ta ta /	SWP(D_μ)	Project(V,μ)	Faith	Non-Fin	Parse-syll	Ft-Bin(μ)
a. μ μ μμ μ μ (<ˈta><ta>)(<ˈtan>)(<ˈta><ta>)	*!**					
b. μ μμ μ (<ˈta.ta>)(<ˈtan>)(<ˈta.ta>)	*!	**				**
c. μμ (<ˈtan>)	*!		**** ****	*		
d. μ μ μμ μ μ (<ˈta>)(<ˈta>)(<ˈtan>)(<ˈta>)(<ˈta>)	*!****			*		****
e. ☞ μ μ μμ μ μ <ta><ta><tan><ta><ta>					*****	
f. μ μμ (<ˈta.ta>)(<ˈtan.ta>)ta		*!**			*	*
g. μ μ μμ μ (<ˈta>)(<ˈta>)(<ˈtan>)(<ˈta>)ta	*!***	*			*	***
h. μ μ μμ μ (<ˈta><ta>)(<ˈtan>)(<ˈta>)ta	*!**	*			*	*

Table 10 is based on Table 8 in Section 3.3.1, and shows on the basis of the same candidate set (in addition to a few more candidates) that stress on every syllable (or on every syllable but the last) is no longer predicted with SWP(D_μ). Whereas FootTail-Nonmoraic only penalizes unstressed moraic syllables within a minimal foot, SWP(D_μ) also penalizes all monosyllabic feet, since they consist of a non-branching Moraic Domain that contains a stressed syllable. Therefore, in this tableau, candidates d. and g., which have obligatory adjacent stress throughout the word, are ruled out by their violations of SWP(D_μ). In fact, all candidates with feet are ruled out by SWP(D_μ) or Project(V,μ), leaving just candidate e., which has no feet and no stress, as the winner.

In general, candidates with obligatory adjacent stress, like candidates d. and g. in Table 10, are harmonically bounded by corresponding candidates with binary feet (d. is harmonically bounded by a. (and h.); g. is harmonically bounded by h.), since the former have the same violations as the latter in addition to more violations of SWP(D_μ) and FT-BIN.[13] This can be seen in comparing, for instance, candidate g. to its corresponding binary-foot candidate, h.

In this manner, with the help of Moraic Domains, non-moraicity in a foot can be motivated, thus deriving the Ambiselectivity Generalization (see Section 5.1 for further illustration), while a preference for monosyllabic feet is not predicted. This avoids the problems of the foot-only approach outlined in Section 3.3.1.

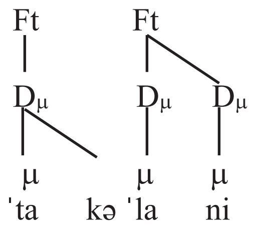
3.4 The interaction of Moraic Domains with other levels of structure

The effect of SWP(D_μ) demonstrated in Section 3.3.2 comes about because Moraic Domains and feet are different levels of structure and have separate category labels. This allows for SWP(D_μ) to require a non-moraic syllable in the same foot as a moraic syllable (by demanding a binary Moraic Domain, as in (<ˈma.nə>)) and not accept monosyllabic feet, as in (<ˈma>)(<ˌna>), as an alternative repair. As shown in Section 3.3.1 above, this is not possible when there is no level of structure between a foot and a syllable.

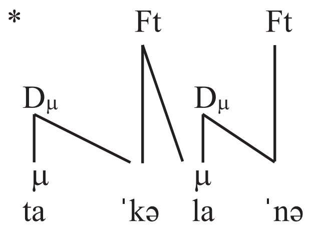
To make SWP(D_μ) work, Moraic Domains must be able to include non-moraic syllables within a foot, like in the leftmost Moraic Domain in (23a) below. Moraic Domains must also be strictly contained within feet, unlike (23b) below, to avoid monomoraic feet as a repair strategy. Therefore, a multiplanar approach (Rappaport 1984: 135–137; Parker 1998/2013) is not compatible with these data. In such approaches, there are several planes of metrical parsing that are not hierarchically ordered with respect to one another. Moreover, I follow Liberman & Prince (1977) and the subsequent literature in the notion that headedness is cumulative: the head of a higher-order element (e.g. a word) must also be the head of a lower-order element (e.g., a foot). Thus, if the stressed syllable of a foot is in a Moraic Domain, then the stress must universally fall on the head (rather than a non-head) of that Moraic Domain, like (23a) and unlike (23c). In the current proposal, this will be an inviolable representational assumption.

(23) *Moraic Domains as proper subconstituents of feet*

a. *Proposed D_μ representation*

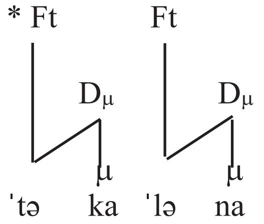


b. *No partial Ft-D_μ overlap*



[13] As pointed out by an anonymous reviewer, this harmonic bounding is contingent upon the absence of any individual constraints that prefer monosyllabic feet (like certain definitions of Iamb and Trochee).

c. *Ft-heads* ⊂ *D*$_\mu$*-heads*



I will follow Selkirk (1996) in maintaining that some syllables may remain unparsed by higher-order constituents. For instance, in tə(<ˈmat>) (see (17b) at the beginning of Section 3 for a full representation), the first syllable is not parsed into a Moraic Domain or a foot, and instead directly adjoined to the Prosodic Word. Even though exhaustivity of Moraic Domain parsing is thus violable (Selkirk 1996), the cumulativity of headedness is assumed to be inviolable, as stated in the preceding paragraph, and as exemplified in (23c). The head of a word must be parsed into a foot, and the head of a feet must be parsed into a Moraic Domain. Thus, representations where a stressed syllable is not in a Moraic Domain, like (ˈta<ka>), are ruled out in all languages. Representations where unstressed syllables are in a foot but not in a Moraic Domain, like (<ˈta>ka), cannot be distinguished empirically from representations where all foot-internal unstressed syllables are parsed into Moraic Domains, like (<ˈta.ka>). Therefore, it is not clear whether such representations should be ruled out, but, in any case, they are harmonically bounded in the analysis proposed here (see Table 25 in Section 4.2.1).

The Moraic Domain introduces a new level of prosodic structure between the foot and the syllable. The idea of such an additional level has various precedents in the literature. For instance, Hammond (1987) uses Hungarian data to motivate a super-foot level, the colon, to differentiate between secondary stress and tertiary stress: heads of feet have at least tertiary stress, heads of cola have at least secondary stress, and heads of words have primary stress;[14] see also Lionnet (2018) for a recent defense of the colon. The "foot proper" (unit of tertiary stress) in the colon proposal can be said to act as an intermediate category between the colon (which assigns secondary stress, and thus corresponds to the traditional foot) and the syllable. Similarly, van der Hulst & Moortgat (1980) use Dutch data to motivate a super-foot level: they assume that their Superfoot (which has the same function as a traditional foot) assigns stress to its head, but there is a smaller unit (the "foot proper") in which the head syllables have full vowels, and the dependent syllables have schwas. This proposal of a level that assigns no stress but does differentiate between full and reduced vowels is an important precursor to the current proposal.

Hermans & Torres-Tamarit (2014), on the other hand, propose a type of a sub-foot level: they assume that feet consist of exactly two morae, but some morae are adjoined to the foot without actually counting towards the binary maximum on a foot. In the case of adjoined morae, the smaller, bimoraic constituent that the additional mora is adjoined to is a unit intermediate between the foot and the mora.

Furthermore, Bennett (2012; 2013); Martínez-Paricio (2013); and Kager & Martínez-Paricio (2014) argue for recursive foot structure: there is a Minimal Foot level which is smaller than the Non-Minimal Foot, but both are units of the type foot. Examples of analysis in this framework can be found in Section 2.1.2 of this paper.

[14] It seems, however, that the tertiary stress data Hammond uses to motivate the assumption of a prosodic level larger than a foot and smaller than a word are not confirmed by native speakers of Hungarian (Miklós Törkenczy, p.c.; there is, of course, the possibility that Hammond's data come from a different dialect of Hungarian).

The previous work cited above does not make a direct connection between metrical levels and vowel reduction rules or constraints as is done here by tying *NONMORAIC/X constraints (Crosswhite 1999; 2001) to particular positions in the lower metrical level (in this case, the Moraic Domain).[15] Van der Hulst & Moortgat (1980), whose proposal was briefly discussed above, were the first to posit that Dutch has a foot (which encodes vowel reduction) as well as a Superfoot (which encodes stress). Van Oostendorp (1995) also explored this idea in his account of Dutch vowel reduction. LeSourd (1993: Section 4.4) independently presents a very similar proposal for Passamaquoddy. Finally, in recent work, Den Dikken & van der Hulst (to appear) have proposed two different levels of projection for vowels: a "light vowel" projection and a general vowel projection, where the general vowel projection is nested inside the light vowel projection. This representation could be used to tie reduced vowels to certain structural positions in the foot – however, this possibility is not worked out in their paper, and therefore cannot be fully evaluated in this paper.

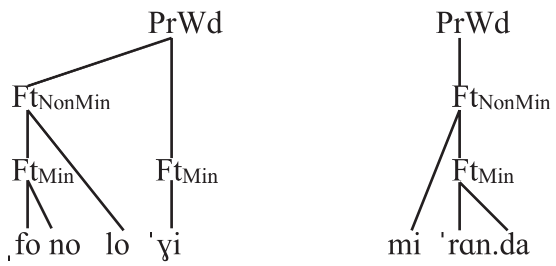
The body of work enumerated in the preceding paragraphs has significantly contributed to the understanding of the structural encoding of vowel reduction. However, the current proposal is the first to work this connection out in detail, and to explicitly tie it to the typology of vowel reduction.

3.5 Recursive feet

3.5.1 Constraints on minimal and non-minimal feet

The only previous account for the Ambiselectivity Generalization comes from Martínez-Paricio (2013), who presupposes a recursive foot framework (Liberman & Prince 1973; Prince 1980; Selkirk 1980; Bennett 2013; Kager & Martínez-Paricio 2014). In this framework, positions outside minimal feet are adjoined at a higher foot level to create a recursive structure involving a minimal and a non-minimal foot, as in (24).

(24)



To account for sonority-reducing reduction, Martínez-Paricio adopts de Lacy's (2002) reduction constraints that minimize sonority in all non-head elements of a prosodic domain. De Lacy uses four nested sonority regions that are banned in a given position: all low vowels (signified here as >e•o), all mid and low full vowels (signified as >i•u), all full vowels (signified as >ə), and anything but the lowest-sonority vowel [ɨ] (signified as >ɨ). This template is shown in (25).

(25) *NON-HEAD(DOMAIN)/>X: One violation mark for every vowel more sonorous than X that occurs in a non-head position of the Domain specified.[16]
(Where X can be [e•o], [i•u], [ə], [ɨ])

[15] The idea of structural change corresponding to vowel reduction also resonates with the idea within Government Phonology (see, for instance, Kaye 1990) that empty vowel positions must be governed by a full vowel – and, crucially, not by schwa. Although the resemblance is not complete, Moraic Domains and vowel government share the idea that moraic and relatively non-reduced vowels having an overt licensing effect on non-moraic and hence potentially reduced vowels.

[16] I will follow de Lacy's inequality notation of the sonority conditions on these reduction constraints ("ban all vowels that are more sonorous than X"). In all other aspects, I will follow Martínez-Paricio's notation.

Table 11: Dutch semi-informal reduction with recursive feet.

/fonoloɣi/	*NON-HEAD(MINFOOT)/>ə	IDENT(V)	*NON-HEAD(NONMINFOOT)/>ə
a. ((ˌfo.no) lo) (ˈɣi)	*!		*
☞ b. ((ˌfo.nə) lo) (ˈɣi))		*	*
c. ((ˌfo.no) lə) (ˈɣi))	*!	*	
d. ((ˌfo.nə) lə) (ˈɣi)		**!	

Using the distinction between minimal and non-minimal feet, Martínez-Paricio (2013) proposes reduction constraints that apply either within or outside of minimal feet, exemplified in (26) with X = ə.

(26) a. *NON-HEAD(MINFOOT)/ > ə: One violation mark for every vowel more sonorous than schwa which is in the non-head position of a minimal foot.
b. *NON-HEAD(NONMINFOOT)/ > ə: One violation mark for every vowel more sonorous than schwa which is in the non-head position of a non-minimal foot (i.e., outside a minimal foot).

To account for a language like semi-informal Dutch, which reduces within a minimal foot only (see Section 4.1 for more details), Martínez-Paricio (2013: 213–226) ranks *NON-HEAD(MINFOOT)/ > ə above *NON-HEAD(NONMINFOOT)/ > ə. When IDENT(V) is ranked between these two constraints, there is selective reduction within a minimal foot, as shown in Table 11.[17] In this tableau, candidates a. and c., which have full vowels in the unstressed position of a minimal foot, are excluded by *NON-HEAD(MINFOOT)/ > ə, while candidate d., which has a reduced vowel outside a minimal foot, is excluded by a superfluous violation of IDENT(V).

Crucially, as long as *NON-HEAD(MINFOOT)/ > X outranks *NON-HEAD(NONMINFOOT)/ > X, reduction outside minimal feet only is not possible. Languages like Russian, in which sonority-reducing reduction happens only outside minimal feet, can be obtained by reversing this ranking. For easier comparison with the Dutch case, I will discuss here a Dutch-prime, which can have selective reduction in the position outside a minimal foot, (27c), but not selective reduction within a minimal foot, (27d).

(27) *Reduction in hypothetical Dutch-prime*
a. (mo(ˈtam)) ~ (mə(ˈtam))
b. (ˌsi.fo)(ˈlof) ~ (ˌsi.fə)(ˈlof)
c. (ˌno.ɣo)(lo(ˈfi)) ~ (ˌno.ɣə)(lə(ˈfi)) ~ (ˌno.ɣo)(lə(ˈfi)
d. *(ˌno.ɣə)(**lo**(ˈfi))

In Martinez-Paricio's account, this language would be accounted for by ranking *NON-HEAD(NONMINFOOT)/ > ə above *NON-HEAD(MINFOOT)/ > ə. IDENT(V) ranked in between these two constraints yields reduction outside a minimal foot only, as in Table 12.

Since *NON-HEAD(NONMINFOOT)/ > ə is top-ranked in Table 12, candidates a. and b., which violate this constraint, are ruled out. Of the remaining candidates, c. and d., the one which minimally violates IDENT(V) wins – which is candidate c., with reduction outside a minimal foot only.

[17] Martínez-Paricio's account is simplified for presentational purposes.

Table 12: Selective reduction outside the minimal foot with recursive feet.

	/noɣolofi/	*NON-HEAD(NONMINFOOT)/>ə	IDENT(V)	*NON-HEAD(MINFOOT)/>ə
	a. ((ˌno.ɣo) lo) (ˈfi)	*!		*
	b. ((ˌno.ɣə) lo) (ˈfi)	*!	*	
☞	c. ((ˌno.ɣo) lə) (ˈfi)		*	*
	d. ((ˌno.ɣə) lə) (ˈfi)		**!	

Thus, the ranking *NON-HEAD(NONMINFOOT)/>ə >> *NON-HEAD(MINFOOT)/>ə yields a language in which selective vowel reduction only applies outside a minimal foot. The opposite ranking, *NON-HEAD(MINFOOT)/>ə >> *NON-HEAD(NONMINFOOT)/>ə, yields selective reduction within a minimal foot only. This makes Martínez-Paricio's foot-based account able to derive the Ambiselectivity Generalization. However, as I will show in Section 3.5.2, this foot-based account also predicts languages that violate the Sonority Requirement Generalization.

3.5.2 Overgeneration under a recursive-foot-only approach

Because the recursive-foot-only approach has separate sonority-reducing Markedness constraints for positions inside and outside minimal feet, this approach predicts that separate sonority-reducing vowel reduction processes may occur independently in each position. It is this complete independence between these positions that allows the recursive-foot-only approach to generate languages, such as the Pseudo-Russian example given in Section 1 (repeated with small modifications in (28)), that contradict the Sonority Requirement Generalization. In this example, all immediately pre-tonic (minimal foot-internal) syllables may be no more sonorous than [i,u], while all other unstressed syllables may be no more sonorous than [ɨ].

(28) *Unattested language: Pseudo-Russian (two reduction processes, both sonority- reducing; repeated from (14) in Section 3.5)*
Stressed: no reduction
/kam(e)nʲ/ → ((ˈka)m**ɨ**nʲ)
Minimal foot-internal: /i,e/ → [i], /a,o/ → [ə], /u/ → [u]
/kam(e)nʲ-ej/ → (k**ə**m.ˈnʲej)
All other unstressed syllables: /i,e,a,o,u/ → [ɨ]
/kam(e)nʲ-ist-oj/ → (k**ɨ**((mʲ**i**.ˈnʲis)t**ɨ**j))
/za-kalʲi-l-a/ → (z**ɨ**((k**ə**.ˈlʲi)l**ɨ**)

Reduction of /a/ to [ə] inside minimal feet can be derived by ranking *NON-HEAD(MINFOOT)/>i•u above IDENT(HIGH) and IDENT(LOW). Reduction of /a/ to [ɨ] outside minimal feet can be derived by ranking *NON-HEAD(NONMINFOOT)/>ɨ above the same Faithfulness constraints.

Because *NON-HEAD(MINFOOT)/>i•u and *NON-HEAD(NONMINFOOT)/>ɨ apply in mutual exclusive contexts (within a minimal foot vs. outside a minimal foot), combining the rankings established above is sufficient to derive the complete pattern of reduction in Pseudo-Russian, which violates the Sonority Requirement Generalization. This is shown in Table 13, which depicts three degrees of reduction for both minimal foot-internal and minimal foot-external positions.

In Table 13, candidates a. and c. violate the high-ranked constraint against unstressed non-high full vowels within a minimal foot, while candidates a and b. violate the high-ranked constraint against non-[ɨ] outside a minimal foot. Of the remaining candidates, d.

Table 13: Pseudo-Russian generated with recursive footing.

/za-kalʲi-l-a/	*NON-HEAD (MINFOOT) />i•u	*NONHEAD (NONMINFOOT) />ɨ	IDENT (HIGH)	IDENT (LOW)	*NONHEAD (MINFOOT) />ɨ
a. (z**a**((k**a**.ˈlʲi)l**a**))	*!	**			*
b. (z**ə**((k**ɨ**.ˈlʲi)l**ə**))		*!*	*	***	
c. (z**ɨ**((k**a**.ˈlʲi)l**ɨ**))	*!		**	**	*
d. (z**ɨ**((kʲ**i**.ˈlʲi)l**ɨ**))			***!	***	*
☞ e. (z**ɨ**((k**ə**.ˈlʲi)l**ɨ**))			**	***	*
f. (z**ɨ**((k**ɨ**.ˈlʲi)l**ɨ**))			***!	***	

and f. are excluded because of their additional violation of IDENT(HIGH), and candidate e. emerges as the winner – which is the predicted pattern for Pseudo-Russian. Minimal foot-internal and minimal foot-external positions in this winning candidate (and the winner for any other input with low vowels that occur in both positions) are completely disjoint in the Markedness forces that apply to them, which means that /a/ can reduce to one non-low vowel, [ə], in foot-internal position, while it reduced to another non-low vowel, [ɨ], in minimal foot-external position – violating the Sonority Requirement Generalization.

Thus, the recursive-foot-only approach, while it does succeed in accounting for the Ambiselectivity Generalization (as shown in Section 3.5.1), does not succeed in accounting for the Sonority Requirement Generalization.

The Moraic Domain proposal set forth in this paper is compatible with recursive footing, since recursive footing makes no claims about moraicity. The only necessary adjustment will be to redefine the Exhaustivity constraints relevant to feet and Moraic Domains (an additional constraint will be needed to require Moraic Domains in minimal feet, and another might require Moraic Domains in all kinds of feet, minimal or non-minimal). However, for empirical reasons laid out in this subsection, I do hypothesize that, instead of the constraints on sonority in minimal and non-minimal foot non-heads proposed by Martínez-Paricio (2013), as exemplified in (26) in Section 3.5.1, the universal constraint set contains *NONMORAIC-X constraints, as introduced in Section 3.1.

3.6 Summary

To summarize, the Moraic Domain proposal extends Crosswhite's (1999; 2001) theory of vowel reduction. The constraints involved in the current proposal are shown in (29).

(29)
a. *NONMORAIC-X constraints, which motivate various degrees of sonority-reducing reduction (to a high full vowel, to schwa, to [ɨ], etc.)
b. Faithfulness constraints on vowels to counteract vowel reduction (these may block particular vowel qualities from reducing)
c. *STRUC-μ, which motivates the absence of morae across the board (and enables reduction if *NONMORAIC-X >> FAITH)
d. PROJECT(V,μ), which motivates the presence of morae on all syllables[18] (and counteracts reduction in all syllables)

[18] Faithfulness constraints on vowel quality may motivate the construction of Moraic Domains: (<ˈta><ta>) is preferred by Faithfulness over (<ˈta.tə>). This superficially suggests that Project(V,μ) may be superfluous. However, motivating unary Moraic Domains with Faithfulness cannot be done in languages in which non-moraic syllables remain unaffected by reduction: (<ˈta><ta>) and (<ˈta.ta>). This means that Project(V,μ) is needed independently to decide between the latter two options.

e. SWP(D_μ), which motivates the absence of morae in unstressed syllables in a foot (and enables reduction in these syllables if *NONMORAIC-X >>FAITH)
f. PROJECT(V,μ)/Ft, which motivates the presence of morae on all syllables in a foot (and counteracts reduction in foot-internal syllables)

The violable nature of Crosswhite's *NONMORAIC/X constraints means that unreduced vowels may remain nonmoraic if Faithfulness outranks all *NONMORAIC/X constraints: (<ˌma$_\mu$.na>)(<ˈka$_\mu$.ta>). However, this does not make Moraic Domains vacuous. Moraic Domains determine the potential location of sonority-reducing reduction in a word: all foot-internal, all foot-external, all unstressed syllables, or no syllables at all. The *NONMORAIC/X constraints do not express anything about the location of reduction, but only specify its extent. Thus, Moraic Domain constraints and *NONMORAIC/X constraints are orthogonal to one other, but they must both be ranked above Faithfulness for reduction to be present.

In Section 4, I will show a case study of the proposal on Dutch vowel reduction (which is of the type that is problematic without Moraic Domains, see Section 3.3). Section 5 will demonstrate how the Moraic Domain proposal accounts for both typological generalizations from Section 2 – a goal shown in Section 3.3 and 3.5 to be unattainable for approaches without a Moraic Domain.

4 Case study: Dutch vowel reduction

4.1 Descriptive facts

Dutch has an optional process of vowel reduction to schwa (Kager 1989; Booij 1995; Van Oostendorp 1995), which may apply either to all unstressed vowels, or selectively to vowels in syllables that directly follow stress, as in (30c). Crucially, selective vowel reduction only applies in unstressed syllables that directly follow a stressed syllable: compare (30c) to (30d).

(30) a. to.ˈmat ~ tə.ˈmat 'tomato'
b. ˌfi.lo.ˈsof ~ ˌfi.lə.ˈsof 'philosopher'
c. ˌfo.no.lo.ˈɣi ~ ˌfo.nə.lə.ˈɣi ~ ˌfo.nə.lo.ˈɣi 'phonology'
d. *ˌfo.no.**lə**.ˈɣi 'phonology'

Kager (1989) defines several types of exceptions to this pattern, the most important of which is that selective reduction in syllables that do not directly follow stress, as in (30d), is actually allowed when the relevant foot-external vowel is /a/ or /e/:

(31) /dekoratif/ → [ˌdekorəˈtif] 'decorative'
/apokalɪps/ → [ˌapokəˈlɪps] 'apocalypse'
/nominatief/ → [ˌnominəˈtif] 'nominative'

Van Oostendorp (1995; 1997) shows that this can be accounted for by assuming a fixed hierarchy of Faithfulness constraints in the language: IDENT(HIGH) >> IDENT(ROUND) >> IDENT(LOW).[19] In Section 4.1, I will show that this can account for the data in (31).

Finally, one exceptionless pattern is that vowels in absolute word-final position are never reduced (Booij 1995; Van Oostendorp 2000: 141–143), as illustrated in (32). Van Oostendorp (1995; 2000) accounts for this with a high-ranked Alignment constraint: under the assumption of Containment Theory (McCarthy & Prince 1993), he concludes that true right alignment of the Prosodic Word to the grammatical word also presupposes

[19] Van Oostendorp's original account uses privative features and MAX(FEATURE) constraints instead of IDENT(FEATURE) and uses [dorsal] instead of [low] for theory-internal reasons.

identity of the rightmost segment in the grammatical word and the Prosodic Word. In a more updated theoretical framework, one could replace this constraint with a positional Faithfulness constraint IDENT(V)/_]$_{\omega}$.

(32) *No word-final reduction in Dutch*
foto, *fotə 'picture'

4.2 Analysis in terms of Moraic Domains

Dutch has strong support for a trochaic foot (e.g., Kager 1989; Booij 1995; Van Oostendorp 1997a). This means that Dutch has selective vowel reduction in foot-internal position only, as illustrated in (33).

(33) *Optional selective reduction in foot-internal position*
(ˌfo.no)lo(ˈɣi) ~ (ˌfo.nə)lə(ˈɣi) ~ (ˌfo.nə)lo(ˈɣi)

As was shown in Section 3.3.1, this is problematic for Crosswhite's (1999; 2001) original analysis, since there is no plausible reason in her theory to require a non-moraic vowel in foot-internal syllables to the exclusion of foot-external syllables.

If, on the other hand, the proposal in Sections 3.1–3.2 is followed, we may say that moraic vowels are Moraic Domain heads and non-moraic vowels are not. Since schwa is the only reduction vowel in Dutch, and Dutch schwa has certain other properties that qualify it as non-moraic (see Van Oostendorp 1995; 2000), I will presume that non-moraic vowels are realized as schwa and all schwas are non-moraic in this language. If this is so, then variation in reduction as shown in (30abc) in Section 4.1 may be seen as variation in Moraic Domain parses. (34) provides examples of such parses for the three types of reduction observed in Dutch: no reduction in (34a), reduction in all unstressed syllables in (34b), and selective reduction in posttonic syllables only in (34c).

(34) a. *no reduction:*
<to>(<ˈmat>)
(<ˌfi><lo>)(<ˈsof>)
(<ˌfo><no>)<lo>(<ˈɣi>)
b. *reduction in all unstressed syllables:*
tə(<ˈmat>)
(<ˌfi.**lə**>)(<ˈsof>)
(<ˌfo.**nə**>)**lə**(<ˈɣi>)
c. *selective reduction in posttonic syllables only:*
<to>(<ˈmat>)
(<ˌfi.**lə**>)(<ˈsof>)
(<ˌfo.**nə**>)<lo>(<ˈɣi>)

4.2.1 Current proposal

The current account of the Dutch data will be built on the (simplifying) assumption that reduction to schwa reflects that a vowel has become non-moraic (as shown in (34)), and that all non-moraic vowels are produced as schwa (see also the beginning of Section 4.2). The latter is reflected in the analysis through the ranking of *NONMORAIC/FULL VOWEL above all faithfulness constraints on vowel features, except IDENT(V)/_]$_{\omega}$, which penalizes reduction at the end of a word (see the end of Section 4.1).[20] This is illustrated

[20] This assumption will be questioned in Section 4.2.1.1.

in Table 14 based on the word /filosof/, in which the non-moraic second syllable is penalized by *Nonmoraic/full vowel when it maintains the underlying vowel quality [o], as in candidate b., whereas the winner, candidate a., foregoes Faithfulness to satisfy *Nonmoraic/full vowel.

In Table 14 and all following tableaux, morae will be indicated with a subscript μ.

The most important aspect of the analysis, which distinguishes it from Crosswhite's original analysis without the use of Moraic Domains, is the assignment of morae to syllables through Moraic Domain parses. The relevant constraints for this are SWP(D_{μ}), as introduced in Section 3.2, as well as Project(V,μ) and *Struc-μ, as introduced in Section 3.3.1. As already shown in Section 3.2, SWP(D_{μ}) can motivate non-moraicity and hence reduction within a foot, while Project(V,μ) and *Struc-μ prefer moraicity for full vowels and non-moraicity for schwas.

When *Struc-μ is ranked above Ident(V) and Project(V,μ), all the unstressed vowels in a word are reduced to schwa, as shown in Tables 15 and 16. *Struc-μ motivates the removal of morae, and ranking this constraint above Project(V,μ) leads to a situation where unstressed syllables become non-moraic. In addition, *Struc-μ must dominate Ident(V) to ensure that vowel reduction can take place in these non-moraic syllables. Candidates where a stressed syllable (like [mat]) remains unparsed by a Moraic Domains are impossible due to the restriction (described in Section 3.4) that the head of a foot must also be the head of a Moraic Domain.

In Table 15, the fact that the fully faithful and fully moraic candidate, a., does not win motivates the ranking of *Struc-μ above Ident(V) and Project(V,μ), since the latter constraints prefer candidate a. over candidate c., which is the desired winner. When the unstressed syllable's vowel is reduced to schwa, but is still moraic, as in candidate b., this is ruled out and, in fact, harmonically bounded, because it introduces a superfluous violation of *Struc-μ compared to candidate c. This allows candidate c. to win: the unstressed syllable is made non-moraic (and is pronounced as schwa).

In Table 16, candidates a. through d. have more than two violations of top-ranked *Struc-μ and are therefore excluded, even if candidate a. has a perfect score on both Ident(V) and Project(V,μ). Candidate d. has a moraic schwa in the head syllable of its second Moraic Domain, <lə>, which creates a additional violation of *Struc-μ on top of the violation profile of candidate b., so that candidate d. is harmonically bounded and will never win. Thus, candidate e., in which all unstressed syllables are non-moraic, wins.

When Project(V,μ) outranks *Struc-μ, unstressed vowels remain without a mora, as shown in Tables 17 and 18.

Table 14: Reduction in non-moraic syllables motivated by *Nonmoraic/full vowel.

/filosof/	*Nonmoraic/full vowel	Ident(V)
☞ a. (<ˌfi$_{\mu}$. lə>)(<ˈsof$_{\mu\mu\mu}$>)		*
b. (<ˌfi$_{\mu}$. lo>)(<ˈsof$_{\mu\mu\mu}$>)	*!	

Table 15: Non-moraicity and reduction motivated by *Struc-μ.

/tomat/	*Struc-μ	Ident(V)	Project(V,μ)
a. <to$_{\mu}$>(<ˈmat$_{\mu\mu\mu}$>)	****!		
b. <tə$_{\mu}$>(<ˈmat$_{\mu\mu\mu}$>)	****!	*	
☞ c. tə(<ˈmat$_{\mu\mu\mu}$>)	***	*	*

In Table 17, candidate b. – together with any other candidates with non-moraic syllables – is ruled out because of its violation of PROJECT(V,μ). Similarly, in Table 18, candidates b.-d. and any others that do not preserve underlying vowel quality are ruled out because of their violation of PROJECT(V,μ). Thus, the relative ranking of *STRUC-μ and PROJECT(V,μ) makes the difference between complete reduction of all syllables, as in Tables 15 and 16, and no reduction at all, as in Tables 17 and 18.

Selective reduction in post-tonic syllables is motivated by the constraint SWP(D$_\mu$) (see Section 3.2), which prefers that a stressed syllable have a (non-moraic) sister in the same Moraic Domain. This triggers reduction in a directly post-tonic syllable, as can be seen by comparing Tables 19 and 20. In these tableaux, SWP(D$_\mu$) is ranked above PROJECT(V,μ)

Table 16: Non-moraicity and reduction motivated by *STRUC-μ.

/fonoloɣi/	*STRUC-μ	IDENT(V)	PROJECT(V,μ)
a. (<ˌfo$_\mu$><no$_\mu$>)<lo$_\mu$>(<ˈɣi$_\mu$>)	***!*		
b. (<ˌfo$_\mu$.nə>)<lo$_\mu$>(<ˈɣi$_\mu$>)	***!	*	*
c. (<ˌfo$_\mu$.no>)<lo$_\mu$>(<ˈɣi$_\mu$>)	***!		*
d. (<ˌfo$_\mu$.nə>)<lə$_\mu$>(<ˈɣi$_\mu$>)	***!	**	*
☞ e. (<ˌfo$_\mu$.nə>)lə(<ˈɣi$_\mu$>)	**	**	**

Table 17: Moracity and lack of reduction motivated by PROJECT(V,μ).

/tomat/	PROJECT(V,μ)	*STRUC-μ
☞ a. <to$_\mu$>(<ˈmat$_{\mu\mu\mu}$>)		****
b. tə(<ˈmat$_{\mu\mu\mu}$>)	*!	***

Table 18: Moracity and lack of reduction motivated by PROJECT(V,μ).

/fonoloɣi/	PROJECT(V,μ)	*STRUC-μ
☞ a. (<ˌfo$_\mu$><no$_\mu$>)<lo$_\mu$>(<ˈɣi$_\mu$>)		****
b. (<ˌfo$_\mu$.nə>)<lo$_\mu$>(<ˈɣi$_\mu$>)	*!	***
c. (<ˌfo$_\mu$><no$_\mu$>)lə(<ˈɣi$_\mu$>)	*!	****
d. (<ˌfo$_\mu$.nə>)lə(<ˈɣi$_\mu$>)	*!*	**

Table 19: Reduction outside the foot not movated by SWP(D$_\mu$).

/tomat/	SWP(D$_\mu$)	PROJECT(V,μ)	*STRUC-μ
☞ a. <to$_\mu$>(<ˈmat$_{\mu\mu\mu}$>)	*		****
b. tə(<ˈmat$_{\mu\mu\mu}$>)	*	*!	***

Table 20: Reduction within the foot motivated by SWP(D$_\mu$).

/fonoloɣi/	SWP(D$_\mu$)	PROJECT(V,μ)	*STRUC-μ
a. (<ˌfo$_\mu$><no$_\mu$>)<lo$_\mu$>(<ˈɣi$_\mu$>)	**!		****
☞ b. (<ˌfo$_\mu$.nə>)<lo$_\mu$>(<ˈɣi$_\mu$>)	*	*	***
c. (<ˌfo$_\mu$><no$_\mu$>)lə(<ˈɣi$_\mu$>)	**!	*	***
d. (<ˌfo$_\mu$.nə>)lə(<ˈɣi$_\mu$>)	*	*!*	**

so that there will be reduction next to a stressed syllable, but *Struc-μ is ranked below Project(V,μ) to prevent reduction of any other unstressed syllables.

In Tables 19 and 20, top-ranked SWP(D_μ) rules out any unary Moraic Domain that contains a stressed syllable, like <ˌfo> in candidates a. and c. in Table 20.[21] At the same time, all unstressed vowels outside the foot retain their underlying quality, since an unstressed unary Moraic Domain like <to> in Table 19 or <lo> in Table 20 does not violate SWP(D_μ). The ranking Project(V,μ) >> *Struc-μ ensures that candidates with reduction outside foot-internal position, like b. in Table 19 or d. in Table 20, are excluded.

However, when Project(V,μ) is ranked above SWP(D_μ) as well as above *Struc-μ, as in Tables 21 and 22, this triggers no reduction at all, since, as can be seen in both tableaux, top-ranked Project(V,μ) rules out all candidates with reduction.

Finally, reduction of all unstressed vowels is achieved under any ranking that has *Struc-μ above Project(V,μ). This is illustrated by Table 23, in which top-ranked SWP(D_μ) rules out candidates a. and c. for only having one syllable in their first Moraic Domain. A superfluous violation of *Struc-μ then rules out all full/moraic vowels in positions outside a minimal foot, as in candidate b., leaving the maximally reduced candidate, d., as the winner.

Since SWP(D_μ) only triggers reduction within (minimal) feet, and *Struc-μ triggers reduction in all unstressed syllables, there is no ranking of these two constraints with respect to Project(V,μ) that favors reduction only outside the foot, as in candidate c. in Table 24. As will become apparent in 5.1, a high ranking of Project(V,μ)/Ft (see Section 3.1) can lead to reduction outside the foot only. Thus, as long as Project(V,μ)/Ft is low-ranked, as in Table 24 below, reduction must apply either inside a foot, or in all unstressed syllables.

Table 21: Top-ranked Project(V,μ) leads to no reduction.

/tomat/	Project(V,μ)	SWP(D_μ)	*Struc-μ
☞ a. <to$_\mu$>(<ˈmat$_{\mu\mu\mu}$>)		*	****
b. tə(<ˈmat$_{\mu\mu\mu}$>)	*!	*	***

Table 22: Top-ranked Project(V,μ) leads to no reduction.

/fonoloɣi/	Project(V,μ)	SWP(D_μ)	*Struc-μ
☞ a. (<ˌfo$_\mu$><no$_\mu$>)<lo$_\mu$>(<ˈɣi$_\mu$>)		**	****
b. (<ˌfo$_\mu$.nə>)<lo$_\mu$>(<ˈɣi$_\mu$>)	*!	*	***
c. (<ˌfo$_\mu$><no$_\mu$>)lə(<ˈɣi$_\mu$>)	*!	**	***
d. (<ˌfo$_\mu$.nə>)lə(<ˈɣi$_\mu$>)	*!*	*	**

Table 23: *Struc-μ >> Project(V,μ) leads to reduction in all unstressed syllables.

/fonoloɣi/		SWP(D_μ)	*Struc-μ	Project(V,μ)
a.	(<ˌfo$_\mu$><no$_\mu$>)<lo$_\mu$>(<ˈɣi$_\mu$>)	**!	****	
b.	(<ˌfo$_\mu$.nə>)<lo$_\mu$>(<ˈɣi$_\mu$>)	*	***!	*
c.	(<ˌfo$_\mu$><no$_\mu$>)lə(<ˈɣi$_\mu$>)	**!	***	*
☞ d.	(<ˌfo$_\mu$.nə>)lə(<ˈɣi$_\mu$>)	*	**	**

[21] For Dutch, it is presumed that all constraints that regulate foot placement outrank SWP(D_μ).

Table 24: Low-ranking Project(V,μ)/Ft cannot lead to selective reduction outside feet.

	/fonoloɣi/	*Struc-μ	SWP(D_μ)	Project(V,μ)	Project(V,μ)/Ft
☞	a. (<ˌfo$_\mu$><no$_\mu$>)<lo$_\mu$>(<ˈɣi$_\mu$>)	****	**		
☞	b. (<ˌfo$_\mu$.nə>)<lo$_\mu$>(<ˈɣi$_\mu$>)	***	*	*	*
	c. (<ˌfo$_\mu$><no$_\mu$>)lə(<ˈɣi$_\mu$>)	***	**!	*	
☞	d. (<ˌfo$_\mu$.nə>)lə(<ˈɣi$_\mu$>)	**	*	**	*

Table 25: Non-exhaustive Moraic Domain parsing within a foot is harmonically bounded.

	/fonoloɣi/	SWP(D_μ)	*Struc-μ	Project(V,μ)
	a. (<ˌfo$_\mu$><no$_\mu$>)<lo$_\mu$>(<ˈɣi$_\mu$>)	**	****	
	b. (<ˌfo$_\mu$.nə>)<lo$_\mu$>(<ˈɣi$_\mu$>)	*	***	*
	c. (<ˌfo$_\mu$.nə>)lə(<ˈɣi$_\mu$>)	*	**	**
☜	d. (<ˌfo$_\mu$>nə)lə(<ˈɣi$_\mu$>)	**	**	**

Finally, within-word variation must also be accounted for: the same word can be produced with no reduction, selective reduction in directly post-tonic position, or reduction in all unstressed syllables, as illustrated in (30) in Section 4.1. The simplest choice might be a theory of variation that uses variable ranking of constraints (Van Oostendorp 1995; 1997b; Anttila 1997; 2002; Nagy & Reynolds 1997; Boersma 1998; Jarosz 2015). In such theories, one may specify that SWP(D_μ), Project(V,μ), and *Struc-μ may be ranked variably with respect to one another, with the following results:

(35) Project(V,μ) >> SWP(D_μ), *Struc-μ:
  No reduction, as in Tables 21 and 22
 SWP(D_μ) >> Project(V,μ) >> *Struc-μ:
  Directly post-tonic reduction, as in Tables 19 and 20
 Any ranking with *Struc-μ >> Project(V,μ):
  Reduction of all unstressed syllables, as in Table 23

Under any ranking of these constraints, structures with foot-internal unstressed syllables that are not in a Moraic Domain are ruled out, as illustrated in Table 25. As can be seen, candidate d. in this tableau, which has an unstressed syllable [nə] that is in a foot but not in a Moraic Domain, is harmonically bounded because it has all the violations of candidate c., but also an addition violation of SWP(D_μ).

As pointed out by an anonymous reviewer, a Maximum Entropy model of variation (Goldwater & Johnson 2003) makes predictions that are slightly different from the variable ranking model. In the variable ranking model used here, either all post-tonic vowels reduce (if SWP >> Project(V,μ) or *Struc-μ >> Project(V,μ)), or no post-tonic vowels reduce (if Project(V,μ) >> SWP, *Struc-μ). Words with multiple non word-final post-tonic vowels are rare in Dutch, but, as illustrated in (36), reducing only one of the post-tonic vowels in such words is very odd (unless one of the vowels is lexically marked as non-reducing).

(36) a. (ˌɛndo)(ˌkrino)(ˈloχ) ~ (ˌɛndə)(ˌkrinə)(ˈloχ) 'endocrinologist'
 b. *(ˌɛndo)(ˌkrinə)(ˈloχ), *(ˌɛndə)(ˌkrino)(ˈloχ)

In a Maximum Entropy model, as pointed out by Vaux (2008); Riggle & Wilson (2005), there is no easy way to capture these facts: any model that allows the variants (36a) must also allow variants (36b). A candidate's probability is proportional to its Harmony (weighted sum of constraint violations). Table 26 below shows candidates' Harmonies relative to those of the ungrammatical candidates, namely, candidates b. and c. Since +(x+y–z) and –(x+y–z) cannot both be greater than zero (compare +x and –x), there is no weighting of the constraints than will give the ungrammatical candidates, b. and c., a lower Harmony (and thus, a smaller probability) than both grammatical candidates, a. and d. Thus, a Maximum Entropy account would fail to model the grammaticality distinctions in (36).

Because of this, a variable ranking account seems to be better suited for these data. However, more empirical investigation into this matter is necessary.

4.2.1.1 The interaction between non-moraicity and vowel quality

As indicated in Section 4.1, there are systematic exceptions to the pattern of foot-internal-only reduction treated in the preceding subsection. When a foot-external vowel has a quality that is more susceptible to reduction than a foot-internal vowel, there is the possibility of reducing the foot-external syllable instead of the foot-internal one:

(37) /dekoratif/ → [ˌdekorəˈtif] 'decorative' (repeated from (31) in Section 4.1)
/apokalɪps/ → [ˌapokəˈlɪps] 'apocalypse'
/nominatief/ → [ˌnominəˈtif] 'nominative'

In the account of Dutch vowel reduction so far, I have assumed that *Nonmoraic/Full Vowel has a fixed ranking above Ident(V). However, to account for these data, this ranking has to be made variable.[22]

Following Van Oostendorp (1995; 2000), I propose to allow a fixed ranking Ident(high) >> Ident(round) >> Ident(low) (which expresses the reducibility hierarchy of Dutch vowels according to Kager 1989) to be ranked variably with respect to *Nonmoraic/Full Vowel.[23] If Ident(round) is ranked above *Nonmoraic/Full Vowel, which, in turn, is above Ident(low), then /a/ reduces, while /o/ remains unaffected, as shown in Table 27.

In Table 27, candidates b. and d. (in which the rounded vowel, /o/, is reduced) are ruled out by high-ranked Ident(round). Candidate a. is ruled out by its additional violation of *Nonmoraic/Full Vowel. Because the foot-external vowel, /a/, violates a low-ranked Faithfulness constraint, while the foot-internal vowel, /o/, violates a high-ranked Faithfulness constraint, reduction in foot-external position is allowed in this particular

Table 26: A Maximum Entropy model cannot derive the facts in (36).

	Weight = x	**Weight = y**	**Weight = z**	
/ɛndokrinoloχ/	***Struc-μ**	**SWP (D_μ)**	**Project (V,μ)**	**Harmony relative to candidates b. and c.**
a. (<ˌɛn$_{\mu\mu}$><do$_{\mu}$>)(<ˌkri$_{\mu}$><no$_{\mu}$>) (<ˈloχ$_{\mu\mu\mu}$>)	−8	−2		-(x+y–z)
b. (<ˌɛn$_{\mu\mu}$><do$_{\mu}$>)(<ˌkri$_{\mu}$.nə>) (<ˈloχ$_{\mu\mu\mu}$>)	−7	−1	−1	0
c. (<ˌɛn$_{\mu\mu}$.də>)(<ˌkri$_{\mu}$><no$_{\mu}$>) (<ˈloχ$_{\mu\mu\mu}$>)	−7	−1	−1	0
d. (<ˌɛn$_{\mu\mu}$.də>)(<ˌkri$_{\mu}$.nə>)(<ˈloχ$_{\mu\mu\mu}$>)	−6		−2	+(x+y–z)

[22] In principle, a variable ranking of Ident with respect to the mora assignment constraints is also possible, but see the end of Section 3.2 for potential problems in the interaction between SWP(D_μ) and Faithfulness.

[23] If a Harmonic Serialism solution were proposed along the lines of Section 3.2, then, instead of Ident-constraints for individual features, Project(Feature,μ) constraints would be substituted. This is because the Harmonic Serialism solution would create Moraic Domain structure at a different step from changing the vowel quality of underlying vowels, and Ident-constraints would not be able to block the creation of a binary Moraic Domain.

Table 27: Vowel quality-dependent selective reduction motivated by Faithfulness.

/dekoratif/	Ident(rnd)	*Nonmoraic/Full Vowel	Ident(Lo)
a. (<ˌde$_\mu$.ko>)ra(<ˈtif$_\mu$>)		**!	
b. (<ˌde$_\mu$.kə>)ra(<ˈtif$_\mu$>)	*!	*	
☞ c. (<ˌde$_\mu$.ko>)rə(<ˈtif$_\mu$>)		*	*
d. (<ˌde$_\mu$.kə>)rə(<ˈtif$_\mu$>)	*!		*

word. However, when both foot-internal and foot-external vowels have the same quality, as in the example considered in Section 4.2.1, /fonoloɣi/, there is no reason to prefer (<ˌfo.no>)<lə>(<ˈɣi>) over (<ˌfo.nə>)<lo>(<ˈɣi>), since they both violate the same Faithfulness constraints.

While a variable relationship between a vowel's moraic status and its quality allows for an account for these additional facts of Dutch vowel reduction, it has to be assured that this does not predict any additional problematic interactions. (38) below provides an overview of how various rankings of Ident(round) >> Ident(low) with respect to *Nonmoraic/Full Vowel affect /fonoloɣi/ and /dekoratif/ under various Moraic Domain parses, showing that this produces foot-external-only reduction precisely when the foot-external vowel has a higher reducibility (as /a/ has a higher reducibility than /o/), but not when the foot-internal and the foot-external vowels have the same quality.

(38) a. Ident(round) >> Ident(low) >> *Nonmoraic/Full Vowel
(<ˌfo><no>)<lo>(<ˈɣi>) (<ˌde><ko>)<ra>(<ˈtif>)
(Project(V,μ) on top)
(<ˌfono>)<lo>(<ˈɣi>) (<ˌdeko>)ra(<ˈtif>)
(SWP>>Project(V, μ)>>*Struc-μ)
(<ˌfono>)lo(<ˈɣi>) (<ˌdeko>)<ra>(<ˈtif>)
(*Struc-μ >> Project(V,μ))

b. Ident(round) >> *Nonmoraic/Full Vowel >> Ident(low)
(<ˌfo><no>)<lo>(<ˈɣi>) (<ˌde><ko>)<ra>(<ˈtif>)
(<ˌfono>)lo(<ˈɣi>) (<ˌdeko>)rə(<ˈtif>)
(<ˌfono>)<lo>(<ˈɣi>) (<ˌdeko>)<ra>(<ˈtif>)

c. *Nonmoraic/Full Vowel >> Ident(round) >> Ident(low)
(<ˌfo><no>)<lo>(<ˈɣi>) (<ˌde><ko>)<ra>(<ˈtif>)
(<ˌfonə>)lə(<ˈɣi>) (<ˌdekə>)rə(<ˈtif>)
(<ˌfonə>)<lo>(<ˈɣi>) (<ˌdekə>)<ra>(<ˈtif>)

4.2.2 Existing approaches

There is an extensive previous literature on Dutch vowel reduction (Kager 1989; Van Oostendorp 1995; 1997b; 2000; de Lacy 2002; Geerts 2008; Martínez-Paricio 2013).

Kager (1989) provides a pre-OT analysis, in which reduction rules are split up by underlying vowel quality and by style. For "rather formal" or semi-informal style (Kager's style level II), reduction of /o/ and /i/ applies only in foot-internal unstressed syllables and not in foot-external syllables (which Kager assumes are adjoined to the foot). This leads to post-tonic reduction only, cf. (34c) in Section 4.1: /fonoloɣi/ → (ˌfonə)lo(ˈɣi). For informal style (Kager's style level I), reduction of /o/ and /i/ applies in all unstressed syllables, yielding forms like /fonoloɣi/ → (ˌfonə)lə(ˈɣi).

Van Oostendorp (1995; 2000) provides a constraint-based analysis of the phenomenon, where schwa is seen as a completely underspecified vowel, and traditionally foot-external vowels are parsed into unstressed unary feet: (ˌfo.no)(lŏ)(ˈɣi). Vowel reduction is accounted for by the interaction of a constraint against unstressed featurally specified vowels with a constraint that protects vowels from reducing in foot heads, and a constraint that protects vowels from reducing in the heads of binary feet. In addition, a ranking of MAX(FEATURE) constraints regulates which vowel reduces in which circumstance. Van Oostendorp (1997b) adds a more sophisticated model of variation to this analysis. Typologically speaking, Van Oostendorp's approach cannot account for the Ambiselectivity Generalization: there is no constraint that motivates reduction in foot-external syllables only (or, in Van Oostendorp's terms, unstressed unary foot heads), so that reduction takes place either inside the foot or in all unstressed positions.

De Lacy (2002) provides an analysis of reduction in terms of his theory of Markedness, in which there are reduction pressures that apply in all foot non-heads (only schwa in all foot-internal unstressed syllables) and reduction pressures that apply in all prosodic word non-heads (only schwa in all syllables without primary stress). In Dutch, these interact with Faithfulness constraints on various vowel qualities and with a Faithfulness constraint that protects syllables with secondary stress from reducing. Typologically, this approach fails to account for the Ambiselectivity Generalization, since there is no constraint that prefers reduction in foot-external syllables only. Martínez-Paricio's (2013) approach to Dutch vowel reduction was laid out in Section 3.5; as explained there, it accounts for the Ambiselectivity Generalization, but not for the Sonority Requirement Generalization.

Geerts (2008) proposes a different kind of analysis, which aims to unify vowel reduction and vowel deletion. This analysis proposes a crucial role for positional Faithfulness constraints on foot heads, foot non-heads ("footweak"), and unfooted syllables, which interact with general Markedness constraints against features and segments. Typologically, this approach can indeed account for the Ambiselectivity Generalization, since MAX-IO-FOOTWEAK >> *FEATURE >> MAX-IO-UNFOOTED yields reduction in foot-internal unstressed syllables only, while MAX-IO-FOOTWEAK >> *FEATURE >> MAX-IO-UNFOOTED yields reduction in foot-external syllables only. However, as soon as this model is adapted to differentiate between specific vowel qualities, it fails to derive the Sonority Requirement Generalization. A ranking like *[LOW], MAX(BACK)-IO-FOOTWEAK >> *ʌ >> MAX(BACK)-IO-UNFOOTED, MAX(LOW) will produce reduction of /ɑ/ to [ə] in foot-internal unstressed position, and /ɑ/ to [ʌ] in foot-external position: two different ways of reducing the same low vowel.

The analysis offered in Section 4.2.1 offers an account of the same basic facts as these previous approaches. However, it is only the current Moraic Domain account that makes predictions about non-moraicity of reduced vowels, and predicts the typology laid out in Section 2.

5 Typological predictions of the Moraic Domains approach

5.1 Accounting for the Ambiselectivity Generalization

Having accounted for selective reduction in Dutch in Section 4.2, I will now show that the current proposal can account for the Ambiselectivity Generalization. Reduction within a (minimal) foot and reduction outside a (minimal) foot can be obtained by adjusting the ranking of PROJECT(V,μ)/FT. When PROJECT(V,μ)/FT is low-ranked, SWP(D_μ) can trigger reduction within a foot and not outside of it. At the same time, when PROJECT(V,μ)/FT outranks SWP(D_μ), unstressed foot-internal syllables are forced to be moraic, and only reduction outside minimal feet is possible.

As shown in Table 28, repeated from Table 24 in Section 4.2, a low ranking of PROJECT(V,μ)/FT means that selective reduction outside a minimal foot cannot win, as is standardly the case in Dutch. Candidate c. in Table 28 embodies this kind of reduction, and it can be seen that, among the higher-ranked constraints, it has a superset of the violations of candidate b.

Table 28: Low-ranking PROJECT(V,μ)/FT cannot lead to selective reduction outside feet (repeated from Table 24 in Section 4.2).

/fonoloɣi/			*STRUC-μ	SWP(D$_\mu$)	PROJECT (V,μ)	PROJECT(V,μ)/FT
☞	a.	(<ˌfo$_\mu$><no$_\mu$>)<lo$_\mu$>(<ˈɣi$_\mu$>)	****	**		
☞	b.	(<ˌfo$_\mu$.nə>)<lo$_\mu$>(<ˈɣi$_\mu$>)	***	*	**	*
	c.	(<ˌfo$_\mu$><no$_\mu$>)lə(<ˈɣi$_\mu$>)	***	**!	**	
☞	d.	(<ˌfo$_\mu$.nə>)lə(<ˈɣi$_\mu$>)	**	*	****	*

Table 29: Selective reduction outside feet motivated by high-ranking PROJECT(V,μ)/FT.

/noɣolofi/			PROJECT(V,μ)/FT	SWP(D$_\mu$)	*STRUC-μ	PROJECT(V,μ)
	a.	(<ˌno$_\mu$><ɣo$_\mu$>) <lo$_\mu$> (<ˈfi$_\mu$>)		**	****!	
	b.	(<ˌno$_\mu$.ɣə>) <lo$_\mu$> (<ˈfi$_\mu$>)	*!	*	***	*
☞	c.	(<ˌno$_\mu$><ɣo$_\mu$>) lə (<ˈfi$_\mu$>)		**	***	*
	d.	(<ˌno$_\mu$.ɣə>) lə (<ˈfi$_\mu$>)	*!	*	**	**

However, when PROJECT(V,μ)/FT dominates SWP(D$_\mu$), selective reduction within minimal feet becomes impossible. This is because PROJECT(V,μ)/FT requires that all vowels in the foot be moraic, and selective reduction applies in non-moraic syllables. This is illustrated for hypothetical Dutch-prime (as in Section 3.5.1), which has reduction outside a minimal foot, but not within a minimal foot. I show in Table 29 that this can be generated if Dutch-prime ranks PROJECT(V,μ)/FT above SWP(D$_\mu$). Specifically, the ranking PROJECT(V,μ)/FT >> SWP(D$_\mu$), *STRUC-μ >> PROJECT(V,μ) generates selective reduction outside a minimal foot.[24] Table 29 illustrates this on the fictional word /noɣolofi/, a permutation of /fonoloɣi/ (chosen to emphasize the fact that this is not an actual possible pattern in Dutch).

The fully faithful candidate in Table 29, candidate a., is excluded because of its excessive violation of *STRUC-μ. Candidates b. and d., which have reduction within a minimal foot, are excluded by top-ranked PROJECT(V,μ)/FT. Thus, candidate c., which has reduction outside a minimal foot only, wins.

Thus, the Ambiselectivity Generalization is accounted for because there are two opposing forces in the constraint set: a constraint in favor of unstressed non-moraic syllables in the minimal foot, SWP(D$_\mu$), and a constraint against non-moraic syllables in the minimal foot, PROJECT(V,μ)/FT. As discussed in Section 3.3.1, Moraic Domains are necessary for a constraint that favors non-moraic footed syllables without creating a major typological pathology: SWP(D$_\mu$) avoids the pitfalls of FOOTTAIL-NONMORAIC.

5.2 Accounting for the Sonority Requirement Generalization

In the current proposal, sonority-reducing reduction (which includes all reduction of low vowels) is conditioned by non-moraicity. When there is more than one vowel reduction process, only one of these processes operates in non-moraic syllables, and it is only this process that can reduce low vowels to non-low vowels. This means that the Sonority Requirement Generalization will be obeyed: there will be at most one reduction process that disallows low vowels in the output. I will demonstrate the fact that the Sonor-

[24] The ranking of SWP(D$_\mu$) with respect to IDENT(V) does not matter in this case.

ity Requirement Generalization is obeyed with an attempt to derive the Pseudo-Russian pattern (Section 3.5.2), repeated in (39), which violates this generalization.

(39) *Pseudo-Russian (two reduction processes, both sonority-reducing) (repeated from (14) in Section 3.5)*
Stressed: no reduction
/kam(e)nʲ/ → ((ˈka)m**ɨ**nʲ)
Minimal foot-internal: /i,e/ → [i], /a,o/ → [ə], /u/ → [u]
/kam(e)nʲ-ej/ → (k**ə**m.ˈnʲej)
All other unstressed syllables: /i,e,a,o,u/ → [ɨ]
/kam(e)nʲ-ist-oj/ → (k**ɨ**((mʲ**i**.ˈnʲis)t**ɨ**j))
/za-kalʲi-l-a/ → (z**ɨ**((k**ə**.ˈlʲi)l**ɨ**)

Table 30 shows the failure of the current approach to generate Pseudo-Russian. As in actual Russian, foot-external positions are made non-moraic and foot-internal syllables are made moraic by ranking PROJECT(V,μ)/FT above *STRUC-μ and SWP(D_μ), and *STRUC-μ above Faithfulness. In order to ensure that foot-external syllables reduce to [ɨ], the constraint *NONMORAIC/>ɨ (formed using Crosswhite's constraint schema: nonmoraic syllables must be no more sonorous than [ɨ]) is ranked above both MAX constraints (which both prefer for /a/ to remain a low vowel). *NONMORAIC/FULL VOWEL is ranked below *NONMORAIC/>ɨ, but still above Faithfulness.

In Table 30, all candidates with moraic foot-external syllables (in this case, a.) are ruled out by their excessive violations of *STRUC-μ, leaving only non-moraic foot-external syllables. Non-moraic foot-internal syllables, as in candidates e. through g., are ruled out by top-ranked PROJECT(V,μ)/FT. Of the candidates with moraicity only inside the foot, those with anything but [ɨ] in non-moraic position (here, these are b., e., and f.) are excluded by top-ranked *NONMORAIC/>ɨ. The remaining candidates (c., d.) both reduce foot-external /a/ to [ɨ], and of these, the winner is the one that does not reduce foot-internal /a/ to a non-low vowel (c.), since the foot-internal /a/ is moraic and is not motivated to reduce in this way, leading to excessive violation of Faithfulness for candidate d.

Table 30: Pseudo-Russian cannot be derived with the current Moraic Domain account.

/za-kalʲi-la/	PROJECT (V,μ)/FT	*NON MORAIC/>ɨ	SWP (D_μ)	*STRUC-μ	*NON MORAIC/ FULL VOWEL	MAX (–HI)	MAX (+LO)
a. μ μ μ μ <za>(<ka><ˈlʲi>)<la>			*	***!*			
b. μ μ za(<ka><ˈlʲi>)la		*!*	*	**	**		
☞ c. μ μ zɨ(<ka><ˈlʲi>)lɨ			*	**		**	**
d. μ μ zɨ(<kə><ˈlʲi>)lɨ			*	**		**	***!
e. μ zɨ(<kə.ˈlʲi>)lɨ	*!	*		*		**	***
f. μ zə(<kə.ˈlʲi>)lə	*!	***		*			***
g. μ zɨ(<kɨ.ˈlʲi>)lɨ	*!			*		***	***

The two candidates that represent the intended Pseudo-Russian pattern, d. and e., are both harmonically bounded. Candidate d. has a superset of candidate c.'s violations. Candidate e. is collectively harmonically bounded by candidates f. and g.: among e.-g., e. is not preferred by any single constraint.

This result was reached because all non-moraic syllables obey the same reduction constraints (which collectively block candidate e. in Table 30 from winning), and no constraints in the current proposal motivate a low vowel to change to a non-low vowel in a moraic syllable (which blocks candidate d. in Table 30 from winning).

5.3 Computational test of typology

To verify computationally that the current account indeed predicts both the Ambiselectivity Generalization and the Sonority Requirement Generalization, OT-Help 2.0 (Staubs et al. 2010) was used to calculate the factorial typology of the constraint set used in the current analysis, as listed in (40a).

The test was performed on an abstract form /salataba/ → [ˈsV.lV.tV.ˈbV]. This form has two unstressed syllables with underlying /a/, one of which is foot-internal and the other, foot-external. This yields a test for the reduction properties of low vowels in these two types of positions. Two foot parses were considered for this form: one trochaic and one iambic, as in (40b). Within these foot parses, every possible Moraic Domain parse was considered, except for foot-internal syllables remaining unparsed by Moraic Domains, which yielded 4 Moraic Domain parses in total, as in (40c). Finally, the surface quality of the vowels could be [a], [ə], or [ɨ], and all 81 possible combinations were considered, as illustrated in (40d). Crucially, in order to address the violable relationship between vowel quality and moraicity, candidates with both moraic and nonmoraic, reduced and unreduced unstressed vowels were included: (<ˈsa$_{\mu}$><la$_{\mu}$>), (<ˈsa$_{\mu}$><lə$_{\mu}$>), (<ˈsa$_{\mu}$.la>), (<ˈsa$_{\mu}$.lə>). This was done to illustrate the fact that this violable relationship does not yield typological intractability. The total number of candidates in the tableau for /salataba/ was 648.

(40) a. *Constraints considered in the OT-Help computation:*

*Nonmoraic/full vowel	(motivates reduction to schwa)
*Nonmoraic/>ɨ	(motivates reduction to [ɨ])
Lic-Nonperiph(Stress)	(motivates reduction to corner vowels)[25]
Project(V,μ)	(motivates a mora on every syllable)
Project(V,μ)/Ft	(motivates a mora on every syllable in a foot)
Ft-Bin(μ)	(motivates feet that are binary in terms of morae)
*Struc-μ	(wants as few morae as possible)
SWP(D$_{\mu}$)	(motivates a non-moraic weak syllable in a foot)
Trochee, Iamb	(motivate trochaic and iambic feet, respectively)
Ident(lo), Ident(hi)	(motivate retention of underlying vowel qualities)

b. *Two foot parses:*

(ˈsa.la)ta(ˈba) (trochaic) (ˈsa)la(ta.ˈba) (iambic)

c. *Moraic Domains:*

{(<ˈsa$_{\mu}$><la$_{\mu}$>),(<ˈsa$_{\mu}$.la>)}	(<ˈsa$_{\mu}$>)
{<ta$_{\mu}$>, ta}	{<la$_{\mu}$>, la}
(<ˈba$_{\mu}$>)	{(<ta$_{\mu}$><ˈba$_{\mu}$>), (<ta.ˈba$_{\mu}$>)}

[25] This constraint, taken from Crosswhite (1999; 2001), penalizes unstressed non-peripheral vowels, and is necessary to motivate contrast-enhancing reduction in Russian.

d. *Vowel quality:*

$$\text{s}\begin{Bmatrix}\text{a}\\ \text{ə}\\ \text{ɨ}\end{Bmatrix}\text{l}\begin{Bmatrix}\text{a}\\ \text{ə}\\ \text{ɨ}\end{Bmatrix}\text{t}\begin{Bmatrix}\text{a}\\ \text{ə}\\ \text{ɨ}\end{Bmatrix}\text{b}\begin{Bmatrix}\text{a}\\ \text{ə}\\ \text{ɨ}\end{Bmatrix}$$

As shown in (41), the set of languages thus predicted features reduction within a foot, outside a foot, and reduction in all unstressed syllables – in accordance with the Ambiselectivity Generalization. In addition, the Sonority Requirement Generalization is also observed: there are no languages predicted in which the mappings /a/ → [ə] and /a/ → [ɨ] co-occur in the same word, like they do in harmonically bounded candidate *(ˈsa.lə)tɨ(ˈba).

(41) *Results of the OT-Help OT factorial typology computation (Moraic Domain structure not shown)*

(ˈsa.la)ta(ˈba)	(ˈsa)la(ta.ˈba)	no reduction
(ˈsa.lə)ta(ˈba)	(ˈsa)la(tə.ˈba)	reduction to [ə] within (minimal) foot only
(ˈsa.la)tə(ˈba)	(ˈsa)lə(ta.ˈba)	reduction to [ə] outside (minimal) foot only
(ˈsa.lə)tə(ˈba)	(ˈsa)lə(tə.ˈba)	reduction to [ə] in all unstressed syllables
(ˈsa.lɨ)ta(ˈba)	(ˈsa)lɨ(ta.ˈba)	reduction to [ɨ] within (minimal) foot only
(ˈsa.la)tɨ(ˈba)	(ˈsa)la(tɨ.ˈba)	reduction to [ɨ] outside (minimal) foot only
(ˈsa.lɨ)tɨ(ˈba)	(ˈsa)lɨ(tɨ.ˈba)	reduction to [ɨ] in all unstressed syllables

6 Concluding remarks

In this paper, I have proposed that an additional prosodic domain between the syllable and the foot, the Moraic Domain, enables a joint account of two typological generalizations: the Ambiselectivity Generalization, based on Martínez-Paricio (2013), and the Sonority Requirement Generalization, based on Crosswhite (1999; 2001). The Ambiselectivity Generalization holds that, when a language reduces vowels in some unstressed syllables but not others, it may choose to reduce only vowels outside the (minimal) foot, or only vowels inside the (minimal) foot. The Sonority Requirement Generalization holds that, when a language has more than one vowel reduction process, only one of these processes can be sonority-reducing, i.e., can impose the requirement that a vowel be no more sonorous than some maximum value.

Both generalizations can be derived with Moraic Domains by appealing to Crosswhite's (1999; 2001) idea that sonority-reducing reduction takes place in non-moraic syllables. Moraic Domains (whose head syllables are moraic, and whose non-head syllables are non-moraic) allow for a constraint, SWP(D_μ), that motivates non-moraic syllables within feet. Combined with a drive towards non-moraicity outside feet (Crosswhite 1999; 2001), this accounts for the Ambiselectivity Generalization (as demonstrated in Section 5.1). The Sonority Requirement Generalization is derived from Crosswhite's (1999; 2001) moraic/non-moraic distinction: all non-moraic syllables undergo the same sonority-reducing reduction process (if any), which means that there will be at most one sonority-reducing vowel reduction process per language (as demonstrated in Section 5.2).

If the same account is attempted without Moraic Domains, then either a preference for monosyllabic feet is predicted (see Section 3.3), or the Sonority Requirement Generalization is not derived (see Section 3.5). Dutch vowel reduction, discussed in Section 4, provided a case study of how Moraic Domains can motivate non-moraicity within a foot. Finally, Section 5 detailed the general mechanisms through which the current proposal accounts for both the Ambiselectivity Generalization and the Sonority Requirement Generalization, as well as a complete search of the typological space with OT-Help 2.0, which showed that the account derives both generalizations.

Several questions and issues still remain. Generally speaking, a more principled investigation into the ontology of Moraic Domains is needed, using experimental and computational evidence. For instance, in the computational domain, hidden structure learning simulations (Tesar & Smolensky 2000; Jarosz 2013) can determine if there is sufficient evidence to induce Moraic Domains from the data discussed in this paper. The details of a Harmonic Serialism account of the current data should also be worked out in future work in order to corroborate the predictions at the end of Section 3.2.

Evidence from other phonological phenomena may also be relevant. One example is stress placement. Selkirk (1978) argues that French does not have foot structure unless the word ends in a schwa syllable, in which case a disyllabic foot is constructed over the last two syllables. In a Moraic Domain account, the requirement that schwa be present in the non-head of the foot could be represented with a high ranking of SWP(D_μ), similar to the analysis of semi-informal reduction in Dutch in Section 4.2.1. This also mirrors a distributional requirement on schwa in German discussed by Itô & Mester (2011; see also references there). Van der Hulst (1984) discusses a similar distributional pattern in Dutch.

Furthermore, there might also be phonetic or intonational processes that refer to Moraic Domain edges (René Kager p.c.), in analogy to Gussenhoven's (1993) diagnostic for foot boundaries in Dutch. The application of such processes would have to vary as Moraic Domain parsing changes, as in (<ˌfo><no>)<lo>(<ˈɣi>) ~ (<ˌfo.nə>)<lo>(<ˈɣi>) in the current analysis of Dutch. For instance, the duration of unary Moraic Domain heads like <**fo**> might be greater than that of binary Moraic Domain heads like <**fo**.nə>.

In addition, some metrically conditioned consonant alternations (Whitgott 1982; Davis & Cho 2003; Davis 2005; Bennett 2012; 2013; Harris 2012; Honeybone 2012) might reference Moraic Domains. For instance, there might be a language in which fricatives are voiced only between a full vowel and schwa, but not in any other context: /afa/ → <a><fa>; /afə/ → <a.və>. Of course, the analysis of such phenomena should include evidence for the moraic status of the vowels/syllables involved.

Finally, one might expect a prosodic domain like the Moraic Domain to function as a reduplication template (Gouskova 2007). One topic for future work would be to investigate whether a Moraic Domain-sized reduplication pattern implies that the vowel reduction pattern in reduplicants might differ from that in their corresponding bases, and to which degree such a prediction would be problematic. Since Gouskova (2007) convincingly argues that reduplication templates are established through constraints that are not specific to reduplication (i.e., there is no constraint like RED = D_μ), the prediction of Moraic Domains for vowel reduction in reduplicants depends on what kinds of constraints might refer to Moraic Domains outside of the phenomenon of reduplication, which means that this prediction cannot be made straightforwardly. More research is necessary to verify and test such predictions. However, I hope to have argued convincingly that the Moraic Domain is worth considering to be a part of the prosodic hierarchy, and that such predictions are worth investigating.

Abbreviations

D_μ = Moraic Domain, Ft = Foot, SWP = Stress-to-Weight Principle, HS = Harmonic Serialism

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The author has no competing interests to declare.

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