UC Santa Cruz

Hana-bana (花々): A Festschrift for Junko Ito and Armin Mester

Title

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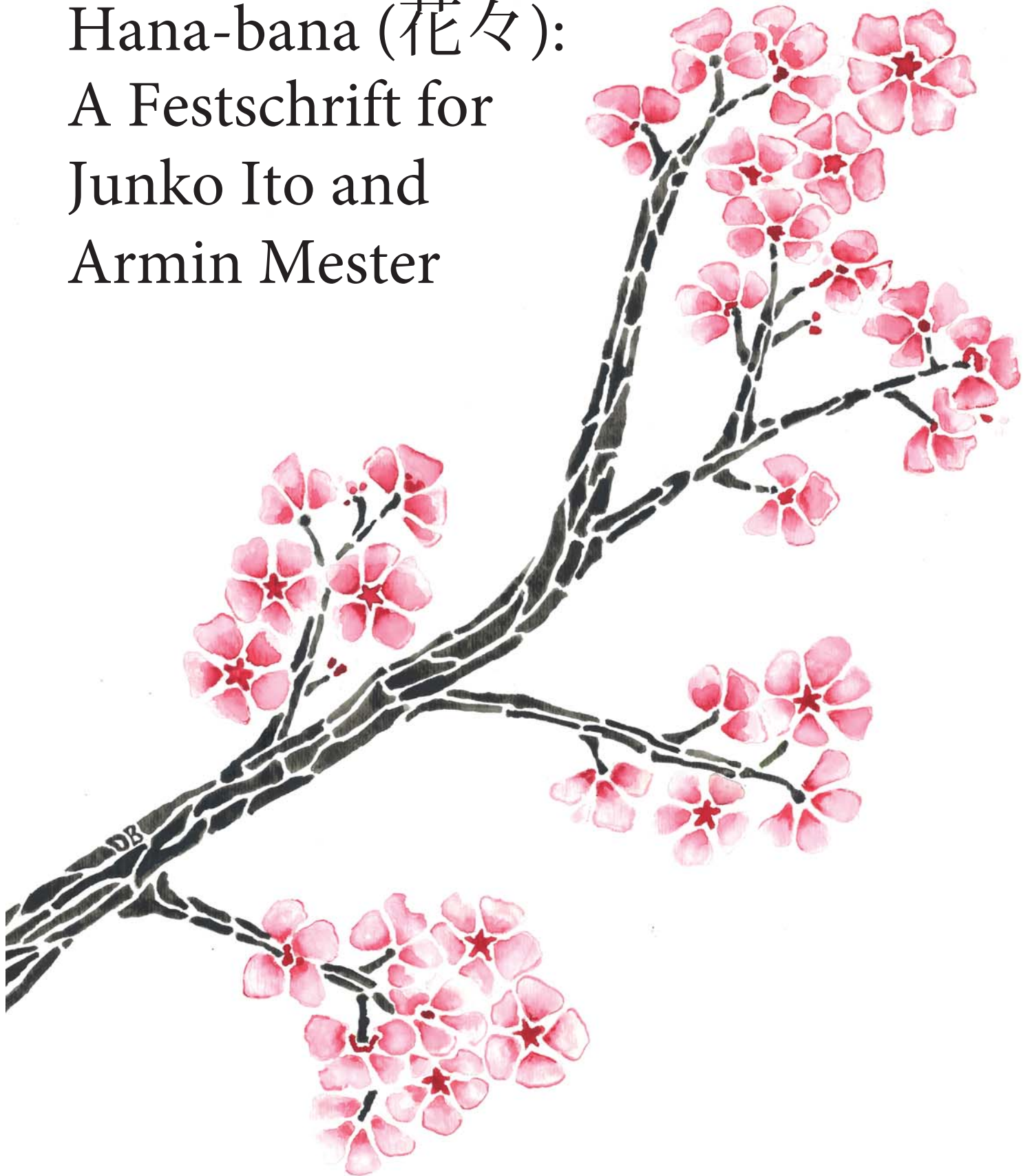Permalink

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Foreword

We are honored to present this Festschrift to celebrate the remarkable careers of Junko Ito and Armin Mester, two of the world's leading theoretical phonologists and one of the most productive, enduring research teams in our field. It is impossible to do justice to the variety and depth of their work, or to adequately express our regard for them as colleagues and friends. But we hope this volume goes some way toward doing both.

One salient feature of Junko and Armin's research—already visible in their dissertation work in the 1980s—is the explanatory depth of their analyses. Consider their research on Lyman's Law and Rendaku in Japanese, for example, which began in the 1980s and culminated in their widely-cited 2003 *Linguistic Inquiry* monograph *Japanese Morphophonemics*. Before their work on these topics, analyses of Rendaku made use of a very general rule of compound voicing, combined with ad hoc 'conditions' blocking that rule in certain highly specific environments. At best, these analyses merely restated the basic empirical observations, without explaining why these patterns have the particular shape they do.

Junko and Armin's work entirely refashioned the field's thinking on this topic. By connecting the language-particular aspects of Rendaku to more general principles like underspecification, the Obligatory Contour Principle, and prosodic recursion, they achieved a remarkable degree of explanatory success in a domain that had already been extensively studied.

Armin and Junko's early work influenced the inception of Optimality Theory—take for example Junko's proposal that an Onset parameter could be 'strong' or 'weak' but never 'off', which was a clear precursor to the notions of constraint ranking and violability. Junko and Armin then became early pioneers of Optimality Theory, applying its insights to problems that had previously seemed intractable. Over the years their work within that framework led to new discoveries about underspecification, derivational opacity, co-occurrence restrictions, all areas of prosody, and the 'core-periphery' structure of the lexicon, among many other topics.

In their work on the core-periphery structure of the lexicon, which focuses particularly on Japanese, Junko and Armin defined and developed an entirely new area of phonology. At the heart of this program is the idea that a language's vocabulary is organized into a hierarchy of 'strata of foreignness' that are in a subset-superset relationship. This claim, captured by means of articulated faithfulness constraints and constraint ranking, imposed structure and predictive power in an area of phonology that had little of either. This work has been pioneering, defining an agenda for everything that came after.

Their work in the area of prosody has been so wide-ranging and sustained that it is difficult to sum up or do right by. They have repeatedly combined the insights of constraint ranking and violability with insights specific to prosody, bringing a level of sophistication and nuance to our understanding of prosody that has been rarely matched by anyone. Their insights about 'weak layering' were an early example of this. Their more recent work on recursion in prosody can be seen as complementary to

this, violating expectations of strict layering in the opposite direction, as it were. With this work, they defined new research areas in phonology and provided new and revealing generalizations about prosodic structure.

What is so enduring about their work? First, it is always dedicated to theoretical elegance. Second, it clarifies the issues involved. It doesn't just put known issues clearly, although it does that outstandingly—there are no better papers to assign for class reading. Rather, their work makes clear *what the issues are*, essentially helping to define problems for the field. Third, their work provides beautiful empirical case studies based on a deep understanding of individual languages, most often Japanese. Armin and Junko have often joked about how well they fit the UC Santa Cruz Linguistics mold, since they work on 'understudied' languages like German and Japanese. Joke taken. But their work really is of a piece with the department, advancing theory at the highest level based on empirical analyses of specific languages that are scrupulously authoritative. They have been by far and for decades the most influential researchers in the area of Japanese phonology.

Junko and Armin are beloved advisors, and have inspired several generations of undergraduate and graduate students. As mentors, they are supportive and encouraging, but they also demand and cultivate in their students the same theoretical and empirical sophistication they display in their own work. Their legacy as teachers and mentors includes scholars around the world. The breadth of this impact can be seen in the many linguists who have shared their gratitude in the *Congratulations* section of the Festschrift web site.

As a colleague Armin has always brought his excitement about research and his practical, giving, and refreshingly honest contributions to department life and business. More than many, Junko has shaped the department and held it together. We appreciate their openness, their good humor, and their ambition. The UC Santa Cruz linguistics department has thrived in good part because of their renown and their desire that it be the best.

We chose *Hana-bana*, the title of this Festschrift, for both semantic and phonological reasons. Semantically, it means something like 'lots of flowers' in Japanese, implying different sorts of colors and kinds. It metaphorically represents Armin and Junko's work throughout their career: each piece is beautiful on its own, and only more striking when their body of work is taken as a whole. Phonologically, the word *hana-bana* involves reduplication, compounding, Rendaku voicing, and a synchronically unusual (and potentially opaque) [h]∼[b](←/p/) alternation—all topics Junko and Armin have worked on over their illustrious careers.

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Adrian Brasoveanu
Dhyana Buckley
Nick Kalivoda
Shigeto Kawahara
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Jaye Padgett

Santa Cruz, California, Dec. 2018

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Contents

OVERAPPLICATION CONVERSION*

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This squib sheds light on the relationship between two types of overapplication opacity, counterbleeding and self-destructive feeding, by demonstrating how one can be formally converted into the other. This demonstration further clarifies the relation between self-destructive feeding and cross-derivational feeding interactions, which have also been identified as involving overapplication opacity (Baković 2007, 2011).

Keywords: overapplication, opacity, counterbleeding, self-destructive feeding, cross-derivational feeding

The larger project

Our joint work (Baković and Blumenfeld 2016, 2017, to appear-a, to appear-b, in prep.) aims to formally characterize how phonological input-output maps (*qua* SPE-style rules) can be related to each other and thus how they can potentially interact with each other, building on very early work in generative phonology (Chafe 1968, Kiparsky 1968, Koutsoudas et al. 1974). One part of our project is to delimit the typology of possible pairwise map interactions, and another is to define the precise relationships between different known rule interactions. This squib is a contribution to the latter part of the project, focussing on a subset of established opaque interactions (Baković 2007, 2011) and conceived in the spirit of Ito and Mester (2003).

1 Introduction

We begin with necessary definitions of some terms as we use them throughout.

- The word *apply* is used to refer to non-vacuous, potential rule application. So, e.g. "*P* applies to *a*" means simply that $P(a) \neq a$, whether or not *P* actually applies to *a* in the language under discussion (see fn. 1), and whether or not *a* or $P(a)$ are actual forms in that language (see fn. 2).

- The word *input* (to *P*) is strictly used to refer to the undergoer of *P*'s non-vacuous application.

- The word *output* (of *P*) is strictly used to refer to the result of *P*'s non-vacuous application.

Now, consider the following interaction between an epenthesis rule and a deletion rule in Turkish.[1]

(1) Epenthesis self-destructively feeds deletion in Turkish

    a. **Epenthesis:** $\varnothing \longrightarrow i$ / C — C#

    b. **Deletion:** $k \longrightarrow \varnothing$ / V — V

    c. **Self-destructive feeding interaction:** *bebekn* $\xrightarrow{ep}$ *bebekin* $\xrightarrow{del}$ *bebein* 'your baby'

        Epenthesis feeds deletion by supplying the second vowel necessary for the deletion of *k*. But this is not a typical, transparent feeding interaction: the deletion of the *k* in turn obscures the reason why the vowel was epenthesized in the first place. This is why Baković (2007) calls this type of rule interaction *self-destructive feeding*. Like counterbleeding, self-destructive feeding is an example of Kiparsky's (1973) 'type

[1]All examples in this squib have been drastically simplified for entirely expository purposes. As an anonymous reviewer reminds us, our references to concrete language names (Turkish, Russian, Polish, English, and Cibaeño Spanish) should not be taken too literally; the actual data stand in for the more abstract types of interaction patterns that are our focus here.

(ii)' opacity, which McCarthy (1999) rechristens *overapplication opacity*: one rule (in this case, epenthesis) appears to have applied in a context where it shouldn't have (here, after a vowel instead of after a consonant) due to the subsequent, obscuring application of another rule (deletion). (See §4 for more discussion.)

Baković and Blumenfeld (2017) provide a formal framework for precisely characterizing the differences between rule interactions such as feeding, counterbleeding, and self-destructive feeding (henceforth 'seeding'). In both feeding and seeding, an earlier rule *P* crucially provides the input conditions for a later rule *Q* to apply, but in the case of feeding, *P* also potentially creates the same *outputs* as does *Q*. Consider in this regard the feeding interaction between deletion and devoicing in Russian.

(2) Deletion feeds devoicing in Russian
  a. **Deletion:** [+lat] $\longrightarrow$ $\varnothing$ / C __ #
  b. **Devoicing:** [−son] $\longrightarrow$ [−voi] / __ #
  c. **Feeding interaction:** *grebl* $\xrightarrow{del}$ *greb* $\xrightarrow{dvc}$ *grep* 'he rowed'

Deletion crucially changes *grebl* to *greb*, providing the input conditions for devoicing to apply, resulting in *grep*. But deletion can also result in an output like *grep* directly, from (hypothetical) input *grepl*. We term this *output provision*: deletion output-provides devoicing. This is not the case with Turkish seeding (1): there is no possible input to which epenthesis can apply directly to render *bebein*.[2]

To fully appreciate the distinction between feeding and seeding, it is useful to also compare seeding to counterbleeding. In both counterbleeding and seeding, there is *output removal*: a later rule *Q* changes the result of *P*'s application such that *Q*'s result is not among the possible (non-vacuous) outputs of *P*. In the case of counterbleeding, application of *P* additionally does not crucially provide inputs to *Q*. Consider in this regard the counterbleeding interaction between raising and devoicing in Polish.

(3) Devoicing counterbleeds raising in Polish
  a. **Raising:** *o* $\longrightarrow$ *u* / __ $\begin{bmatrix} +\text{voi} \\ -\text{nas} \end{bmatrix}$#
  b. **Devoicing:** [−son] $\longrightarrow$ [−voi] / __ #
  c. **Counterbleeding interaction:** *ʒwob* $\xrightarrow{rse}$ *ʒwub* $\xrightarrow{dvc}$ *ʒwup* 'crib'

Devoicing changes *ʒwub* to *ʒwup*, destroying the input conditions that made it possible for raising to apply (from *ʒwob* to *ʒwub*) and thus creating a result that is not among the possible outputs of raising. This output removal is also found in the case of seeding in Turkish: deletion changes *bebekin* to *bebein*, destroying the input conditions that made it possible for epenthesis to apply and thus resulting in a form that is not among the possible outputs of epenthesis. But in the Polish counterbleeding case, devoicing is defined such that it could (hypothetically) apply directly to input *ʒwob*, changing it to *ʒwop*. This is not true in the case of seeding in Turkish: deletion cannot apply to *bebekn* unless epenthesis changes it to *bebekin*.

The following figures summarize the key similarities and differences among these three types of rule interaction. Figure 1 illustrates the situation for feeding: one rule (in this case, Russian deletion) crucially provides both inputs and outputs for another (devoicing). Because deletion both input-provides and output-provides devoicing, devoicing does not output-provide deletion. Figure 2 illustrates the situation for counterbleeding: one rule (Polish devoicing) crucially removes both inputs and outputs from another (raising). Because devoicing both input-removes and output-removes raising, raising does not input-remove devoicing. Finally, Figure 3 illustrates the situation for seeding: one rule (Turkish epenthesis) crucially

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[2]Note that the existence or non-existence of an actual input like *grepl* in Russian has no bearing on the point just made. Rules are functions that are everywhere defined — for any possible input, a rule either produces an identical form or applies (non-vacuously) to produce something else. This means that in this example and others in this squib, we may consider input-output pairs that are abstract in the sense that they may not be found in the actual languages used as examples of the interactions of interest.

provides inputs for another rule (deletion), which in turn crucially removes outputs from the first. Seeding thus shares formal properties with both feeding (input-provision) and counterbleeding (output-removal), corresponding to its characterization as feeding with overapplication (Baković and Blumenfeld 2017).
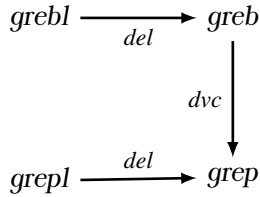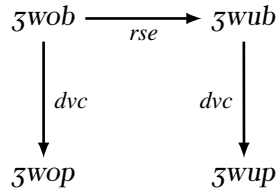

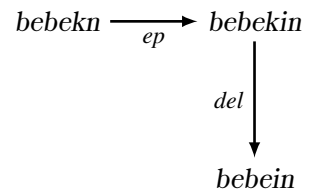**Figure 1:** *del* feeds *dvc*   **Figure 2:** *dvc* counterbleeds *rse*   **Figure 3:** *ep* seeds *del*

A convention we follow in these figures is that the first of the two rules in the ordered-rule analyses sketched in (1)-(3) above is represented horizontally, with inputs on the left and outputs on the right, while the second rule is represented vertically, with inputs above and outputs below.

Note also that the absence of an arrow is as significant as its presence in these figures: it is crucial, for example, that there is no arrow connecting *grebl* and *grepl* in the feeding example in Figure 1. If there were such an arrow, i.e. if devoicing applied to pre-sonorant obstruents as well as word-finally, then there would be no feeding — and indeed, no interaction of any kind between deletion and devoicing.

More generally, as Baković and Blumenfeld (2017) argue, any pairwise rule interaction can be characterized as some combination of one of the four basic types of relations defined in (4) below. The innovation in our work that allows us to distinguish, e.g., seeding from feeding and counterbleeding, are the output interactions in (4c,d) which have not been considered in previous work.[3]

(4)   Basic relations between rules

    a.   *P* **input-provides** *Q* if there are forms a, b such that $P(a) = b$ and *Q* applies to b but not a.

    b.   *P* **input-removes** *Q* if there are forms a, b such that $P(a) = b$ and *Q* applies to a but not b.

    c.   *P* **output-provides** *Q* if there are forms a, b such that $P(a) = b$ and there exists a form c such that $Q(c) = b$ but there does not exist a form d such that $Q(d) = a$.

    d.   *P* **output-removes** *Q* if there are forms a, b such that $P(a) = b$ and there exists a form c such that $Q(c) = a$ but there does not exist a form d such that $Q(d) = b$.

2 Conversion

Assuming that *P* is the first and *Q* is the second rule in the ordered-rule analyses, feeding as in Russian (2) is $\{P$ input-provides Q, P output-provides $Q\}$, counterbleeding as in Polish (3) is $\{Q$ input-removes P, Q output-removes $P\}$, and seeding as in Turkish (1) is $\{P$ input-provides Q, Q output-removes $P\}$. These interactions are thus defined by the structure of the mappings illustrated in Figures 1–3.

A consequence of this is that one type of interaction can — abstractly, if not concretely — be *converted* into another by adding or removing a mapping, as represented by an arrow in the diagram. For example, taking seeding as a starting point, adding a downward arrow originating in *bebekn* will yield the counterbleeding structure, while adding a leftward arrow that ends at *bebein* will yield the feeding structure. Note that this conversion operation is not (necessarily) grammar-preserving: its purpose is simply to illustrate the formal connections between various types of interactions, and to uncover their hidden commonalities. After introducing the operation, in the following subsection, we will uncover such a commonality between counterbleeding and another interaction called *cross-derivational feeding* (Baković 2007, 2011).

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[3]These definitions are somewhat simplified here, in that they do not cover certain types of cases where e.g. there is more than one locus of application of a rule in a form. For a more formally comprehensive account, see Baković and Blumenfeld (in prep.).

2.1 Converting Russian feeding to seeding

In the rule formalism of *SPE* (Chomsky and Halle 1968), these mappings can be excised or added via judicious rule re-writing. For example, in order to convert the Russian feeding example in (2) to seeding, we can specify that the consonant in the environment of deletion (2a) must be voiced, as in (5).

(5) **Modified deletion:** $[+\text{lat}] \longrightarrow \varnothing \ / \ \underset{[+\text{voi}]}{C} \underline{\quad} \#$

$$grebl \xrightarrow{\ mod\text{-}del\ } greb$$
$$\downarrow {\scriptstyle dvc}$$
$$grep$$
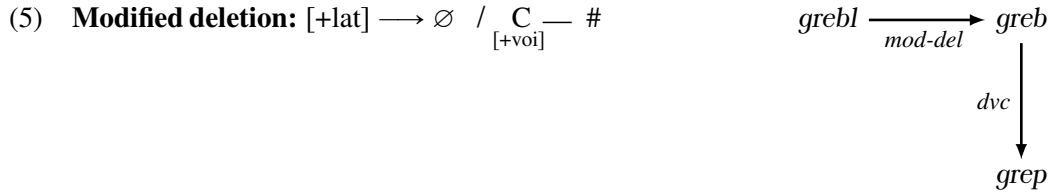
Figure 4: *mod-del* seeds *dvc*

This successfully excises the output-providing $grepl \xrightarrow{del} grep$ mapping from Figure 1 that differentiates this case of feeding from seeding: removal of a lateral after a voiced obstruent exposes that obstruent to devoicing, which in turn obscures the reason for the removal of the lateral. But of course, the resulting seeding interaction does not generate the same overall input-output map as the original Russian feeding interaction in (2): final laterals preceded by **any consonant** are deleted in Russian, but only laterals preceded by **voiced consonants** are deleted if we substitute the modified version of deletion in (5) for (2a).

As an anonymous reviewer points out, it could also be questioned whether the modified deletion rule in (5) is 'natural' (e.g., phonetically motivated), and the same can be said for the other modified rules contemplated for Polish and Turkish in the subsections below. Our focus here is on the *formal relationships* between different abstract types of rule interactions, not on the *substantive differences* between different particular tokens of rules; whether a rule rewritten for the purposes of conversion is 'natural' — or 'as natural' as the original rule — is beside the point; but see §3 for some further discussion of this issue.

2.2 Converting Polish counterbleeding to seeding

Rule re-writing is not always achievable in practice, given the limitations of (specific theories of) natural class descriptions. For example, in order to convert the Polish counterbleeding example to seeding, we need to excise the input-removing $ʒwob \xrightarrow{dvc} ʒwop$ mapping from Figure 2 that differentiates this case of counterbleeding from seeding. We can achieve this excision by specifying that the vowel preceding the obstruent target of devoicing (3b) must not be *o*, but there is no clear way of accomplishing this in most if not all distinctive feature theories except in the most *ad hoc* of ways, as in (6).

(6) **Modified devoicing:** $[-\text{son}] \longrightarrow [-\text{voi}] \ / \ \underset{\neg o}{V} \underline{\quad} \#$

$$ʒwob \xrightarrow{\ rse\ } ʒwub$$
$$\downarrow {\scriptstyle mod\text{-}dvc}$$
$$ʒwup$$
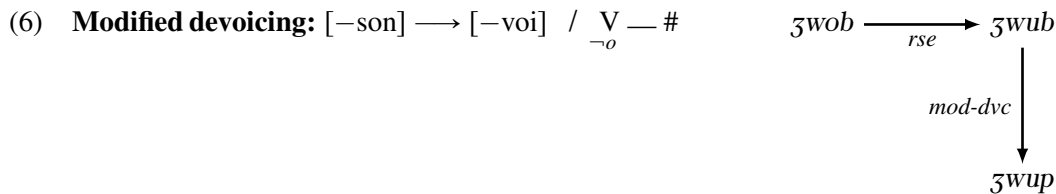
Figure 5: *rse* seeds *mod-dvc*

This challenge of formalism aside, the resulting interaction in this case *does* generate the same overall input-output map as the original counterbleeding interaction in (3) because final voiced obstruents preceded by *o* don't (directly) undergo devoicing either way. With the original devoicing rule in (3b), potential inputs to mappings like $ʒwob \xrightarrow{dvc} ʒwop$ all undergo raising instead ($ʒwob \xrightarrow{rse} ʒwub$) because

raising precedes devoicing; the result is only subsequently devoiced ($\text{ʒwub} \xrightarrow{dvc} \text{ʒwup}$). The only difference with the modified version of devoicing in (6) is that there is no need to rely on the prior application of raising to prevent *ʒwob* from undergoing devoicing; the conversion to seeding has no empirical effect.

2.3 Converting Turkish seeding to feeding or counterbleeding

To convert the Turkish case of seeding to feeding, we need to add to Figure 3 the output-providing mapping *beben* $\xrightarrow{ep}$ *bebein*, which means that the epenthesis rule in (1a) needs to be re-written as in (7).

(7) **Modified epenthesis:** $\varnothing \longrightarrow i \ / \ \text{—} \ \text{C\#}$

$$
\begin{array}{ccc}
\text{bebekn} & \xrightarrow{\ \ mod\text{-}ep\ \ } & \text{bebekin} \\
& & \downarrow{\scriptstyle del} \\
\text{beben} & \xrightarrow{\ \ mod\text{-}ep\ \ } & \text{bebein}
\end{array}
$$
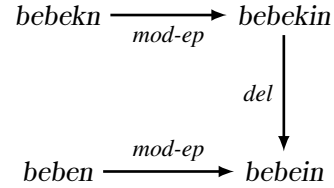
Figure 6: *mod-ep* feeds *del*

To convert the Turkish case to counterbleeding, we instead need to add the input-removing mapping *bebekn* $\xrightarrow{del}$ *beben* to Figure 3, which means that the deletion rule in (1b) needs to be re-written as in (8).

(8) **Modified deletion:** $k \longrightarrow \varnothing \ / \ \text{V} \ \text{—}$

$$
\begin{array}{ccc}
\text{bebekn} & \xrightarrow{\ \ ep\ \ } & \text{bebekin} \\
\downarrow{\scriptstyle mod\text{-}del} & & \downarrow{\scriptstyle mod\text{-}del} \\
\text{beben} & & \text{bebein}
\end{array}
$$
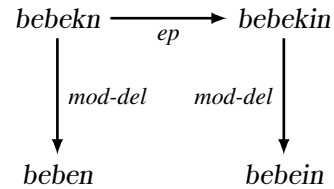
Figure 7: *mod-del* counterbleeds *ep*

As in the Russian example, the resulting interaction given either of these conversions does not generate the same overall input-output map as the original seeding interaction in (1). In Turkish, *i* is epenthesized **between pairs** of word-final consonants; the modified version of epenthesis in (7) more generally epenthesizes *i* **before any single** word-final consonant. Similarly, *k* is deleted **between pairs** of vowels in Turkish; the modified version of deletion in (8) more generally deletes *k* **after any single** vowel.

2.4 Summary

Any feeding or counterbleeding interaction can be converted to seeding by excising a relevant mapping: an output-provision one in the case of feeding or an input-removal one in the case of counterbleeding. The same is of course true in the opposite direction, *mutatis mutandis*: seeding can be converted to feeding by adding an output-provision mapping, or to counterbleeding by adding an input-removal mapping.

The relative ease or lack of ease with which conversion can be achieved is entirely a property of the formalism in which the maps are expressed rather than of the maps themselves, and it is independent of the particular type or direction of conversion. This is clear from the comparison between Polish and Turkish: if the interaction we had started from in the Turkish example were the counterbleeding interaction illustrated in Figure 7, the conversion to seeding would involve excision of the input-removal mapping just as in the Polish example; the formalism allows this to be expressed easily in the case of Turkish, but not in the case of Polish. The observation about the relationship between types of interactions is formalism-neutral.

Finally, the result of conversion may or may not result in the same overall input-output map as the original. This also appears to be independent of the particular type or direction of conversion: if the

interaction we had started from in the Turkish example were the counterbleeding interaction illustrated in Figure 7, the conversion to seeding would involve excision of the input-removal mapping just as in the Polish example; the result is grammar-preserving in the case of Polish, but not in the case of Turkish.

3 From bleeding to cross-derivational feeding

Conversion via mapping excision or addition is just one way to convert one type of interaction into another. As is well-known from the rule-ordering literature, feeding and counterfeeding can be converted into one another via rule re-ordering; likewise for bleeding and counterbleeding.[4] Here we discuss a specific case of a bleeding interaction, change it to counterbleeding via rule re-ordering, and then convert that counterbleeding interaction into seeding via excision of the input-removal mapping, as we did in the case of Polish.

Like the Polish case, the overall map generated by counterbleeding and by seeding is the same. Unlike the Polish case, however, the modified rule is formally unremarkable, and the modification corresponds to the structural description of the rule necessary for a *cross-derivational feeding* analysis of the map generated by the original bleeding interaction (Baković 2005, 2007, 2011, Pająk and Baković 2010). This is of formal interest given the claim made by Baković (2007) that cross-derivational feeding, like counterbleeding and seeding, involves overapplication opacity, even though the map generated by cross-derivational feeding is the same as the one generated by (transparent) bleeding, as discussed in more detail in §4.

3.1 From bleeding to counterbleeding

Consider now the bleeding interaction (9c) between epenthesis (9a) and assimilation (9b) in the English past tense alternation, which we can convert to counterbleeding (9d) via rule re-ordering.[5]

(9) Epenthesis bleeds assimilation in English

a. **Epenthesis:** $\varnothing \longrightarrow \partial\ /\ \begin{bmatrix} +\text{cor} \\ -\text{son} \\ -\text{cont} \end{bmatrix} - \begin{bmatrix} +\text{cor} \\ -\text{son} \\ -\text{cont} \end{bmatrix} \#$

b. **Assimilation:** $[-\text{son}] \longrightarrow [\alpha\text{voi}]\ /\ \begin{bmatrix} -\text{son} \\ \alpha\text{voi} \end{bmatrix} - \#$

c. **Actual bleeding interaction:** *hitd* $\xrightarrow{ep}$ *hitəd* $\xrightarrow{asm}$ *hitəd* 'heated'

d. **Hypothetical counterbleeding interaction:** *hitd* $\xrightarrow{asm}$ *hitt* $\xrightarrow{ep}$ *hitət*

The epenthesis rule (9a) is stated such that it applies between final sequences of coronal stops; that is, to the set of input substrings $\{td\#,\ tt\#,\ dt\#,\ dd\#\}$. The fact that this rule specifically ignores possible differences in voicing between the two coronal stops is necessary for the bleeding interaction (9c) to effect the actual English input-output mappings: epenthesis must have priority to apply to the input substring *td#*; assimilation (9b) is also applicable to this substring, but does not in fact apply to it. For the hypothetical counterbleeding interaction (9d), however, epenthesis effectively applies only between final sequences of *identical* coronal stops, $\{tt\#,\ dd\#\}$, because the prior application of assimilation ensures that the voicing-wise distinct sequences $\{td\#,\ dt\#\}$ are mapped to the completely identical sequences $\{tt\#,\ dd\#\}$.

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[4]Hein et al. (2014) also propose a *rule flipping* operation that converts between (counter)feeding and (counter)bleeding. See Baković and Blumenfeld (to appear-b) for more extensive discussion of all three of these conversion operations.

[5]Vaux and Myler (2018: 180-181), citing Anderson (1973), claim that dialects of English consistent with this counterbleeding interaction exist; Vaux (2016) reports on a follow-up confirmation of their existence via a query on Facebook. The present authors are skeptical and await properly controlled phonetic verification, though nothing in the following relies on the result.

3.2 From counterbleeding to seeding

This means that, as far as the hypothetical counterbleeding interaction (9d) goes, the epenthesis rule can be innocuously re-written as (10). This modification excises the input-removing mapping $hitd \xrightarrow{ep} hit\partial d$, which effectively converts the counterbleeding interaction (Figure 9) into seeding (Figure 10).[6]

(10) **Modified epenthesis:** $\varnothing \longrightarrow \partial \left/ \begin{bmatrix} +\text{cor} & -\text{son} \\ -\text{cont} & \alpha\text{voi} \end{bmatrix} - \begin{bmatrix} +\text{cor} & -\text{son} \\ -\text{cont} & \alpha\text{voi} \end{bmatrix}\# \right.$
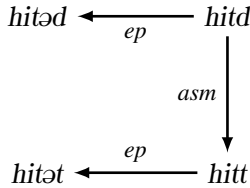
Figure 8: *ep* bleeds *asm*
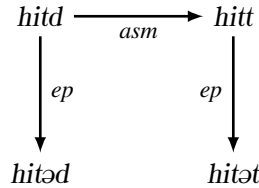
Figure 9: *ep* counterbleeds *asm*
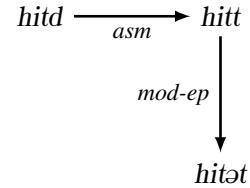
Figure 10: *asm* seeds *mod-ep*

3.3 From seeding to cross-derivational feeding

The addition of [αvoi] to the original epenthesis rule (9a) to create the modified epenthesis rule (10) allows us to generalize the structural description of this rule to (11), where 'C_α' is a shorthand for 'consonant that shares all the same features with another C_α'.

(11) **Generalized epenthesis:** $\varnothing \longrightarrow \partial \left/ C_\alpha - C_\alpha\# \right.$

Baković (2005) argues that this generalized structural description is the right one for the analysis of the actual English facts in OT (Prince and Smolensky 2004). Satisfaction of a markedness constraint with this structural description — NoGem in Baković (2005) — as well as of the markedness constraint responsible for assimilation — Agree(voi) — ensures that, from input *hitd*, epenthesis (*hit∂d*) is better than both the faithful candidate (*hitd*) and assimilation (*hitt*), and also better than both epenthesis and assimilation (*hit∂t*), which gratuitously violates Ident(voi). This type of interaction is called *cross-derivational feeding* (henceforth *cd-feeding*), alluding to the fact that explicit consideration of the mistaken derivational path with assimilation $hitd \xrightarrow{asm} hitt$ is crucial to finding the correct derivational path with epenthesis $hitd \xrightarrow{gen-ep} hit\partial d$.[7]

(12) Assimilation cd-feeds epenthesis in English

hitd	$\mathbb{M}_2$:NoGem	$\mathbb{M}_1$:Agree(voi)	$\mathbb{F}_2$:Dep-V	$\mathbb{F}_1$:Ident(voi)	*Remarks*
hitd		* !			*faithful*
hitt	* !			*	*assimilation*
☞ *hit∂d*			*		*epenthesis*
hit∂t			*	* !	*both*

---

[6]The original bleeding interaction is also illustrated in Figure 8 for completeness. It is technically identical to counterbleeding in terms of the formal relationships between the two rules, but given the convention noted toward the end of §1 that the first rule in an order is represented horizontally and the second rule is represented vertically, the rule re-ordering operation amounts to a 90°-rotation of the figure. See Baković and Blumenfeld (to appear-b) for more details on all of these operations.

[7]Note that this would still be cd-feeding if NoGem were replaced by a more specific constraint with the structural description of the modified epenthesis rule in (10). The generalization to (11) simply motivates the pursuit of the cd-feeding analysis further.

Here is another view on the information in (12). Given the bottom-rank of IDENT(voi) (= $\mathbb{F}_1$), the generally preferred way to satisfy undominated AGREE(voi) (= $\mathbb{M}_1$) is to assimilate. But, in the case of input *hitd*, assimilation leads to *hitt*, with a pair of adjacent identical consonants, violating equally undominated NOGEM (= $\mathbb{M}_2$). The candidate with epenthesis, *hitǝd*, is thus preferred instead, avoiding violation of both $\mathbb{M}_1$ and $\mathbb{M}_2$ via violation of mid-ranked DEP-V (= $\mathbb{F}_2$). The candidate with both epenthesis and assimilation, *hitǝt*, violates both $\mathbb{F}_1$ and $\mathbb{F}_2$, and is dispreferred due to the gratuitous violation of $\mathbb{F}_1$.

A diagram for cd-feeding, similar to the ones shown before, is given in Figure 11; the squiggly arrows highlight the crucial assimilation and modified epenthesis path from *hitd* through *hitt* to *hitǝt* that results in the selection of the direct, non-gratuitous path (dotted) — corresponding to the structural description of no rule or constraint in the analysis — from *hitd* to *hitǝd*. This cd-feeding diagram resembles in key respects the seeding diagram in Figure 10, repeated here for convenience of comparison.
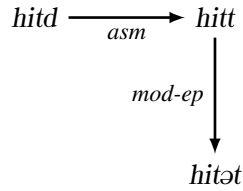
Figure 10: *asm* seeds *mod-ep*
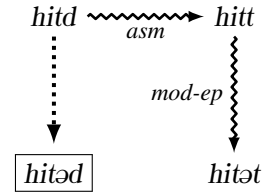
Figure 11: *asm* cd-feeds *mod-ep*

The resemblance between seeding and cd-feeding can perhaps be better appreciated via consideration of a final example: the interaction between gliding and deletion in Cibaeño Spanish, which Baković (2007) classifies both as an example of seeding (13) and as an example of cd-feeding (14).

(13) Gliding seeds deletion in Cibaeño Spanish

a. **Gliding:** $\begin{Bmatrix} r \\ l \end{Bmatrix} \longrightarrow j \, / \, — \begin{Bmatrix} C \\ \# \end{Bmatrix}$

b. **Deletion:** $G_\alpha \longrightarrow \varnothing \, / \, V_\alpha$ —

c. **Self-destructive feeding interaction:** *silβo* $\xrightarrow{gld}$ *sijβo* $\xrightarrow{del}$ *siβo* 'I whistle'

(14) Gliding cd-feeds deletion in Cibaeño Spanish

silβo	$\mathbb{M}_2$:NOV$_\alpha$G$_\alpha$	$\mathbb{M}_1$:NOCODALIQUID	$\mathbb{F}_2$:MAX-C	$\mathbb{F}_1$:IDENT(cons)	*Remarks*
silβo		* !			*faithful*
sijβo	* !			*	*gliding*
☞ *siβo*			*		*deletion*

Unlike the English past tense case, the constraints in (14) match the structural descriptions of the rules in (13) exactly.[8] The reason this is possible in the case of Cibaeño Spanish is because of the nature of deletion: the winning deletion candidate in (14) does not distinguish whether it is the underlying liquid or the derived glide that has been deleted, thus conflating the alternative routes to deletion.[9] The diagrams for both analyses can thus be viewed as one and the same; this diagram is given in Figure 12.

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[8] But note that if glides and corresponding high vowels are assumed to be featurally identical, the structural description of deletion ($V_\alpha G_\alpha$) can be assumed to correspond to something more like the more general NOGEM constraint used for English in (12) above. This is really neither here nor there, however, for the reasons already noted in footnote 7 above.

[9] Baković (2007: 254) conjectures that it has something to do with the Cibaeño Spanish case being an example of *feeding-on-focus* vs. the English case being an example of *feeding-on-environment*, but this now appears to be a secondary factor at best.

$$silβo \xrightarrow[gld]{} sijβo$$

$$del \downarrow$$

$$siβo$$
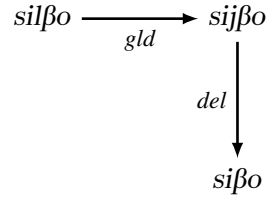
Figure 12: *gld* seeds / cd-feeds *del*

Clearly, then, seeding and cd-feeding are closely related types of interactions. Conversion from one to the other, when their empirical predictions differ as in the English case, can be accomplished via switching between a packaged-and-ordered rule system like *SPE* (for the result of the seeding analysis) and an unpackaged-and-ranked constraint system like OT (for the result of the cd-feeding analysis). This re-emphasizes a point made by Baković (2007): seeding is in general not possible to model in OT, and cd-feeding is in general not possible to model in *SPE* — but when the empirical predictions of a seeding analysis in *SPE* and a cd-feeding analysis in OT converge, there is no distinction between seeding and cd-feeding in either of the two theoretical frameworks.[10]

4 Overapplication opacity

As noted in the introduction, counterbleeding and seeding share in common the fact that they both involve overapplication opacity. In the terms originally defined by Kiparsky (1971, 1973), both seeding and counterbleeding involve the surface result of the application of a rule in a context other than that authorized by the structural description of the rule. In the case of Turkish seeding, the overall map *bebekn* $\longrightarrow$ *bebein* shows the surface result of the application of epenthesis, but because the *k* has been subsequently deleted, the epenthesized vowel is in a context other than that authorized by the structural description of the epenthesis rule. In the case of Polish counterbleeding, *ʒwob* $\longrightarrow$ *ʒwup* shows the surface result of the application of raising, but because the *b* has been subsequently devoiced, the vowel has been raised in a context other than that authorized by the structural description of the raising rule.

McCarthy (1999) calls this kind of opaque rule application *non-surface-apparent*: the reasons for the application of one rule are not apparent on the surface due to the subsequent, obscuring application of another rule. McCarthy's terminology succinctly captures Kiparsky's (1973) characterization of overapplication ('type (ii)') opacity: 'A phonological rule $\mathbb{P}$ of the form $A \longrightarrow B \ / \ C — D$ is OPAQUE if there are surface structures with [. . .] instances of *B* derived by $\mathbb{P}$ that occur in environments other than $C — D$.'

From the perspective of OT, which is in general unable to model overapplication opacity, what seeding and counterbleeding have in common is the fact that they both involve a *gratuitous violation* of faithfulness (McCarthy 1999, Baković 2007). In the case of Turkish seeding, the intended optimal candidate in the overall map *bebekn* $\longrightarrow$ *bebein* evinces both epenthesis of *i* (violating DEP-V) to avoid final clusters and deletion of *k* (violating MAX-C) to avoid intervocalic velar stops, but violation of MAX-C alone (*bebekn* $\longrightarrow$ **beben*) would have been sufficient to satisfy both markedness demands simultaneously. In the case of Polish counterbleeding, the intended optimal candidate in the overall map *ʒwob* $\longrightarrow$ *ʒwup* both raises *o* to avoid *o* preceding final voiced non-nasals, in violation of IDENT(high), and devoices obstruents to avoid word-final voiced obstruents, in violation of IDENT(voi), but again, violation of IDENT(voi) alone (*ʒwob* $\longrightarrow$ **ʒwop*) would have been sufficient to satisfy both markedness demands simultaneously.

With this as background, let's reconsider the cd-feeding analysis of English in (12). The gratuitous violation of faithfulness in this case is incurred by the last candidate, *hitət*, corresponding to the result of the counterbleeding analysis (Figure 9) or the seeding analysis (Figure 10) with both assimilation and

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[10]Thanks to an anonymous reviewer for prompting us to clarify this point.

(modified) epenthesis applying. However, Baković (2007, 2011) argues that the winning candidate, *hitəd*, with epenthesis applying alone, should be properly construed as also involving overapplication opacity. The close relationships among counterbleeding, seeding, and cd-feeding identified in this squib bolster this argument, presented in abbreviated form in (15).

(15) Cross-derivational feeding involves overapplication opacity (Baković 2007, 2011)

    a. Voice-disagreeing adjacent obstruents are generally best-repaired by assimilation.

    b. Adjacent identical consonants are generally best-repaired by epenthesis.

    c. In the subset of inputs where final obstruents differ *only* in voicing, the preferred assimilation repair results in adjacent identical consonants, to which epenthesis is predicted to apply.

    d. Epenthesis applies alone instead. This application of epenthesis is not surface-apparent, since the obstruents between which the epenthetic vowel has been inserted are not identical.

As Baković and Blumenfeld (2017) more narrowly conclude for counterbleeding and seeding, what unites all three of these interactions formally is that they crucially involve output-removal, highlighted with red arrows in the following repeated diagrams.
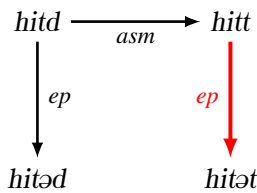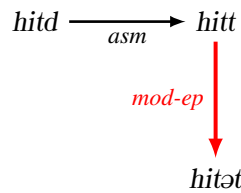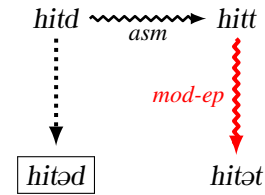
Figure 9: *ep* counterbleeds *asm*   **Figure 10:** *asm* seeds *mod-ep*   **Figure 11:** *asm* cd-feeds *mod-ep*

5 Concluding remarks

We hope to have demonstrated in this squib how three different types of overapplication opacity — counterbleeding, seeding, and cd-feeding — are formally closely related. Counterbleeding and seeding can each be converted into the other via a formal operation of excision or addition of an input-removing mapping; seeding and cd-feeding can each be converted into the other via switching between ordered rules and ranked constraints. This demonstration sheds light not only on the formal relationships among these types of overapplication opacity, but among different types of map interactions more generally.

One question left unanswered here is how to distinguish cases like Turkish, in which the conversion between counterbleeding and seeding results in differences in the overall input-output map generated, from cases like Polish and English, in which the same conversion results in no differences in the overall input-output map generated. We hope to find an answer to this question in our continued collaboration.

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Nasal hardening and aspect allomorphy in Kaqchikel*

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The aspect prefix /n-/ in Comalapa Kaqchikel (Mayan) surfaces with a following [t] or [d] when attaching to monosyllabic, vowel-initial verbs. We refer to this process as NASAL HARDENING, and argue that it emerges from constraints barring affixal material from positions of phonological prominence; these constraints team-up with phonetically-grounded constraints on onset sonority and place licensing to produce [t]~[d] epenthesis. The analysis is supported by allophonic evidence which identifies stressed syllables and word-initial syllables as 'strong' positions in Kaqchikel and other K'ichean-branch Mayan languages. Curiously, the oral stop [d] which results from nasal hardening is otherwise quite rare in Mayan languages. We deal with with the oddity of finding [d] in this context by means of THE EMERGENCE OF THE UNMARKED: certain constraints on [NC] clusters become crucially active only in contexts of epenthesis, when IO-FAITHFULNESS is rendered inert. The paper closes with some discussion of the historical development of these patterns across dialects of Kaqchikel.

Keywords: Epenthesis, assimilation, nasals, phonological strength, Mayan

1 Introduction

In this paper we describe and analyze the prosodic conditions governing the surface form of the incompletive aspect marker /n-/ in the Mayan language Kaqchikel, as spoken in the vicinity of San Juan Comalapa, Guatemala. In this dialect, the aspect prefix /n-/ has a series of phonologically-conditioned surface variants which reveal phonotactic pressures that are otherwise largely latent in Kaqchikel. Aspect marking can produce marked /#nC/ sequences, which are often repaired by epenthesis (1a). More curiously, aspect marking also reveals a dispreference for [#nV] sequences, which are permitted in polysyllabic verbs (1b) but repaired in monosyllabic ones (1c). The repair for such [#nV...]$_\sigma$ sequences is the insertion of an oral stop [t] or [d], a process we refer to as NASAL HARDENING (1c), adapting a term from Rosenthall (1989), Padgett (1994) and others.

(1)   a.   ***n(i)tikïr*** [n(i)-tikɪr̥] '(s)he is able'

     b.   ***nanin*** [n-anin] '(s)he runs'

     c.   ***ndok*** [nd-ok^h] '(s)he enters'

In what follows we focus on nasal hardening (1c), which we argue emerges from the interaction of several phonological factors which converge in vowel-initial monosyllabic verb stems. Specifically, such stems always constitute word-initial stressed syllables, a position of particular phonological strength. We suggest that a constraint barring affixal material from positions of phonological prominence forces epenthesis (1c), and that additional constraints on onset sonority and place licensing ensure the epenthesis of [t d] over other consonants in this environment. Nasal hardening is particularly interesting from a synchronic perspective, as [d] is otherwise a highly marginal sound in Mayan languages, though its occurrence in this context can be understood as a reflection of phonological requirements which are typologically well-attested and

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functionally grounded in phonetics and speech processing. (On post-nasal fortition in other languages, see Rosenthall 1989, Padgett 1994, Gouskova et al. 2011, Zsiga 2018 and references there.)

2 Kaqchikel

Kaqchikel is a K'ichean-branch Mayan language spoken by $\frac{1}{2}$-1 million people in the southern highlands of Guatemala (Fig. 1; Richards 2003, Maxwell and Hill 2010, Fischer and Brown 1996:fn. 3). This paper is primarily concerned with the variety of Kaqchikel spoken in the town of San Juan Comalapa, Chimaltenango, which has an especially complex pattern of allomorphy in aspect marking (we briefly discuss other varieties of Kaqchikel in section 4).
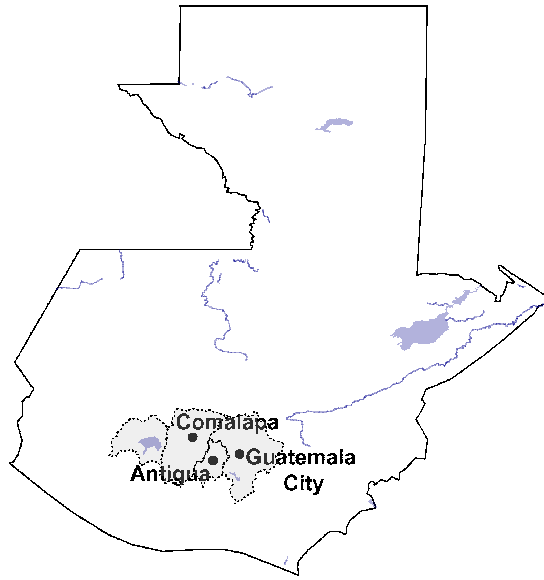
Figure 1: Map of Guatemala showing the four administrative departments in which Kaqchikel is most widely spoken as a community language (from east to west, these are the departments of Guatemala, Sacatepéquez, Chimaltenango, and Sololá) (Richards 2003, Brown et al. 2010, Maxwell and Hill 2010)

The phonemic inventory of Comalapa Kaqchikel is given in Table 1 and Figure 2. For more background on the linguistic structure of Kaqchikel, as well as its socio-linguistic context and historical development, see Cojtí Macario et al. (1998), García Matzar and Rodríguez Guaján (1997), García Matzar et al. (1999), Patal Majzul et al. (2000), Patal Majzul (2007), Brown et al. (2010), Maxwell and Hill (2010). For more on the phonology and phonetics of Kaqchikel, see Cojtí Macario and Lopez (1990), Chacach Cutzal (1990), Nasukawa et al. (2011), Bennett (2016, 2018, To appear), Bennett et al. (2018a,b, In revision) and work cited there.

2.1 Verbal morphology in Kaqchikel

Kaqchikel, like all Mayan languages, has an ergative-absolutive agreement system. Transitive subjects are cross-referenced on verbs with the ergative agreement prefixes in Figure 3. Transitive objects and intransitive subjects are cross-referenced on verbs with the absolutive agreement prefixes in Figure 4. The form of these ergative and absolutive prefixes varies with the initial segment of their stem. These alternations are essentially suppletive: for the most part, there is no synchronic phonological basis for these patterns (though see Kenstowicz 2013 for a different view).

	Bilabial	Dental/ alveolar	Post- alveolar	Velar	Uvular	Glottal
Stop	p ɓ̥	t t^ʔ		k k^ʔ	q q^ʔ~ɢ̥	ʔ
Affricate		$\widehat{ts}$ $\widehat{ts}^ʔ$	$\widehat{tʃ}$ $\widehat{tʃ}^ʔ$			
Fricative		s	ʃ	x ~ χ		
Nasal	m	n				
Semivowel	w		j			
Liquid		l r				

Table 1: The phonemic consonants of Comalapa Kaqchikel
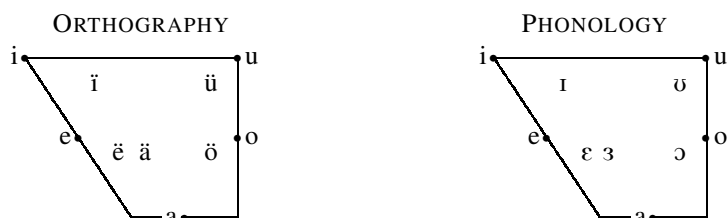
Figure 2: The vowels of Comalapa Kaqchikel (following Chacach Cutzal 1990, Patal Majzul et al. 2000:24,35,40-1, García Matzar and Rodríguez Guaján 1997:17-9, Comunidad Lingüística Kaqchikel 2004:35-44; see also Bennett To appear)

	SG		PL	
	_C _V		_C _V	
1st	in- ~ inw-		qa- ~ q-	
2nd	a- ~ aw-		i- ~ iw-	
3rd	(r)u- ~ r-		ki- ~ k-	

Figure 3: Ergative agreement prefixes on verbs (orthographically)

	SG		PL	
	_C _V		_C _V	
1st	i- ~ in-		oj-	
2nd	a- ~ at-		ix-	
3rd	Ø-		e- ~ e'-	

Figure 4: Absolutive agreement prefixes on verbs (orthographically)

The absolutive agreement prefixes play a special role in the analysis that follows, because the phonetically null 3S.ABS marker [Ø-] (Fig. 4) triggers aspect allomorphy, which then feeds phonological processes like vowel epenthesis and nasal hardening. When absolutive agreement is null [Ø-] 3S.ABS, the imperfective aspect prefix /n-/ is used in place of the default form /j-/. Examples (2) and (3) illustrate this alternation for transitive and intransitive verbs respectively. As should be clear, /j-/~/n-/ allomorphy is morphologically-conditioned and suppletive, rather than being phonologically predictable.

(2)   Aspect allmorphy on transitive verbs in standard Kaqchikel

    a.   *y-a-ki-tz'ët* [**j**-a-ki-$\widehat{\text{ts}}$ʔɛtʰ]
        ASP.INCP-2S.ABS-3P.ERG-see
        'They see you.'

    b.   *n-Ø-ki-tz'ët* [**n**-Ø-ki-$\widehat{\text{ts}}$ʔɛtʰ]
        ASP.INCP-3S.ABS-3P.ERG-see
        'They see him/her/it.'

(3)   Aspect allmorphy on intransitive verbs in standard Kaqchikel

    a.   *y-e-b'ixan* [**j**-e-ɓ̥iʃan]
        ASP.INCP-3P.ABS-sing
        'They sing.'

    b.   *n-Ø-b'ixan* [**n**-ɓ̥iʃan]
        ASP.INCP-3S.ABS-sing
        '(S)he/It sings.'

In what follows, we will see that /j-/~/n-/ allomorphy can create marked sequences which are repaired in some surprising ways.

2.2 The phonology of aspect marking

Aspect allomorphy for incompletive /j-/~/n-/ derives [#nC] and [#nV] sequences, some of which may be marked. In standard Kaqchikel, [#nV] sequences are permitted in all cases (4), while [nC] sequences—especially those that have differing places of articulation—frequently trigger epenthesis of the high front vowel [i] (5). (In our analysis, epenthesis into word-initial [#CC] clusters is a means of avoiding unsyllabified consonants; see section 3.4.) Standard Kaqchikel thus does not display the pattern of nasal hardening exemplified in (1c), in which [t] or [d] intrudes after the nasal aspect marker /n-/ in words like (4).

(4)   *n-Ø-ok* [**n**-okʰ]
        ASP.INCP-3S.ABS-enter
        'She/He entered.'

(5)   *n-Ø-ki-tz'ët* [**ni**-ki-$\widehat{\text{ts}}$ʔɛtʰ]
        ASP.INCP-3S.ABS-3P.ERG-see
        'They see her.'

Beyond standard Kaqchikel, dialects differ as to whether and when incompletive /n-/ is realized as [nt-] or [nd-]. Regarding the realization of /n-/, Patal Majzul et al. (2000:52) and Brown et al. (2010:29) identify five distinct dialect types. This includes the Type (i) pattern instantiated by standard Kaqchikel (4)-(5), in which the aspect marker is uniformly realized as [n-], and vowel epenthesis breaks up marked #[nC] sequences.

  (i)   Use of [n-] in all contexts (with or without epenthesis)

  (ii) Use of [nt-]~[nd-] with monosyllabic verb stems, and [n-] otherwise (possibly with epenthesis)

  (iii) Use of [nd-] with all verb stems (sometimes in free variation with [n-])

  (iv) Use of [nd-]~[d-] with all verb stems, shifting toward fixed [d-] over time

  (v) Use of [nd-] with intransitives, and use of [n-] with transitives

In this paper we focus on Comalapa Kaqchikel, a Type (ii) variety. Like standard Kaqchikel, Comalapa Kaqchikel uses epenthesis to resolve certain [#nC] clusters, at least variably. Unlike standard Kaqchikel, Comalapa Kaqchikel makes frequent and predictable use of the [nd-] and [nt-] allomorphs of the incompletive aspect marker /n-/. This pattern of variation is noteworthy, in that the [nd-] and [nt-] realizations of /n-/ appear to be conditioned allophonically in Comalapa Kaqchikel, rather than just morphologically, a point we expand on below. (We comment on the remaining dialect types in section 4.)

Concretely, Comalapa Kaqchikel is somewhat unique in that the form of incompletive /n-/ depends on the syllable count of the verb stem. This is illustrated in Figs. 5-7 below. Fig. 5 shows that the aspect marker /n-/ is realized as a simple nasal [n-] with polysyllabic vowel-initial stems like *naläx* [n-alɜʃ] '(s)he was born'. Figs. 6 and 7 show that this same aspect marker is realized as [nd-] when prefixed to a monosyllabic vowel-initial stem. (Fig. 7 is from Sololá Kaqchikel, a dialect which appears to be another Type (ii) variety.) The presence of an oral stop between [n] and the following vowel in these examples is supported by the occurrence of a release burst before the vowel onset, by the lowered intensity of voicing preceding this release burst, and by a weakening of energy in the higher harmonics during the same pre-release phase. All of these features are absent at the [#nV] transition for [nalɜʃ] (Fig. 5), in which the aspect marker is realized as a simple nasal without any oral stop component. Additionally, the two instances of [#nd] in these figures are noticeably longer than the single instance of [#n] in Fig. 5, consistent with the presence of an additional stop consonant following the aspect marker when it occurs on monosyllabic vowel-initial stems. We thus fully agree with previous reports of nasal hardening /n-/ → [nt-, nd-] in Comalapa Kaqchikel, as described in sources like Patal Majzul et al. (2000) and Comunidad Lingüística Kaqchikel (2004).[1]
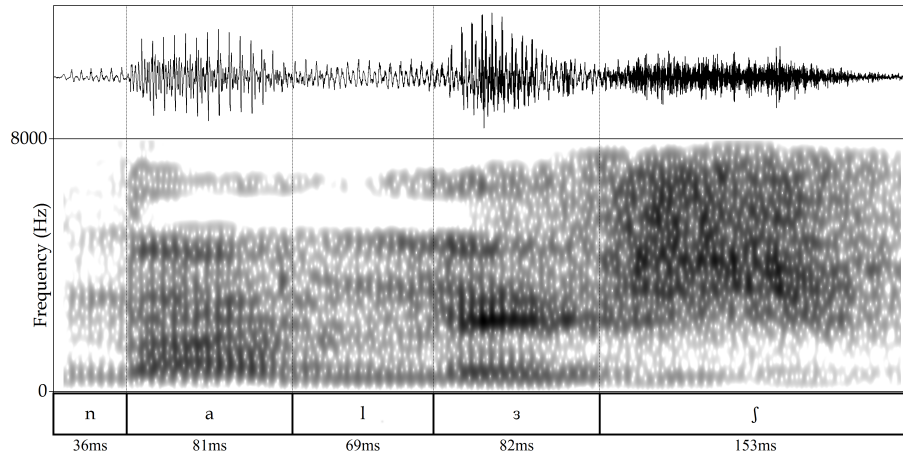
Figure 5: *naläx* [n-alɜʃ] '(s)he was born', as produced by a female speaker of Comalapa Kaqchikel

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[1]These examples were excised from free narratives, and so their segmentation may not seem perfectly crisp. We are nonetheless confident that we have accurately located the boundaries of the initial [n]'s in these examples, which were all utterance-initial or preceded by clearly-definable vowels. For segmentation criteria, see Turk et al. (2006).

A reviewer correctly notes that the initial [n] in Fig. 5 seems very short. For comparison, we can consider the typical duration of [n] as it occurs in a corpus of spontaneous spoken Kaqchikel collected by one of the authors (Bennett and Ajsivinac Sian In preparation; see also Bennett et al. 2018b, Tang and Bennett Submitted). In this corpus, 70% of [n] tokens have a duration of 80ms or less, collapsed across all contexts (mean = 76ms, median = 60ms; n = 2880). In initial position, 70% of [#n] tokens have a duration of 90ms or less (mean = 88ms, median = 70ms; n = 902). While this is clearly longer than the [#n] in Fig. 5, it is also substantially shorter than the durations of [#nd] in Figs. 6 and 7. We leave a full exploration of the durational properties of initial [#n] vs. [#nd] clusters for future work. In any case, the phonological analysis we develop here does not hinge in any substantive way on the phonetic duration of initial [#n] vs. [#nd].
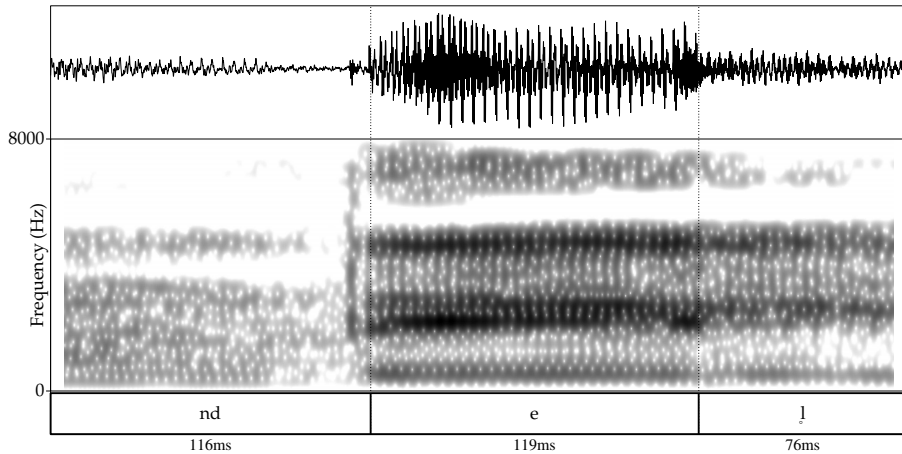
Figure 6: *ndel* [nd-el] '(s)he leaves', as produced by a female speaker of Comalapa Kaqchikel[2]
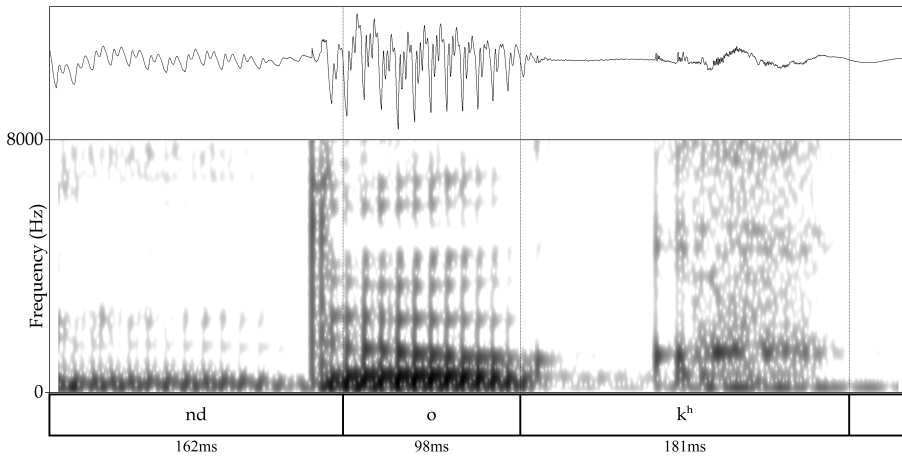
Figure 7: *ndok* [nd-okʰ] '(s)he entered', as produced by a male speaker of Sololá Kaqchikel (Bennett and Ajsivinac Sian In preparation)

Before proceeding, we want to be clear that the scope of nasal hardening /n-/ → [nt-, nd-] in Kaqchikel is quite narrow—it occurs with exactly one morpheme, incompletive *n-* /n-/. The simplest analysis of these alternations, then, would be to treat nasal hardening as suppletive allomorphy, specific to incompletive *n-*, and listed in its lexical entry. This is a reasonable path to take, especially since phonologically-conditioned suppletion is common for prefixes in Kaqchikel (section 2.1 above). However, treating nasal hardening as lexical allomorphy comes with its own complications (sections 3.6, 4). For that reason, we undertake the task of developing a phonological treatment of nasal hardening here, if only to sharpen the comparison between the two approaches. While the phonological approach requires more complex analytical machinery, it also provides some insights into the nature of nasal hardening which, we think, would be lost by just lexically listing the allomorphs of incompletive *n-* /n-/. (On the general tension between phonological vs. morphological treatments of semi-predictable allomorphy, see Itô and Mester 2006.)

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[2]Word-final approximants are normally devoiced in Kaqchikel, but curiously, the final [l] of [nd-el] remains voiced in the example shown in Fig. 6.

To develop a phonological analysis of nasal hardening, we will need to identify some systematic difference between monosyllabic and polysyllabic verb stems which could plausibly be responsible for the appearance of [t d] in post-nasal position. In the following section, we argue that monosyllabic stems count as phonologically 'strong' in a variety of respects. We then argue that the phonological strength of such stems is responsible for conditioning Type (ii) allomorphy in dialects like Comalapa Kaqchikel.

3 Analysis

3.1 Stress as a strong position in Kaqchikel

Stressed syllables commonly host a wider range of segmental and suprasegmental contrasts than unstressed syllables (e.g. Trubetzkoy 1939, Beckman 1998, Smith 2005, Barnes 2006, Teeple 2009). Such asymmetries suggest that stressed syllables count, in some sense, as positions of phonological strength.

Stress in Kaqchikel is quite uniform, falling mostly on word-final syllables, with only a very small handful of exceptions showing non-final stress of any kind. The positional prominence of stressed syllables manifests itself in at least two ways in this language. First, vowels in Kaqchikel (Fig. 2) contrast for tenseness in stressed syllables (6), but neutralize to the tense series in unstressed (i.e. non-final) syllables (7) (e.g. Bennett To appear).

(6)   a.   *ak'* /ak^ʔ/ → [ˈʔak^ʔ] 'Hyptis Suaveolens'

        b.   *äk'* /ɜk^ʔ/ → [ˈʔɜk^ʔ] 'chicken'

        c.   *k'ay* /k^{ʔ}aj/ → [ˈk^{ʔ}aj̥] 'bile'

        d.   *k'äy* /k^{ʔ}ɜj/ → [ˈk^{ʔ}ɜj̥] 'bitter'   (Cojtí Macario et al. 1998)

(7)   a.   *wäy* /wɜy/ → [ˈwɜj̥] 'tortilla'

        b.   *wayb'äl* /wɜj-ɓɜl/ → [waj.ˈɓɜl̥] 'restaurant'

        c.   *xintïk* /ʃ-in-tɪk/ → /ʃin.ˈtɪkʰ/ 'I planted it'

        d.   *xitikon* /ʃ-i-tɪk-on/ → /ʃi.ti.ˈkon/ 'I planted (something)'   (Cojtí Macario et al. 1998)

Similar restrictions on vowel distributions are found in other, related K'ichean-branch languages, such as those varieties of K'iche' which restrict long vowels to stressed syllables (e.g. Baird 2010, Bennett 2016 and references there).

The second manifestation of phonological strength in stressed syllables in Kaqchikel concerns the distribution of [VʔC] sequences. Word-final, stressed syllables may end in [ʔC] (8), but under suffixation, the pre-consonantal [ʔ] disappears (9) (e.g. García Matzar and Rodríguez Guaján 1997:32-3).

(8)   a.   *po't* /poʔt/ → [ˈpoʔt] 'blouse'

        b.   *kuta'm* /kutaʔm/ → [ku.ˈtaʔm] 'trunk'

(9)   a.   *ija'tz* /iχaʔt͡s/ → [ʔi.ˈχaʔt͡s] 'seed'

        b.   *rijatzul* /r-iχaʔt͡s-ul/ → [ri.χa.ˈt͡sul] 'her/his inheritance'

        c.   *ajch'ame'y* /aχ-t͡ʃ^{ʔ}am-eʔj/ → [ʔaχ.t͡ʃ^{ʔ}a.ˈmeʔj̥] 'municipal official'

        d.   *ajch'ameya'* /aχ-t͡ʃ^{ʔ}am-eʔj-aʔ/ → [ʔaχ.t͡ʃ^{ʔ}a.me.ˈjaʔ] 'municipal officials'

We take alternations like (9) as an indication that [VʔC] sequences are only licensed under stress in Kaqchikel, similar to lax vowels. Indeed, across Mayan there is independent evidence that glottal stop sometimes pat-

terns as a vowel feature, and sometimes patterns as an independent consonant; see Bennett and Henderson (2013), Bennett (2016), England and Baird (2017).[3]

To our knowledge, there are no consonant phonotactics which demonstrate the phonological strength of stressed syllables in Kaqchikel (apart from nasal hardening itself, as we argue below). However, one does not have to look too far afield to find such evidence in closely related languages. We begin by considering the distribution of epenthetic glottal stop.

Glottal stop insertion is a common allophonic process in Mayan languages (Bennett 2016, Bennett et al. 2018a, Bennett 2018). It is commonly observed in two environments. First, words which begin in an underlying vowel typically bear an epenthetic [ʔ] on the surface (10).

(10)   a.   *aq'on* /aqˀon/ → [ʔa.ˈqˀon] 'medicine'
        b.   *ajk'en* /aχ-kˀen/ → [ʔaχ.ˈkˀen] 'weaver' (García Matzar and Rodríguez Guaján 1997:30-31)

Second, [ʔ]-epenthesis often occurs in word-medial position to resolve onsetless syllables under hiatus (11).

(11)   a.   *xe'el* /ʃ-e-el/ → [ʃeˈʔel] '(s)he left'
        b.   *achi'a'* /at͡ʃi-aʔ/ → [ʔat͡ʃiˈʔaʔ] 'men'   (García Matzar and Rodríguez Guaján 1997:31-32)

Word-initial [ʔ]-insertion (10) is plausibly just a special case of the more general use of [ʔ]-insertion to avoid onsetless syllables (11). However, it should be noted that (i) Kaqchikel makes use of other hiatus-avoidance strategies as well (such as vowel deletion) which do not occur word-initially (Heaton 2016), and (ii) there are Mayan languages which ban word-initial vowels while still permitting internal hiatus (Bennett 2016:§2.4).

Glottal stop insertion occasionally shows evidence of prosodic conditioning in the Mayan family. In some languages, [ʔ]-insertion is most prevalent in utterance- or phrase-initial position (Garellek 2013, 2014, Bennett 2016:477), and many references there). A particularly relevant observation comes from Dayley (1985), who describes [ʔ]-insertion for Tz'utujil, a K'ichean-branch Guatemalan Mayan language which is genetically and geographically close to Kaqchikel. In Tz'utujil, word-initial [ʔ]-insertion is optional on polysyllabic stems (12a). However, on monosyllabic stems, [ʔ]-insertion is instead obligatory (12b).

(12)   [ʔ]-epenthesis in Tz'utujil

        a.   *ajq'iij* /aχ-qˀiːχ/ → [ʔaχ.ˈqˀiːχ] ~ [_aχ.ˈqˀiːχ] 'shaman'
        b.   *ooj* /oːχ/ → [ˈʔoːχ], *[ˈ_oːχ] 'avocado'

We believe that this sensitivity to syllable count reflects a more basic fact about the accentual system of Tz'utujil, Kaqchikel, and related K'ichean branch languages: with few exceptions, stress is word-final in these languages. We can thus recast Dayley's (1985) observation as follows: [ʔ]-insertion is optional in word-initial unstressed syllables, but obligatory in word-initial *stressed* syllables (see also Flack 2009). The fact that stressed syllables place stricter requirements on their onsets is entirely expected: typologically, stressed syllables may require onsets even in languages which otherwise permit onsetless syllables (e.g. Smith 2005); and fortition processes like initial [ʔ]-insertion are more likely to apply at stronger prosodic boundaries than at weaker prosodic boundaries (e.g. Fougeron and Keating 1997, Keating et al. 2003, Cho and Keating 2009, Garellek 2013, 2014, etc.). These tendencies are exemplified by Dutch (13), which permits unstressed onsetless syllables, but which avoids *stressed* onsetless syllables through [ʔ]-epenthesis.

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[3]Relatedly, Comunidad Lingüística Kaqchikel (2004:57) report that stress is actually drawn to non-final [ˈVʔ.C...] in some dialects of Kaqchikel, e.g. *ye'ruxim* [ˈjeʔ.ru.ʃim] '(s)he will tie them'.

(13) Stress-sensitive [ʔ]-epenthesis in Dutch (Booij 1999, Smith 2005)

  a. *chaos* /xaɔs/ → [ˈxa.ɔs] 'chaos'

  b. *aorta* /aɔrta/ → [a.ˈʔor.ta] 'aorta'

Although we are unaware of any research suggesting that [ʔ]-insertion is conditioned by stress in Kaqchikel, the Tz'utujil facts are of a kind with the vowel distributions discussed above: they provide general evidence for the positional prominence of word-final stressed syllables in K'ichean-branch Mayan languages.

3.2 Word-initial position as a strong position

Along with stressed syllables, word-initial position has also been identified as a position of phonological strength, showing either a greater range of contrasts than other positions (e.g. Beckman 1998), a resistance to alternation (e.g. Becker et al. 2012, 2017), or evidence of fortition processes (e.g. Smith 2005, Lavoie 2001), including patterns of neutralizing fortition.

The evidence for treating word-initial position as a strong position in Kaqchikel is limited, but nonetheless clear. Descriptive sources commonly describe glide hardening for the approximant /w/, with the particular outcome of hardening varying across vowel context and position within the word (14) (Cojtí Macario and Lopez 1990:213-20, García Matzar and Rodríguez Guaján 1997:16-7, Patal Majzul et al. 2000:26-8, Comunidad Lingüística Kaqchikel 2004:32-4, etc.). (In many dialects of Kaqchikel, historical /w/ is usually realized as [v], but the point is the same in either case.)

(14) a. *winäq* /w̲inɜq/~/v̲inɜq/ → [b̲i.ˈnɜqˣ]

  b. *wuj* /w̲uχ/~/v̲uχ/ → [b̲uχ] (Cojtí Macario and Lopez 1990)

There is an important generalization to be made about the environments in which glide hardening takes place: hardening in medial positions entails hardening in initial position, but not vice-versa. In (15), for example, all combinations of hardening in the word *wawe'* /waweʔ/~/vaveʔ/ 'here' are attested, *except* the form *[vabeʔ], which hardens the medial [v] without also hardening the initial [v].

(15) Glide hardening in Santiago Sacatepequez Kaqchikel *wawe'* 'here' (Cojtí Macario and Lopez 1990)

  a. [vaveʔ]
  b. [boveʔ]
  c. [babeʔ]
  d. *[vabeʔ]

We interpret this asymmetry as evidence of the positional prominence of word-initial syllables, reflecting a preference for lower-sonority onset consonants in word-initial position (see especially Lavoie 2001, Smith 2005, and also Bennett 2013:§6.2).[4]

Though somewhat more tenuous, [ʔ]-epenthesis can also be construed as a case of word-initial prominence. For at least some speakers of Kaqchikel, word-medial onsetless syllables in hiatus are resolved by vowel deletion (16b) rather than [ʔ]-insertion (16a) (e.g. Heaton 2016).

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[4]Word-initial glide hardening is also attested in other Mayan languages, including those of the K'ichean branch. Q'eqchi' (K'ichean) has a particularly notable process of word-initial hardening which derives pre-stopped glides, e.g. *winq* [ᵏwiŋqʰ] 'man' and *yu'am* [ˡjuʔam] 'life' (England 2001, Tzul and Cacao 2002, Caz Cho 2007). Co-author Bennett has observed the same process in Tila Ch'ol (Western Mayan, Mexico); see too England (1983:29) on Mam and Bruce (1968:22) on Lacandon, among various others.

(16)   *yixb'e'intz'ub'aj* /j-iʃ-ɓe-in-t͡sʔuɓ-aχ/ 'I go kiss y'all' (Heaton 2016:320)

   a.   [jiʃ.ɓe̥.ʔin.t͡sʔu.ˈɓaχ] (epenthesis)

   b.   [jiʃ.ɓe̥n.t͡sʔu.ˈɓaχ] (deletion)

Word-initial onsetless syllables are never resolved through vowel deletion, only through [ʔ]-epenthesis (see also Bennett 2016:§2.4.4). This asymmetry may also reflect the phonological prominence of word-initial position in Kaqchikel, as strong positions are typically resistant to weakening and lenition processes like deletion.[5]

3.3 Nasal hardening as cumulative phonological strength

We can now assess why the phonetic realization of the aspect marker *n-* /n-/ is conditioned by the syllable count of its stem—or more precisely, by stress. Drawing a parallel with the discussion of glide hardening above, we assume that the realization of /n-/ as [nt-]~[nd-] serves to provide a better (lower sonority) onset for stressed syllables, particularly those which appear in word-initial position. As noted in the preceding section, there is a cross-linguistic preference for low-sonority onsets, particularly in prominent positions like stressed and word-initial syllables (e.g. Lavoie 2001, Gurevich 2004, Smith 2005, Gordon 2005). Stopping of /n-/ → [nt-]~[nd-] in forms like [ndokʰ] '(s)he entered' could therefore be driven by sonority-related pressures. Specifically, we take the process of nasal hardening which derives [nt-]~[nd-] from /n-/ to be a species of consonant epenthesis, driven by a preferences for low-sonority onsets.

   Implementing this intuition requires several ingredients. First, we need to specify the contexts in which hardening of the nasal aspect marker /n-/ occurs. In Comalapa Kaqchikel, nasal hardening is restricted to monosyllabic verb stems; these are precisely those stems in which the nasal aspect marker /n-/ → [n-] would *simultaneously* occur in both word-initial position and in the onset of a stressed syllable (17).

(17)   a.   [n.ˈtokʰ.]

   b.   *[.nokʰ.]

We emphasize that nasal hardening does not in general occur in initial position in Kaqchikel (18a), nor does it occur in stressed syllables more broadly (18b). It is the *joint* effect of word-initial position and stress that appears to drive nasal hardening; neither condition is on its own sufficient to produce the epenthesis of [t]~[d].

(18)   a.   *nint'is* [nin.ˈtʔis], *[n.tin.ˈtʔis.] 'I sew it'

   b.   *yinel* [ji.ˈne̥l.], *[jin.ˈte̥l] 'I leave'

In our analysis, nasal hardening is thus an instance of a *gang effect*, typically modeled using constraint conjunction (e.g. Itô and Mester 2003a, Smolensky and Legendre 2006, Crowhurst 2011) or the numerically-weighted constraints of Harmonic Grammar (e.g. Smolensky and Legendre 2006, Pater 2016) (see also Padgett 2002, Shih 2017 for relevant discussion). For simplicity of exposition, we adopt constraint conjunction here, acknowledging that the Kaqchikel facts themselves do not distinguish between these two

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[5]An interesting fact about [ʔ]-insertion in Kaqchikel, and in Mayan languages more generally, is that [ʔ] is very often realized phonetically as creakiness on adjacent vowels and sonorants, and *not* as a true stop (e.g. Bennett 2016, England and Baird 2017 and references there). This is notable because the distribution of [ʔ]-insertion is easily understood as a strategy for providing onset consonants in otherwise onsetless syllables, despite the fact that [ʔ] does not necessarily function as an onset consonant in the phonetics. We believe that [ʔ]-insertion in initial positions can be understood as a case of phonetic/phonological strengthening in either case, as initial laryngealization (including creakiness) is quite broadly conditioned by strong positions cross-linguistically (e.g. Borroff 2007, Garellek 2013, 2014).

alternatives. (For other cases of cumulative prominence effects in phonology, which can also be modeled using local constraint conjunction, see Parker 1998, de Lacy 2001, and references there.)

(19)   Constraints on onset sonority in strong positions (see Lavoie 2001, Parker 2002, Smith 2004, 2005, 2008, Gordon 2005, Flack 2007, 2009)

   a.   *ONSET$\geq_{son}$N/σ_1:
        Assign one violation for every syllable σ_x such that σ_x is initial within its containing prosodic word, and begins with an onset consonant with sonority greater than or equal to a nasal stop.

   b.   *ONSET$\geq_{son}$N/$\acute{\sigma}$:
        Assign one violation for every syllable $\acute{\sigma}_x$ such that $\acute{\sigma}_x$ is stressed, and begins with an onset consonant with sonority greater than or equal to a nasal stop.

(20)   STRONGONSET (=*ONSET$\geq_{son}$N/σ_1 &$_{syll}$ *ONSET$\geq_{son}$N/$\acute{\sigma}$)
       Assign one violation for every syllable σ_x such that σ_x is a stressed, word-initial syllable and begins with an onset consonant with sonority greater than or equal to a nasal stop (i.e. is a locus of violation for both *ONSET$\geq_{son}$N/σ_1 and *ONSET$\geq_{son}$N/$\acute{\sigma}$).

(21)   STRONGONSET ≫ DEP-C

/n-ok/	STRONGONSET	DEP-C
a. ☞ .n.ˈt<u>ok</u>.		*
b. .ˈn<u>ok</u>.	*! W	L

nok /n-ok/ → [n.ˈtok^h]~[n.ˈdok^h] (Fig. 7) '(s)he enters'

The positional privilege of word-initial, stressed syllables in Kaqchikel can in fact be seen in the historical development of nasal hardening in Kaqchikel. The distal source of this phenomenon lies in the tense-aspect system of Colonial Kaqchikel, as recorded in the 16th century, during the post-conquest period (Maxwell and Hill 2010). Colonial Kaqchikel marked present tense on verbs with /t-/ whenever the absolutive argument was 3S.ABS (e.g. *t-i-xib'-in* 'it (3S.ABS) was frightening'), and with /k-/ (or /q-/ 1P.ABS) otherwise (e.g. *k-e-achij-ïr* 'they (3P.ABS) were becoming warriors'; Robertson 1992:66,131-6, Maxwell and Hill 2010:53-6). Incompletive aspect was marked with an independent pre-verbal morpheme *tan* (e.g. *tan k-e-q'aq'-är* 'they (3P.ABS) were becoming powerful'). Over time, *tan* underwent phonological weakening, yielding *tan t-. . .* > *nt-/nd-. . .* > *n-. . .*, and *tan k-. . .* > *nk-/ng-. . .* > *y-. . . .*

The retention of *nt-/nd-. . .* in all verb paradigms (Type (iii) systems) is thus conservative when compared to those dialects which mark 3S.INCP with *n-* across the board (Type (i) systems). The question, then, is why dialects like that of Comalapa Kaqchikel (Type (ii)) neutralized *nt-/nd-. . .* with *n-. . .* in all verb forms *except* those which were both monosyllabic and vowel-initial. We suggest that this resistance to simplification reflects the phonetic and phonological prominence of word-initial, stressed syllables invoked above.

We hasten to add that the distribution of *n-* vs. *nt-/nd-* has clearly been reanalyzed in diverse ways by different Kaqchikel dialects (section 4). As such, the existence of a historical source for modern *n-~nt-/nd-* alternations does not obviate the need for a synchronic analysis of these same facts (see Anderson 1992, Mester 1994, Blevins 2004 for related discussion).

3.4 Morphological conditioning of nasal hardening

As it currently stands, our analysis wrongly predicts nasal hardening for *all* monosyllabic words, not just verbs. Monomorphemic /n/-initial words like *nïm* [nɪm] 'large' show no evidence of nasal hardening in any dialect of Kaqchikel. The generalization to be captured here concerns a specific morpheme, the aspect marker /n-/, and not word-initial /n/ *tout court*. Some reference to morphology is clearly key.

　　We suggest that the nasal hardening observed in Comalapa Kaqchikel and other varieties owes to a grammatical pressure which prefers morphological boundaries to coincide with prosodic boundaries (Prince and Smolensky 1993/2004, McCarthy and Prince 1993a). In particular, we assume a constraint demanding that stressed syllables contain only those segments which belong to a morphological root (22). This constraint is functionally grounded in the fact that stressed syllables and roots are both important for lexical access (Smith 2005).

(22)　　MATCH($\acute{\sigma}$, ROOT) (inspired by Itô and Mester 1999, 2015, Selkirk 2011, Elfner 2012)
　　　　Assign one violation for every segment $\mathbb{S}$ contained in a stressed syllable $\acute{\sigma}_x$, such that $\mathbb{S}$ belongs to an affix (i.e. a morpheme other than a root morpheme).

The workings of (22) can be seen in (23). In (23a), we see that nasal hardening has the effect of pushing the aspect marker /n-/ into a separate syllable, leaving the root (underlined) as the sole morpheme contained within the stressed syllable. The post-nasal [t], being epenthetic (see below) has no morphological affiliation of its own ('consistency of exponence', e.g. Pyle 1972, McCarthy and Prince 1993b, 1994). For this reason, the presence of epenthetic, post-nasal [t] (in boldface) in the same stressed syllable as the root in (23a) does not contribute to violations of MATCH($\acute{\sigma}$, ROOT) (22), but rather serves to resolve them.[6]

(23)　　MATCH($\acute{\sigma}$, ROOT) ≫ DEP-C ≫ STRONGONSET

a.

/n-ok/	MATCH($\acute{\sigma}$, ROOT)	DEP-C	STRONGONSET
a. ☞ .n.ˈ**t**<u>ok</u>.		*	
b. 　.ˈn<u>ok</u>.	*! W	L	* W

nok /n-ok/ → [n.ˈtokʰ]~[n.ˈdokʰ] (Fig. 7) '(s)he enters'

b.

/nɪm/	MATCH($\acute{\sigma}$, ROOT)	DEP-C	STRONGONSET
a. ☞ .nɪm.			*
b. 　.n.tɪm.		*! W	L

nïm [nɪm] → [nɪm] 'big'

Tableau (23b) further demonstrates the failure of nasal hardening in monosyllabic /n/-initial roots. Note that this analysis requires the ranking DEP-C ≫ STRONGONSET, which is in direct contradiction to the proposal made in section 3.3. We return to this issue in section 3.7, where we argue that it is in fact the *joint* influence of STRONGONSET and MATCH($\acute{\sigma}$, ROOT) which triggers nasal hardening in Kaqchikel.

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[6]There are thus theory-internal reasons for treating post-nasal [t]~[d] as being inserted rather than 'fissioned' off from underlying /n$_i$/ → [n$_i$d$_i$]: fissioned [t]~[d] would have a morphological affiliation, being associated with input /n-/, and thus would not resolve violations of MATCH($\acute{\sigma}$, ROOT). (On consonant fission and epenthesis in OT, see Staroverov 2014.)

In contrast with monosyllabic roots, polysyllabic roots and stems do not induce nasal hardening (24), because the stressed syllable is never at risk of containing anything other than root material. Additionally, polysyllabic roots and stems will never violate STRONGONSET (20), because [n-] will never be contained in the stressed syllable. Epenthesis of [d] is thus gratuitous in this case, and therefore prohibited as a standard economy effect (e.g. McCarthy 2002:23-4,134-8).[7]

(24)

/n-alʒʃ/	MATCH(σ́, ROOT)	DEP-C	STRONGONSET
a. .n.**ta**.ˈlʒʃ.		*! W	
b. ☞ .n<u>a</u>.ˈlʒʃ.			

naläx /n-alʒʃ/ → [na.ˈlʒʃ] (Fig. 5) '(s)he is born'

This analysis also correctly predicts that monosyllabic roots, when suffixed, will suddenly fail to evince nasal hardening (25). In this case, stress being word-final, there is no way to satisfy MATCH(σ́, ROOT), because the stressed syllable will necessarily contain affixal material.

(25)

/n-ok-is-ʒʃ/	MATCH(σ́, ROOT)	DEP-C	STRONGONSET
a. ☞ .n<u>o</u>.<u>ki</u>.ˈsʒʃ.	*		
b. .n.**t**<u>o</u>.<u>ki</u>.ˈsʒʃ.	*	*! W	

nokisäx /n-ok-is-ʒʃ/ → [no.ki.ˈsʒʃ] 'it was used'

3.4.1 The syllabification of [#nC] clusters

We are presuming here that the pre-consonantal nasal in hardening contexts (24a) is syllabic [#n̩.t], or at least external to the syllable which contains the root and epenthetic [t]~[d]—otherwise, nasal hardening would not lead to satisfaction of MATCH(σ́, ROOT). Evidence supporting this claim comes from the broader distribution of consonant clusters in Kaqchikel.

Word-medially, clusters are mostly heterosyllabic [C.C], as in *saqsöj* [saqˣ.ˈsɔχ] 'whiteish'. But prefixation frequently derives initial consonant clusters which are impossible in word-medial position, e.g. *xtqab'än* [ʃ-t-qa-ɓən] 'they will do it' (García Matzar and Rodríguez Guaján 1997:21-5, Comunidad Lingüística Kaqchikel 2004:57-60; see also Bennett 2016, DiCanio and Bennett To appear on other Mayan languages). If tautosyllabic, these clusters would seem to implicate complex onsets which are otherwise unattested in the language: compare e.g. *jantape* [χan.ta.pe] 'always' with *ntik* [ntikʰ] 'it is planted'.

A reasonable alternative is that these word-initial clusters involve syllabic underparsing, i.e. extrametricality: [ʃt(qa)σ(ˈɓən)σ], [n(tikʰ)σ], and so on. Contextual extrametricality explains why these complex

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[7]Monosyllabic verbs in Kaqchikel are always bare roots, while polysyllabic verbs are typically morphologically complex, derived verb stems (e.g. Coon 2016 and references there). For example, the stem *-aläx* [-alʒʃ] 'to be born' can probably be decomposed into a root [-al] and a valence-determining suffix [-ʒʃ] (or even possibly [-ʒ-ʃ]). The analytical point goes through in either case, because the ostensible root [-al], by virtue of its position, cannot be the unique morpheme which contributes segmental material to the word-final stressed syllable. See also (25).

clusters are limited to initial position, under the assumption that syllabic underparsing may only occur at the edges of words (see Itô 1986, 1989, Gouskova 2012 and references there). Extrametricality also accounts for the fact that clusters derived by prefixation routinely violate the sonority sequencing principle, which is otherwise obeyed in roots and in word-medial positions in Kaqchikel (e.g. [t-kamisaχ] 'kill it!'). Furthermore, vowel epenthesis, which variably splits up initial /#nC/ clusters in words like [nqaɓən]~[niqaɓən] 'we do it', can be understood as a strategy for avoiding unparsed initial consonants.

It thus seems credible that the nasal in initial [#nt] sequences is *not* parsed into the same syllable as epenthetic [t]~[d] under nasal hardening, as [nt] onset clusters are otherwise unattested in the language. We don't know of any further evidence internal to Kaqchikel which would help assess the syllabification of initial [#nC] clusters. In particular, there are no syllable-sensitive allophonic processes which clearly indicate how these word-initial clusters are parsed (see again Bennett 2016). We thus leave further investigation of this aspect of our analysis to another occasion.[8]

3.5 Why epenthetic [t d]?

We have not yet explained the *quality* of the epenthetic consonant in this context. Why does it surface as [t]~[d], when the default epenthetic consonant of Kaqchikel is clearly [ʔ] (section 3.1)? Both [n.**t**okʰ] and [n.**ʔ**okʰ] equally satisfy Match($\acute{\sigma}$, Root), and along with the language-internal evidence suggesting that [ʔ] is the preferred epenthetic segment in Kaqchikel, epenthetic [ʔ] arguably has the virtue of being less phonologically marked than an oral stop like [t] or [d] (see de Lacy 2006:Ch.3, Staroverov 2014 for discussion).

The answer, we contend, has to do with phonological conditions on the licensing of nasal place features. Cross-linguistically, nasals frequently undergo place neutralization word-finally and before consonants; often, nasals in these contexts assimilate in place to a following segment. This pattern is extremely widespread, and has been analyzed as the effect of a broad prohibition on coda nasals which sponsor independent, phonologically-specified place of articulation features (26) (Itô 1986, 1989, Goldsmith 1990, Padgett 1994). Place assimilation subverts this restriction because the coda nasal 'borrows' its place of articulation from a consonant in the syllable onset—a position where place of articulation features *are* independently licensed (on 'indirect licensing', see also Itô et al. 1995, Beckman 1997, 1998).

(26)

[PLACE]

N . C
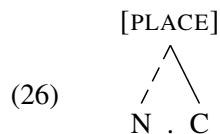
A second, though related line of thinking takes nasal place assimilation to reflect phonetic facts about the perceptual salience of nasal place features in different segmental contexts (e.g. Steriade 1994, 2001, Jun 1995, 2004, Kawahara and Garvey 2011). Nasal place is most perceptible in [V-N-V] sequences, where it can be identified on the basis of acoustic properties of the nasal during closure (e.g. spectral structure and duration), as well as in more salient cues on the flanking vowels (e.g. formant trajectories; Malécot 1956 and others). [C-V] transitions are particularly important for identifying nasal place, as they seem to provide more reliable cues to consonant place than [V-C] transitions (at least for most places of articulation; see e.g. Fujimura et al. 1978, Repp and Svastikula 1988, Recasens 1988, Steriade 2001 and references there). In word-final position, nasal place can only be cued by the weaker information in [V-N#]

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[8]The extended duration of the nasal murmur in Figs. 6 and 7 is consistent with an initial syllabic nasal in [#n̩.C], but evidence of this kind must be treated with care, especially since we have not conducted a systematic study of nasal duration in Kaqchikel. See also footnotes 1 and 11, and Byrd (1993), Pouplier and Beňuš (2011).

transitions, as well as steady-state properties of closure, and possibly properties of consonant release.[9] Pre-consonantal nasals [VNC] are even worse off: place may be cued in the [V-N] transition, and by properties of the nasal resonance, but pre-consonantal nasals are unlikely to be released (Jun 2004 and references there). Worst of all, perhaps, are initial, pre-consonantal nasals: in [#NC], nasal place is solely cued by properties of the nasal resonance, a singularly unhelpful perceptual cue (e.g. Johnson 2012:Ch. 9.2).

We contend that epenthetic [t]~[d] is a superior epenthetic consonant to [ʔ] following the word-initial aspect marker /n-/ because [d] *redundantly cues the nasal place features of the aspect marker* in an environment—[#NC]—-in which those features are difficult to reliably perceive. We implement this intuition with the PRESERVE constraint (27) (Flemming 1995, Jun 2004):

(27) PRESERVE[PLACE,NASAL]:
Assign one violation for every nasal consonant N_x present in the output, such that N_x is also present in the input and its place features are not perceptually recoverable in the output.

The workings of (27) can be seen in tableau (28). Candidate (28b), [nʔok], fails to robustly cue the [CORONAL] place feature of the aspect marker [n-]: [n] is in pre-consonantal position, a perceptually weak position, and [ʔ] provides no information about the [CORONAL] place feature of the nasal. In contrast, candidate (28a) [ntok] signals the [CORONAL] feature of the nasal well, because it is redundantly specified on the following, pre-vocalic [t], which carries perceptible [PLACE] features. (The idea that perceptually weak features are more likely to undergo spreading has precedent in research on vowel harmony systems; see especially Kaun 1995, Walker 2011, Rose and Walker 2011.)

(28) PRESERVE[PLACE,NASAL] ≫ *[t d]

/n-ok/	PRESERVE[PLACE,NASAL]	*[t d]
a. ☞ .n.<u>tok</u>.		*
b. .n.<u>ʔok</u>.	*! W	

nok /n-ok/ → [n.ˈtokʰ]~[n.ˈdokʰ] (Fig. 7) '(s)he enters'

Provided that PRESERVE[PLACE,NASAL] is satisfied whenever [n] is vowel-adjacent, we derive the fact that epenthesis in [nC] clusters is limited to word-initial position.[10]

We close this section with a brief comment the assumption that nasal hardening involves consonant epenthesis. This is not the only conceivable treatment of the 'intrusive' [t]~[d] seen in nasal hardening environments. For example, [t]~[d] could be oral transitions out of a singleton nasal stop [nᵗ], rather than fully-fledged, independent segments of their own (see e.g. Anderson 1976, Steriade 1993, Stanton 2016, 2017, To appear and references there).[11] However, there is a technical problem with this analysis: it provides little insight into the morphological conditioning of this pattern. If both *[.nokʰ.] and [.nᵗokʰ.] begin with a unitary onset consonant, they involve exactly the same syllabification, and we can no longer invoke

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[9]Languages differ as to whether nasal stops are produced with a salient release burst, at least in word-final position (e.g. Peperkamp et al. 2008 and references there).

[10]Intriguingly, the initial [#nt]~[#nd] clusters derived by nasal hardening never seem to undergo further vowel epenthesis: neither *[<u>ni</u>.tokʰ] nor *[<u>ni</u>.ʔokʰ] are attested alternative realizations of /n-ok/ → [n.tokʰ]~[n.dokʰ], despite their avoidance of unparsed consonants. Perhaps the joint application of *both* consonant and vowel epenthesis is simply too unfaithful to be permitted; see e.g. Farris-Trimble (2010).

[11]As we noted above, the [nd] sequences derived by nasal hardening in Comalapa Kaqchikel do seem to be longer than single segments. However, Ladefoged and Maddieson (1996:Ch. 4.3) point out that segmental duration alone may not be a good way of distinguishing mixed oral+nasal stops from corresponding clusters.

MATCH($\acute{\sigma}$, ROOT) to explain why nasal hardening is strictly limited to the initial aspect marker /n-/. For this reason, it seems to us that treating [t]~[d] as epenthetic rather than transitional is a more promising analytic option.

3.6 Nasal hardening is phonology, not suppletive allomorphy

An alternative analysis of nasal hardening in Kaqchikel might be to treat [n-]~[nt-/nd-] alternations as suppletive allomorphy rather than phonology *per se*. Under this analysis, the underlying form of the incompletive would be as in (29) (following Paster 2006, Bye 2007 and others): the more specific allomorph /nt-, nd-/ subcategorizes for stems beginning in a stressed vowel (i.e. vowel-initial, monosyllabic stems), and the less specific allomorph /n-/ occurs in all other environments.[12]

(29)   a.   INCOMPLETIVE.3S.ABS → /nt-, nd-/ / _____ – 'V

        b.   INCOMPLETIVE.3S.ABS → /n-/ / elsewhere

One argument against treating nasal hardening as allomorph selection, rather than a phonological process, concerns the form of the aspect marker when realized as [nd-]. Voiced obstruents like [d] are only sparsely attested in Kaqchikel: there are no voiced obstruents at all in the native vocabulary (Table 1), and there are no allophonic processes which regularly derive voiced obstruents from other segments. Most importantly, there is no general process of post-nasal voicing which could account for the occurrence of [d] in [nd-] (section 3.8). To the extent that voiced stops like [d] occur in the language, they are limited to relatively recent, unassimilated loanwords from Spanish; older loanwords tend to be phonologically nativized (e.g. Stenson 1998, Adell 2014).

    As far as we are aware, [nd-] is the *only* morpheme in the native Kaqchikel vocabulary which contains [d]. At best, [d] is a marginal phoneme in Kaqchikel—in fact, it is literally as marginal as a sound can be while still being present in a language, as part of the native vocabulary (see e.g. Hall 2013). For these reasons, it seems highly suspect to us to set up an underlying form like /nd-/ for the incompletive marker, even if only as a contextually-conditioned suppletive allomorph.[13] The alternative is to take the analytical path we follow here, and analyze [nt-, nd-] realizations of the incompletive marker as phonologically-derived variants of a single underlying form, /n-/.

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[12]Monosyllabic verb stems are exclusively bare roots in Kaqchikel, while polysyllabic verb stems are mostly morphologically complex. This follows from the fact that roots are in general /CVC/ in shape in Mayan languages (e.g. Coon 2016, Bennett 2016 and references there). It is thus conceivable that [n-]~[nt-, nd-] allomorphy for the incompletive aspect marker is directly conditioned by the morphological distinction between root and derived verbs, rather than by syllable count or other phonological factors. We believe that the arguments laid out here in favor of a phonological treatment of [n-]~[nt-, nd-] allomorphy apply equally to this alternative analysis.

[13]Shigeto Kawahara asks whether the existence of [d] in some loanwords might provide native speakers with a sufficient basis to postulate underlying /d/ in the aspect marker [nd-]. In raising this question, he points us to the interesting case of Japanese [p]. In the historical development of the native Japanese vocabulary, singleton [p] shifted to [h pː b], depending on its position (e.g. McCawley 1968:77-79, Itô and Mester 2003a:11). This gave rise to [h]~[pː]~[b] alternations which arguably implicate underlying /p/—a sound which never surfaces in the native Japanese vocabulary, but which *does* surface in loanwords (e.g. [paː.tiː] 'party'; Itô and Mester 2008).

    We believe that the presence of [d] under nasal hardening in Kaqchikel represents a fundamentally different phenomenon. The evidence for underlying /p/ in the native Japanese vocabulary comes from [h]~[pː]~[b] alternations which can be easily reduced to general phonological patterns (e.g. post-nasal voicing) if underlying /p/ is assumed. These [h]~[pː]~[b] alternations are also exemplified by a diverse set of morphemes. In contrast, [d] occurs in exactly *one* morpheme in Kaqchikel; it cannot be accounted for by independent phonological processes in the language (section 3.8); and it is not particularly well-attested even in recent loans, as far as we can tell. See Fries and Pike (1949), Hall (2013), and references there for related discussion.

3.7 Other affixes

In our analysis, nasal hardening in Kaqchikel reflects the confluence of several factors: the cumulative phonological strength of stressed and word-initial syllables; and a morpho-phonological pressure to exclude affixal material from stressed syllables, which are positions of psycholinguistic and phonological prominence. These assumptions jointly account for the fact that nasal hardening is restricted to a single morpheme, the aspect marker /n-/.

To illustrate, Kaqchikel has two other aspect markers which can attach directly to monosyllabic verb stems (section 2.1): these are /ʃ-/ COMPLETIVE and /t-/ IRREALIS.3ABS. Since both of these aspect markers are voiceless obstuents, they will satisfy the conjoined constraint STRONGONSET (=*ONSET$\geq_{son}$N/σ_1 &$_{syll}$ *ONSET$\geq_{son}$N/$\acute{\sigma}$) even when attaching to vowel-initial, monosyllabic stems.

(30)   STRONGONSET ≫ DEP-C

/ʃ-ok/	STRONGONSET	DEP-C
a. .ʃ.'t<u>ok</u>.		*! W
b. .'ʃt<u>ok</u>.		*! W
c. ☞ .'ʃ<u>ok</u>.		

xok /ʃ-ok/ → ['ʃokʰ] '(s)he entered'

However, the simple ranking MATCH($\acute{\sigma}$, ROOT) ≫ DEP-C (23) would suggest that these non-nasal aspect markers should still trigger epenthesis with monosyllabic verb stems. Indeed, this ranking predicts, quite incorrectly, that consonant epenthesis should target *all* words with the underlying form /C-V(C)/.

Our resolution to this problem involves another layer of constraint cumulativity. It appears that MATCH($\acute{\sigma}$, ROOT), on its own, is insufficient to trigger epenthesis (though it remains *necessary* for explaining the morphological conditioning of nasal hardening; tableau (23)). Hardening occurs only when the outcome of epenthesis is to displace affixal material from stressed position, while *also* reducing onset sonority in strong, word-initial stressed syllables. Forms like (30b,c) fail on this latter count, as non-epenthetic *xok* ['ʃokʰ.] already contains a relatively low-sonority onset.

These intutions can be formally implemented through multiple constraint conjunction: the conjoined constraints demanding low-sonority onsets in strong positions, when conjoined further with MATCH($\acute{\sigma}$, ROOT) (31), will produce the observed cumulativity effects (32).

(31)   AFFIXHARDENING = *ONSET$\geq_{son}$N/σ_1 &$_{syll}$ *ONSET$\geq_{son}$N/$\acute{\sigma}$ &$_{syll}$ MATCH($\acute{\sigma}$, ROOT)

(32)   AFFIXHARDENING ≫ DEP-C

/ʃ-ok/	AFFIXHARDENING	DEP-C
a. .ʃ.'t<u>ok</u>.		*! W
b. .'ʃt<u>ok</u>.		*! W
c. ☞ .'ʃ<u>ok</u>.		

xok /ʃ-ok/ → ['ʃokʰ] '(s)he entered'

(For related discussion, see Itô and Mester 2003a:Ch.2.)

We must also consider the /n/-final ergative and absolutive markers, which can also attach to vowel-initial, monosyllabic stems (i.e. 1S.ERG /in(w)-/ and 1S.ABS /i(n)-/; Figs. 3, 4). In fact, the analysis developed above to account for the lack of epenthesis with non-nasal aspect markers straightforwardly extends to these cases as well. The final nasal in these prefixes can occur as the onset of a stressed syllable, but *never* occurs in word-initial position. The constraint AFFIXHARDENING (32) is thus trivially satisfied by these agreement markers, leaving epenthesis wholly unmotivated.

(33) AFFIXHARDENING ≫ DEP-C

/j-in-ok/	AFFIXHARDENING	DEP-C
a. .jin.ˈt<u>ok</u>.		*! W
b. ☞ .ji.ˈn<u>ok</u>.		

yinok /j-in-ok/ → [ji.ˈnok^h] 'I entered'

Similar reasoning explains the failure of epenthesis with /n/-final verb stems and suffixes, e.g. *kanonïk* /kan-on-ɪk/ → [ka.no.nɪk^h] 'hunting', *[ka<u>n.ton.tɪ</u>k^h].

3.7.1 Noun prefixes

Our analysis still overgenerates consonant epenthesis in certain contexts. AFFIXHARDENING predicts the insertion of [t]~[d] in /C-VC/ words whenever the prefixal consonant is at least as sonorous as a nasal. Two prefixes are relevant here, both of them possessive prefixes on nouns (possessive prefixes are largely, but not entirely homophonous with the verbal ergative prefixes in Table 3). The possessive prefixes 1S.ERG /w-/ and 3S.ERG /r-/ are both more sonorous than nasals, but neither prefix conditions consonant epenthesis (34):

(34) a. /w-ɜk^ʔ/ → [wɜk^ʔ], *[wpɜk^ʔ] 'my chicken'
      b. /r-ɜk^ʔ/ → [rɜk^ʔ], *[rtɜk^ʔ] 'his/her/its chicken'

One possibility is that the initial clusters produced by consonant epenthesis in forms like (34) are simply too marked, in some respect, to be tolerated. This seems reasonable, though it is complicated by the fact that Kaqchikel does allow at least some marked clusters in initial position (section 3.4.1).

Alternatively, the lack of epenthesis with possessive prefixes (34) may be rooted in deeper facts about the morpho-phonology of Kaqchikel. Morphological roots in Mayan languages tend to be /(C)VC/ in shape (see Bennett 2016, Bennett et al. In revision, Coon 2017 and references there). This /(C)VC/ root template is imposed more strictly on some lexical categories than others: verb roots are overwhelmingly /(C)VC/, while noun roots are frequently larger in size (e.g. /at͡ʃin/ 'man').

We speculate that one of the constraints driving consonant epenthesis in our analysis—-MATCH($\acute{\sigma}$, ROOT)—is grounded in the templatic character of the verbal root in Kaqchikel. Consonant epenthesis always produces a [CVC] sequence consisting of root material and an epenthetic C, but no affixal material. We might assume, then, that epenthetic [n-tVC] better satisfies the templatic requirements of verb roots than non-epenthetic [n-VC], perhaps because the affixal character of initial [n] is more transparent in [n-tVC] than in [n-VC]. If this is on the right track, the fact that prefixes undergo hardening in verbs, but not in nouns (34), then reduces to the independent fact that templatic requirements are more stringent for verbs than for nouns.

3.8 Voicing

In section 3.6 we noted a surprising fact about nasal hardening: in some dialects of Kaqchikel, hardening co-occurs with post-nasal voicing, /#n-ˈV.../ → [#n̯t-ˈV...]~[#n̯d-ˈV...]. To our knowledge, this is the only context in which post-nasal voicing occurs in Kaqchikel, as voiceless obstruents of all types are robustly attested following nasal consonants in the language (35).

(35)   a.   *jampe* [χam.pe] 'how many'
        b.   *ntix* [n-tiʃ](~[ni-tiʃ]) 'it was eaten'
        c.   *xintij* [ʃ-in-tiχ] 'I ate it'
        d.   *xinkanoj* [ʃ-in-kan-oχ] 'I looked for it'

      We believe that post-nasal voicing follows directly from the epenthetic status of the post-nasal, coronal stop. In underlying /NC̥/ clusters, post-nasal voicing is blocked by high-ranked DEP[VOI] (36a).[14] In contrast, the coronal stop which appears in nasal hardening contexts is inserted rather than underlying. As a result, its form is regulated only by phonological markedness constraints, and not by faithfulness constraints (e.g. Lombardi 2002a,b, de Lacy 2006). DEP[VOI] is therefore unable to prevent post-nasal voicing from occurring (36b). Post-nasal voicing in nasal hardening contexts thus emerges as a textbook case of THE EMERGENCE OF THE UNMARKED (McCarthy and Prince 1994, Becker and Flack Potts 2011, and many others). (On the phonology of post-nasal voicing, see Itô and Mester 1986, Itô et al. 1995, Itô and Mester 2003a, Pater 1999, Hayes 1999.)

(36)   DEP[VOI] ≫ *NC̥ and TETU in nasal hardening

a.

/ʃ-in-kanoχ/	DEP[VOI]	*NC̥
a. ☞ .ʃin.ka.ˈnoχ.		*
b. .ʃin.ga.ˈnoχ.	*! W	L

xinkanoj /ʃ-in-kan-oχ/ → [.ʃin.ka.ˈnoχ.] 'I searched for it'

b.

/n-ok/	DEP[VOI]	*NC̥
a. ☞ .n.ˈdokʰ.		
b. .n.ˈtokʰ.		*! W

nok /n-ok/ → [n.ˈdokʰ] (Fig. 7) '(s)he enters'

For those dialects which do not show post-nasal voicing in nasal hardening contexts, we assume that a context-free constraint against voiced obstruents (*VOIOBS) outranks *NC̥ (37) (see also Gouskova et al. 2011). This constraint is clearly active in Kaqchikel, given the general lack of voiced obstruents in the language (Table 1) (i.e. *VOIOBS ≫ MAX[VOI]).

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[14]We follow Mester and Itô (1989), Lombardi (1991, 1995, 1999, 2001), Kehrein and Golston (2004), and Beckman et al. (2013) (among others) in assuming a privative [VOICE] feature, rather than binary [±VOICE] (Jakobson et al. 1952, Chomsky and Halle 1968). The voicing of underlyingly voiceless consonants is banned by DEP[VOICE], and devoicing is banned by MAX[VOICE].

(37) a. No TETU voicing in some dialects: {DEP[VOI],*VOIOBS} ≫ *NC̥

/n-ok/	DEP[VOI]	*VOIOBS	*NC̥
a. .n.ˈdokʰ.		*! W	
b. ☞ .n.ˈtokʰ.			* L

b. TETU voicing in other dialects: DEP[VOI] ≫ *NC̥ ≫ *VOIOBS

/n-ok/	DEP[VOI]	*NC̥	*VOIOBS
a. ☞ .n.ˈdokʰ.			* L
b. .n.ˈtokʰ.		*! W	

We speculate that post-nasal voicing may play an additional functional role: the presence of otherwise unattested [d] in nasal hardening environments prevents surface merger between underlyingly vowel-initial and /t/-initial roots, and serves as a possible signal of the epenthetic origin (synchronically speaking) of the [d] itself. (The idea that phonological 'misapplication' is useful for identifying underlying forms can also be found in the literature on opacity; see e.g. Itô and Mester 2003b, Baković 2011 and references there.)

The voicing of post-nasal [t] → [d] in nasal hardening environments is, we think, another clue to the epenthetic status of this consonant. As noted in section 3.6, post-nasal voicing is not otherwise attested in Kaqchikel, including in those dialects which allow initial [#NC-] clusters under affixation of the aspect marker /n-/ (e.g. [n-tiχ-ɔx] '(s)he teaches', Comunidad Lingüística Kaqchikel 2004:204). Furthermore, voiced [nd-] is actually innovative when compared to historical [nt-] (section 3.3), meaning that post-nasal voicing must have developed in this context even in the complete absence of post-nasal voicing elsewhere in the language (and indeed, the complete absence of surface [d]). We conjecture that this otherwise surprising development can be rationalized as an instance of the emergence of the unmarked, but only if the post-nasal stop is taken to be epenthetic, and thus exempt from the faithfulness pressures which prevent post-nasal voicing in other environments.

4 Other varieties of Kaqchikel

In section 2.2 we observed that dialects of Kaqchikel differ in the conditions governing [n-]~[nt-, nd-] allomorphy in the incompletive aspect. We repeat the basic classification here:[15]

(i) Use of [n-] in all contexts (with or without epenthesis)

(ii) Use of [nt-]~[nd-] with monosyllabic verb stems, and [n-] otherwise (possibly with epenthesis)

(iii) Use of [nd-] with all verb stems (sometimes in free variation with [n-])

(iv) Use of [nd-]~[d-] with all verb stems, shifting toward fixed [d-] over time

(v) Use of [nd-] with intransitives, and use of [n-] with transitives

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[15]Comunidad Lingüística Kaqchikel (2004:50-1) suggest that [nt-V…] has, in some sporadic cases, been reanalyzed as [n-tV…] (e.g. *xojtel* [ʃ-oχ-teḷ] 'we left' < historical [ʃ-oχ-eḷ] 'we left' + [nt-eḷ] '(s)he leaves'). Such cases of reanalysis do not appear to be systematic.

Our primary focus in this paper has been Type (ii) dialects, particularly the dialect of San Juan Comalapa Kaqchikel. We nonetheless feel that we are in a position to comment briefly on the distribution of [nt-]~[nd-] in other dialects of the language.

As discussed previously, Type (iii) dialects are in fact conservative (apart from the voicing of post-nasal [t], which we return to below). We take it, then, that the task before us is to explain the historical development of all other dialect types. There is a clear affinity between Type (i) (standard Kaqchikel) and Type (iv): these are dialects in which the complex initial cluster [#nd-] has been simplified across the board, albeit in different ways in Type (i) [n-] vs. Type (iv) [d-] languages. Type (ii) languages are a special case of Type (i), in which [#nd-] has simplified to [#n-], *except* when protected by the positional privilege of stressed, word-initial syllables (sections 3.3, 3.7).

This leaves only the Type (v) varieties in need of explanation. In these varieties, nasal hardening appears to be conditioned by transitivity rather than phonology, as in Type (ii) systems like Comalapa. In fact, we take Type (v) systems to be a further development of Type (ii) systems. True monosyllabic verb stems are always intransitive in Kaqchikel; this follows from the fact that the ergative agreement markers, which cross-reference transitive subjects, almost always contribute an extra syllable to the verbal stem (e.g. intransitive *nel* /n-el/ '(s)he left' vs. intransitive *naya'* /n-a-jaʔ/ 'you give it'). Comalapa Kaqchikel (Type (ii)) draws a line between monosyllabic—always intransitive—verb stems (e.g. *-el* /-el/ 'to leave') and polysyllabic stems of any class (e.g. intransitive *-atin* /-atin/ 'to bathe' or transitive *-elesaj* /-el-es-aχ/ 'to remove'). Type (v) dialects may have simply reanalyzed this pattern in morphological terms.[16]

One aspect of this landscape remains mysterious under our analysis. In sections 3.6 and 3.8 we argued that surface voiced [d] indicates that epenthesis has occurred, since [d] is not in general a phoneme of the language, and is conditioned by a process of post-nasal voicing that *only* applies after the aspect marker /n-/. The distribution of surface [d] in allomorphs of the incompletive aspect marker in Type (iii), (iv), and (v) dialects is surprising under this view.

To unpack why, we assume (temporarily, for the sake of argument) that surface [d] is always the result of consonant epenthesis. For Type (iii) dialects, we must then explain why epenthesis occurs after *all* instances of incompletive /n-/, but never after any other instance of word-initial [#n]. (In our analysis of Comalapa Kaqchikel (Type (ii)), this follows from constraints like MATCH($\acute{\sigma}$, ROOT), which are sensitive to *both* prosody and morphology; note that these constraints will not produce epenthesis on polysyllabic verb roots.) Type (iv) dialects pose the same problem, with the additional complication that incompletive aspect is sometimes marked *only* with 'epenthetic' [#d-], even though neither [t d]-epenthesis nor stop voicing are motivated (in our analysis) in the absence of initial [#n-] (which is perhaps present underlyingly, but lost in some opaque process of [n]-deletion). For Type (v) dialects, we would appear to be committed to the view that epenthesis is conditioned by verb transitivity directly.

The alternative, of course, is to assume that Type (iii), (iv), and/or (v) dialects have simply innovated /d/ as a highly marginal phoneme (despite our protestations in section 3.6). The phonemicization of /d/ would immediately explain why this segment occurs in contexts in which its appearance lacks any clear phonological motivation. If correct, this strikes us a surprising development, given that [d]—even in these dialects—is entirely unattested outside of incompletive aspect marking. These issues seem to us worthy of further investigation.

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[16]Alternatively, Type (v) varieties are a direct reanalysis of the more conservative Type (iii) varieties, though we are unsure why Type (iii) dialects would give rise to an immediate split in terms of transitivity distinctions without an intervening stage in which transitivity is correlated with some other factor conditioning allomorphy, such as syllable count in Type (ii) systems.

5 Conclusion

Nasal hardening in Kaqchikel is a morpheme-specific phenomenon which can be straightforwardly analyzed as run-of-the-mill suppletive allomorphy. In that light, nasal hardening seems to be nothing more than a minor issue in the morpho-phonology of Kaqchikel. But as we have often learned from Junko and Armin's work, sustained engagement with seemingly simple problems can reveal new puzzles, as well as deep insights into the workings of grammar.

The phonological analysis of nasal hardening is considerably more complex than simple lexical listing of allomorphs. Readers might reasonably favor lexical listing on those grounds alone. Still, crafting a phonological model of nasal hardening is, we think, a useful exercise: it has forced us to make connections between phonetics, phonology, and morphology which we might not have otherwise made. And in drawing those connections, we cannot help but think of Junko and Armin, who always encouraged us to consider the bigger picture.

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Notes on Prosodic Headedness and Tone in Tokyo Japanese, Standard English, and Northern Bizkaian Basque[*]

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This paper explores how the notion 'prosodic head' comes into play in providing an account for certain facts concerning the distribution of tonal pitch accents in Tokyo Japanese, Standard American and British English, and Northern Bizkaian Basque. Building on evidence from I&M on Tokyo Japanese, it is argued that there is a class of violable phonological markedness constraints on the headedness of prosodic constituents. A class of markedness constraints calling for a prosodic head/abstract prominence to be associated with tone is also motivated. Together, these constraints play a role in accounts of tone epenthesis on prosodic heads or displacement of lexical tone to prosodic heads that are found in both 'pitch accent languages' and in 'intonation languages'. These two prosodic headedness-related constraint types also play a role in accounting for the disappearance of expected phonological phrasing in cases of the absence of tonal 'accent' and the related absence of word-level prosodic headedness.
Keywords: prosodic head, tone, Japanese, English, Basque

1 Introduction

This paper explores how the notion 'prosodic head' comes into play in providing an account for certain facts concerning the distribution of tonal pitch accents in Tokyo Japanese, Standard American and British English, and Northern Bizkaian Basque. We have been prompted to put thoughts on paper at this point by the stimulating account of unaccentedness and accentedness in Tokyo Japanese loanwords by Ito and Mester (2016) (I&M, henceforth), and by the opportunity to engage with their account that this festschrift volume in their honor presents.

We assume that a prosodic constituent is headed if a unique daughter constituent is designated as its head.[1] ($f'\ f$)PW and (f')PW each represent prosodic words with a head foot,[2] ($\sigma'\ \sigma$)$_f$ and (σ')$_f$ each

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[1] One of the general "constraints on prosodic domination" put forward in Selkirk (1996) was, unfortunately, called Headedness, in a departure from prior usage of that term. This constraint Headedness required that a prosodic constituent immediately dominate a constituent at the next level down in the Prosodic Hierarchy. It had no function in identifying one of the daughter feet of a prosodic word as the 'prosodic head' of that word, for example.

[2] In this paper, in general, the head status of a daughter is indicated by a superscript prime symbol. I&M utilize an acute accent mark to indicate the head syllable of a foot, but not to indicate the head foot of a prosodic word, as we see in (6) which is repeated here from their paper.

represent feet with a head syllable, and so on. The notion 'head' can be thought of as encoding an abstract notion of prominence. Prosodic constituent headedness is key to an understanding of the distribution of a variety of phonological and phonetic properties within an utterance.[3] In Tokyo Japanese, I&M propose, the head syllable of a prosodic word (i.e. the syllable that is the head of the foot that is the head of a prosodic word) must carry a pitch accent. In Standard American and British English, by contrast, the head syllable (of the head foot) of a prosodic word is phonetically interpreted as "stressed"; it has greater duration, intensity, etc., than non-head syllables. But, though pitch accenting of the head is not a word-level phenomenon in Standard English, the head syllable of a phonological phrase is necessarily associated with a tonal pitch accent, whether it be a default H* or a pitch accent that is an intonational morpheme (Ladd 1996/2008; Truckenbrodt 2007). A system of constraints on prosodic headedness and its reflexes in phonological representation and phonetic interpretation has to make sense of these, and other, crosslinguistic differences.

The questions we want to address in this paper concern the nature of phonological markedness constraints that make appeal to the notion prosodic head. Specifically: What is the nature of any phonological constraint(s) on the relation between a prosodic head and the tone(s) referred to as pitch accents? Also to be considered: Can a prosodic constituent not have a head? Is there a class of potentially violable phonological markedness constraints that call for prosodic constituents to immediately dominate a head constituent? I&M have opened the door to a discussion of these questions in arguing that the absence of tonal pitch accent (unaccentedness) in Tokyo Japanese loanwords is a consequence of the absence of a word-level prosodic head or 'prominence peak' in words with the particular prosodic structure profile which is associated with lack of accent.

In implementing their analysis of unaccentedness and accentedness in Tokyo Japanese loanwords, I&M propose that WordAccent is the constraint that is violated when word-level head/prominence is absent. This constraint is stated as in (1):

(1) WordAccent [WdAcc]   (I&M, p. 485)

A prosodic word contains a prominence peak.

(Violated by prosodic words not having a prominence peak (peak = primary stress or pitch accent, in Japanese: High*Low))

We suggest in this paper that the constraint WdAcc should instead be factored into two distinct constraints, both of which appeal to the notion prosodic head. The violable constraint (2) that calls for a prosodic word to be headed can take the place of I&M's WdAcc constraint in the analysis of the presence or absence of a 'prominence peak' in Tokyo Japanese loanwords (cf. tableaux in section 1):

(2) ProsodicWord:Head [ω:Hd]

A prosodic word must have a unique daughter constituent that is its head.

(Violated by any prosodic word which lacks a daughter designated as its head.)

[The colon in the constraint name stands for the '⇒' of logical implication.]

Like WdAcc in the I&M account, ω:Head would be violable.

As for the H*L pitch accent that is phonologically associated with the head of a prosodic word in surface phonological representation in Tokyo Japanese, a distinct phonological markedness constraint (3) can be given responsibility for the predictable presence of H*L in the surface representations of loanwords:

(3) Head-Mora-of-Prosodic Word: Tone   [Hdμ(ω):Tone]

> The head mora (μ) of a prosodic word (ω) must be associated with some tone.
> [The head μ of ω is the head mora of the head syllable of the head foot of ω.]

> The constraint is violated if the head mora (μ) of a prosodic word ω is not associated with a tone.

Constraint (3) can simply be added to a revised I&M analysis of Tokyo Japanese loanwords, providing an explicit account of the association of predictable tone to the head mora of the word.

The notions 'prosodic head' and 'tone' are appealed to throughout I&M's paper. Perhaps I&M intend their formulation of WordAccent as it pertains to Japanese in (1) as a convenient shorthand for a conjunction of the two constraints in (2) and (3), one conjunct calling for the presence of the prosodic head and the other calling for tone to be associated to that head. In the next sections, the advantages of assuming distinct constraints of the types (2) and (3) and the distinct phonological representations of tone and prosodic headedness (or 'prominence') that are implied by these will become clear. With them, we can account for certain important aspects of the relation between tone, headedness/prominence and prosodic constituency in Tokyo Japanese, Standard English and Northern Bizkaian Basque.

It should be said, for clarification, that the notion 'head' in prosodic phonology is not the same notion as in syntax. In syntax, the properties of higher order constituents are projected from a lexical or functional category item, which is referred to as the head of those constituents. A syntactic constituent VP, for example, would not exist if it dominated no verb (or trace of a verb). In prosodic structure, by contrast, there are independent sources in the grammar for the prosodic constituents that play a role in phonological representation (and which may or may not be headed). One source of prosodic constituency are markedness constraints that are proper to the phonology itself — those that call for the grouping of segments into syllables or for the grouping of syllables into feet. A different source of prosodic constituency in the phonological representation of a sentence is its syntactic constituent structure. The proposal made by Selkirk (2009, 2011), referred to as Match Theory, is that the phonological constituents prosodic word, phonological phrase and intonational phrase are in effect the phonological expression of the corresponding syntactic constituents word, phrase and clause (the former are 'grounded' in the latter). In other words, the notion 'head' in prosodic phonology is defined in terms of prosodic constituents that themselves have an independent source in the grammar. So, a phrasal constituent in syntax is headed, as a matter of theoretical necessity, but the same is not true of prosodic constituents.

A yet further clarification concerning the notion of 'head' in prosodic phonology is needed. Constraint (2) defines 'head' in terms of immediate domination (the mother-daughter relation). In the statement of (3) the 'head mora' that must be tone-bearing is not directly dominated by prosodic word. The expression 'head mora of prosodic word' is intended as shorthand for 'head mora of the head syllable of the head foot of prosodic word'. We need to go one step further on the road to clarification of the notion 'head' and make explicit what's implied in using the expression 'head mora of π' (where π is any prosodic category):

(4) The Head Chain Condition (see Selkirk 2007)[4]

> A prosodic constituent π^b qualifies as the head of its mother constituent π^a if there is a prosodic constituent π^c which is the head of π^b.

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[4] The idea behind this Head Chain Condition on headedness is made explicit in Selkirk (2007), though not under this name or formulation.

The Head Chain Condition says that a mother constituent π^a may be headed only if it dominates a chain of heads "all the way down". Satisfying constraint (2) ω:Hd means that a prosodic word must have a head mora, and heads at every prosodic level in between, as illustrated in (5). In this representation, head constituents are marked with a prime symbol at the upper right.

(5)   *caramels*

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                    ω
                   / \
                  f′  f′
                 /\   |
                σ′ σ  σ′
                | |   /\
                μ′ μ  μ′μ
                ca ra mels
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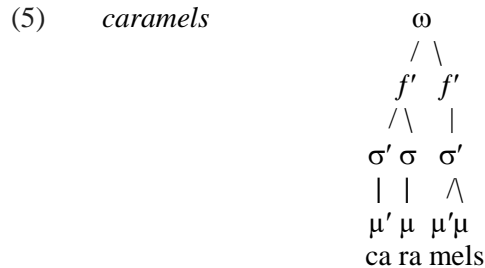
A last clarification is perhaps necessary. While we are adopting the hypothesis of the violability of the constraint ω:Hd, (2), that requires the presence of a head daughter for a prosodic word ω, adopting the Head Chain Condition (4) imposes the requirement, that, when defined, a head must have the property that it dominates a chain of heads below it. The Head Chain Condition can be thought of as a "hardware commitment"; it is not a violable constraint.

Despite there being no theoretical necessity for the presence of a prosodic head in a phonological constituent, putting forward ω:Hd as a violable constraint, as suggested above, does go counter to common phonological thinking on this matter. As McCarthy (2003, 110) points out, "The existence and uniqueness of the head foot [of a prosodic word] are usually taken to be axiomatic — universal properties of GEN, rather than violable constraints". The importance of Ito and Mester's empirical investigation of the distribution of accentedness and unaccentedness in Tokyo Japanese loanwords is that it leads to the conclusion that the head of a prosodic word is not defined in the case of unaccented words, whether loanwords or native. They show that whether or not a prosodic constituent is headed arguably involves a language-particular choice in the ranking of violable constraints.

In what follows, we will also show the broader empirical coverage of our proposal to decompose I&M's constraint WordAccent into the two constraints ω:Head ("A prosodic word must have a unique daughter constituent that is its head") and Hdμ(ω):Tone ("The head mora of a prosodic word must be associated with some tone"). First, the introduction of epenthetic pitch accent at the phrasal level in Standard American and British English (section 3) motivates the constraint Hdμ(φ):Tone, providing independent evidence for a larger constraint family Hdμ(π):Tone to which Hdμ(ω):Tone would belong, and at the same time it motivates the constraint φ:Head calling for a φ to be headed, which is a member of the same general constraint family π:Head to which the proposed ω:Head would belong. Second, we will argue that the "dephrasing" of unaccented φ in Northern Bizkaian Basque receives an explanation if we assume (i) that the dephrasing is the language-particular consequence of the violation of the constraint φ:Head and (ii) that the violation of φ:Head is the consequence of the absence of a head for that φ, that is due to the absence in an unaccented ω of the tone that would be required for a daughter ω to itself be headed. Sections 3 and 4 are dedicated to fleshing out the analyses that are synopsized here.

2   Tone and prosodic headedness in Tokyo Japanese

We will first briefly review I&M's analysis of unaccentedness (and accentedness) in Tokyo Japanese loanwords. The core component is a constraint-based account of the foot and prosodic word structure exhibited in loanwords, which bring with them no lexical properties beyond the segmental makeup. I&M's account persuasively characterizes the prosodic configurations in which the prosodic head ('prominence peak') of a word is defined, and those where it is not. Their proposal is that a H*L accent appears just in loanwords where word-level prosodic headedness has representation, that there is no H*L

accent in words where the head syllable (or head mora) of the word is not defined. Their important insight is that the *lack* of prosodic headedness can play a key role in explaining phonological patterning. In what follows we implement this analysis using the constraints ω:Hd (2) and Head-μ(ω):Tone (3) instead of the constraint WordAccent.

The table in (6), repeated here from I&M, p. 485, shows representative cases of Tokyo Japanese loanwords consisting of light (single-mora) syllables only, organized into head-initial trochaic feet. The examples illustrate the generalization established by I&M that, with the exception of words with four syllables, words with three or more light syllables have a tonal accent that falls on the antepenultimate syllable, which is the head syllable of the rightmost (binary) foot in the word. Any prosodic pattern showing antepenultimacy effects naturally leads to the hypothesis that the prosodic structure of the word includes a trochaic (left-headed) head foot that is one syllable away from the right edge of the word. In addition to the foot representation that is the basis of antepenultimate prominence, the organization of the initial two syllables into feet within the words in (6) (p. 485) reflects I&M's solution to the two questions raised by the systematic unaccentedness of four-light-syllable words. On the one hand, (i) why is it that four-light-syllable words do not show the antepenultimate pattern? On the other, (ii) why is it that unaccentedness (lack of tonal accent) accompanies the departure from that pattern?

(6) [From I&M, 485]

Accented			Unaccented	Accented		
1L	2L	3L	4L	5L	6L	7L
^{1}(Ĺ)	^{2}(ĹL)	^{3}(ĹL)L	^{0}(LL)(LL)	^{3}(LL)(ĹL)L	^{3}(LL)L(ĹL)L	^{3}(LL)(LL)(ĹL)L
(dó)	(pári)	(bána)na	(riha)(biri)	(kuri)(súma)su	(meto)ro(póri)su	(ana)(kuro)(nízu)mu
(ré)	(páte)	(góri)ra	(ame)(rika)	(asu)(fáru)to	(eko)no(mísu)to	(namu)(ami)(dábu)tu
(mí)	(mémo)	(sháto)ru	(kari)(suma)	(pia)(nísu)to	(asu)pa(rága)su	(abu)(suto)(ráku)to

I&M's answer to question (i) is that, in Japanese, satisfaction of the constraint Initial Foot, which parses the first two syllables of a prosodic word into a foot, plays a key role in determining the absence in four syllable words of the footing which results in antepenultimate prominence. The other key element of I&M's answer to question (i) is their argument that the lack of a head foot altogether (and resultant lack of tonal accent) is the consequence of a constraint ranking which places a *violable* constraint calling for a prosodic word to be headed (their constraint WordAccent, our constraint ω:Hd (2)) *below* all the constraints that define the distribution of feet in a word. We will see this in the tableau below in (8).

Aside from WordAccent, the set of constraints that I&M exploit in their account have commonly played a role in defining the distribution of feet in the languages of the world.[5] They are given in (7), corresponding to (17) in I&M (p. 485):

(7)   [From I&M: 485]

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[5] InitialFoot is what gives the initial footing in the five syllable English word *àbracadábra* — (àbra)ca(dábra) with secondary word prominence on the initial syllable. But, as the English pronunciation of *A(méri)ca* with antepenultimate word prominence shows, InitialFoot would appear to be subordinated to Rightmost and Nonfinality(Ft′) in the grammar of English.

a. *WORDACCENT (WDACC)*
   A prosodic word contains a prominence peak. Violated by prosodic words not having a prominence peak (peak = primary stress or pitch accent, in Japanese: High*Low).
b. *RIGHTMOST*
   *FT′ . . . FT . . .]ω   Violated by any foot following the head foot within the prosodic word. This is the *End Rule (Final)* of Prince 1983, in a version modeled on the foot-based restatement in McCarthy 2003:111.
c. *NONFINALITY(FT′) (NONFIN(FT′))*
   *FT′]ω   Violated by any head foot that is final in its prosodic word (Prince and Smolensky 1993:45).[27]
d. *INITIALFOOT (INITFT)*
   *ω[o   A prosodic word begins with a foot (Ito and Mester 1992:31, McCarthy and Prince 1993:81). Violated by any prosodic word whose left edge is aligned with the left edge, not of a foot, but of an unfooted syllable.
e. *PARSE-σ*
   *o   All syllables are parsed into feet (Prince and Smolensky 1993:62). Violated by unfooted syllables.
f. *NOLAPSE*
   *oo   Syllables are maximally parsed. Violated by two consecutive unparsed syllables.

I&M propose that in Tokyo Japanese these constraints are ranked as in the tableau in (8), from I&M's (18), on page 486. (The superscript numbering at the left edge of a candidate indicates the locus of the head syllable of the head foot of the word, counting from the end.) We see in (8) that the parsing of 4-light-syllable words into two feet, both of which lack prominence, is optimal.

(8)   [From I&M: 486]

	INITFT	NOLAPSE	NONFIN(FT′)	RIGHTMOST	WDACC	PARSE-σ
/amerika/ ▶ a. ^{0}[(ame)(rika)]					*	
b. ^{4}[(áme)(rika)]				*!		
c. ^{2}[(ame)(ríka)]			*!			
d. ^{4}[(áme)rika]		*!				**
e. ^{3}[a(méri)ka]	*!					**

In the optimal candidate (a), the four light syllables of the PWd are parsed as two feet, with neither foot having the status of the head foot of the PWd. For this reason there is no violation of either Rightmost or Nonfinality(Ft′) in (a); both these constraints govern only the distribution of the head foot (Ft′) of a prosodic word. The headless candidate (a) is optimal because it is the only candidate which does not violate any of the set of constraints determining the distribution of feet, and these all dominate the lower-ranked constraint WordAccent. Each of that set of higher-ranked constraints displays a violation in one of

the other, nonoptimal, candidates, where the head of prosodic word is defined.[6] Our modest suggestion is that WordAccent should be supplanted by the constraint ProsodicWord:Head (ω:Hd), which explicitly calls for the headedness of prosodic word, and, more importantly, would be a member of a larger constraint family, including Foot:Head (*f*:Hd), PhonologicalPhrase:Head (φ:Hd), etc. whose members would be expected to play a role in cross-linguistic typology.

As for question (ii) concerning the absence of tone (pitch accent) in the four-syllable words, this absence may simply be understood as due to the absence of a ω-head ('prominence peak' in I&M's terms). Our suggestion is that the absence of the ω-head in the four-light-syllable loan cases means the absence of any pressure from the markedness constraint Hdμ(ω):Tone (3) for there to be a tone (accent) associated with the head mora of the PWd, hence the unaccentedness of the four-syllable cases in (8).

Turning to accented words of 3, 5, or 6 syllables, for example, in each type of case there is an optimal candidate in which *all* the relevant constraints on PWd-internal prosodic structure are satisfied. This includes the constraints determining the organization and distribution of feet in the word — InitialFoot, NoLapse, NonFin(Ft′), Rightmost — as well as the constraint WordAccent (or our ω:Hd), which calls for the PWd to be headed. Candidate (a) is the optimal candidate in (9) (from I&M's (20), p. 487) for the 3-syllable word and candidate (d) is the optimal candidate for the 5-syllable word. In these optimal cases, the PWd has a daughter which is a head foot which has a daughter which is a head syllable (which has a daughter which is the head mora (consistent with the Head Chain Condition in (4) above).

(9) [From I&M: 487]

	InitFt	NoLapse	NonFin(Ft′)	Rightmost	WdAcc	Parse-σ
/banana/ ▶ a. ^{3}[(bána)na]						*
b. ^{0}[(bana)na]					*!	*
c. ^{2}[ba(nána)]	*!		*!			*
/baruserona/ ▶ d. ^{3}[(baru)(séro)na]						*
e. ^{0}[(baru)(sero)na]					*!	*
f. ^{5}[(báru)(sero)na]				*!		*
g. ^{2}[(baru)se(róna)]			*!			*
h. ^{5}[(báru)serona]		*!				***
i. ^{4}[ba(rúse)(rona)]	*!			*!		*

As for the predictable, arguably epenthetic, tonal accent H*L which accompanies the head syllable of the head foot in the surface phonological representation of these word types, we take it to be epenthetic, present in surface phonological representation as a consequence of a phonological markedness constraint that governs the tone-head or tone-prominence peak relation, namely Hdμ(ω):Tone in (3).

In other words, in the case of loanwords, which are assumed to lack lexical tone, the surface tonal pitch accent is only epenthetic, appearing in response to the high-ranked prosodic markedness constraint Hd-μ(ω):Tone, which would be violated were there no such epenthesis. This constraint must, of course,

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[6] It would have been helpful for the reader for the head foot to have been marked in the candidates with a prime symbol, consistent with the notation supplied in the definition of the head-foot-sensitive constraints Rightmost and Nonfinality(Ft′) in I&M's (17), i.e. our tableau in (8).

dominate the tonal faithfulness constraint Dep(Tone) (Myers 1997), which weighs in against the epenthesis of tone in surface representation.[7]

(10)   Hdμ(ω):Tone >> Dep(Tone)   (ranking in loanword vocabulary)

In summary, we have proposed a slight revision of I&M's analysis of accentedness and unaccentedness in loanwords in Tokyo Japanese which substitutes the constraint PWd:Head (ω:Hd) for I&M's constraint WordAccent. The two reasons for that are: (i) ω:Hd makes more explicit the idea that it is the abstract property of prosodic headhood that is at issue, and (ii) ω:Hd implies the existence of a family of violable constraints on the headedness of prosodic constituents. We have also introduced a markedness constraint Head-μ-of-PWd: Tone (also written as Hdμ(ω):Tone) that explicitly calls for the head mora/syllable of a prosodic word to have a tone associated with it in surface representation. It turns out that these two types of constraint provide a good basis for addressing a variety of further aspects of the phonology of 'accent', both in Tokyo Japanese and in Standard English and Northern Bizkaian Basque.

Let us briefly consider the relation between ω-headedness and tone in inflected verbs and nouns of the native vocabulary in Japanese. An important fact is that verb and adjective roots are either lexically accented or unaccented. We take this to mean that (lexical) tone may, or may not, form part of the underlying, input, representation of these native roots. At the same time, the location of the syllable where the lexical tonal accent appears in surface representation is determined by general principles: the accent appears in antepenultimate position. Indeed, the constraints in (7) on the distribution of the (head syllable of) the head foot of PWd-head correctly predict that the antepenultimate position in surface representation within the PWd corresponding to the inflected verbs and adjectives of the native vocabulary is the position in which a lexical accent/tone belonging to the root morpheme in underlying representation will appear.

The examples in (11) from I&M (p. 474-5) illustrate the antepenultimate position of the lexical accent in inflected verbs of the native vocabulary (a HL tone representation of the verb's lexical accent appearing in its underlying and surface position has been added by us).

(11)   Accented surface forms with verb root with lexical accent:

    a.   Underlying representation of verb root with accent: [tabe]^{HL} 'eat'
    b.   Surface representation of verbal PWd containing accent

      ta'be-ta 'ate'   *tabe-sa'se-ta* 'made to eat'   *tabe-sase-ra're-ta*   'was made to eat'
      HL   HL   HL

In the case of unaccented verb or adjective roots, by contrast, the inflected surface form lacks any tone/accent, as seen in (12). In particular, there is no epenthesis of tone/accent in antepenultimate position (unlike in loanwords).

(12)   Unaccented surface forms with verb root with *no* lexical accent [ire] 'insert':

      ire-ta 'inserted', *ire-sase-ta* 'made to insert', *ire-sase-rare-ta* 'was made to insert', etc.

In the verb forms in (11), then, the prosodic structure constraints of (7) are responsible for the presence and location of a prosodic word head, as in loanwords. The constraint Head-μ-of-ω: Tone (= Hdμ(ω):Tone) is not the "source" of the surface tone associated with the ω-head, however. Rather, the constraint Hdμ(ω):Tone seemingly provides the pressure for the attested *shift* of the lexical tone/accent from the verb root to the antepenultimate head syllable of the ω. In this case, Hdμ(ω):Tone would

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[7] With Dep(Tone) and other constraints on input-output correspondence in the representation of tone, Myers (1997) extends to tonal faithfulness the McCarthy and Prince (1995) correspondence theory of segmental faithfulness.

dominate tonal faithfulness constraints that would (a) call for the lexical tone to remain in its lexical location, or (b) rule against any surface association of a tone to a mora/syllable which is not present in underlying representation. These would be the constraints Max(Assoc) and Dep(Assoc) proposed by Myers (1997) (see also Yip 2002: 82-6), following the format of correspondence constraints in McCarthy and Prince (1995). Also playing a role, obviously, is the constraint Max(Tone) which rules against deletion of underlying tone.

(13) Max(Assoc): A tone association in the input must have a correspondent in the output. [Myers 1997: 865]

(14) Dep(Assoc): An association in the output must have a correspondent in the input. [Myers 1997: 861]

(15) Max(Tone): A tone in input representation must have a correspondent in output representation.

The ranking in (16) would predict the displacement of lexical tone from the verbal root to the antepenultimate head syllable of the verb seen in (11):

(16)   Hdμ(ω):Tone, Max(Tone) >> Max(Assoc), Dep(Assoc)

Turning now to the case of lexically toneless (unaccented) verbs and adjectives in (12), as the shift of tone/accent to the antepenultimate syllable in (11) shows, there should be no obstacle to the defining of the ω-head when the verb root has no lexical accent. Yet that putative ω-head would be unaccompanied by a surface tonal accent. This violation of Headμ(ω):Tone) is not seen in the class of loanwords, where lexical tone/accent is absent throughout and epenthesis is systematically permitted. We must assume that the tonal faithfulness constraint Dep(Tone) dominates Hdμ(ω):Tone in order to guarantee the absence of epenthetic accent (tone) in native verbs or adjectives whose roots are not lexically accented:

(17)   No tone ('accent') epenthesis on PWd-head in native verbs and adjectives

         Dep(Tone) >> Hdμ(ω):Tone

The constraint ranking in (17) is the opposite of that in (10), which allows for the epenthesis of tonal accent in the case of loanwords. But this apparent 'inconsistency' in ranking should be permitted. As Ito and Mester (2002, 2009) have argued in earlier work, permitting variation in constraint ranking for well-defined strata of the vocabulary of a language allows for principled accounts of language-internal morphological strata-related variation in phonological patterning.
         Summarizing, the facts about Tokyo word prosody that have been reviewed above suggest a major advantage of a tonal representation of 'accent' that is distinct from the representation of antepenultimate prosodic headedness. Characterizing (pitch) accent as tone allows for familiar, independently motivated constraints from the analysis of tone languages to play the role that we expect them to have in any language where the relation between tone and prosodic headedness is constraint-governed. These are (a) tone-related faithfulness constraints, which regulate the correspondence relation between tones ('accents') in the input and output representations of phonology (Myers 1997 and others), and (b) tone-related markedness constraints which regulate, among other things, the relation between tone and prosodic structure (e.g. between tone and prosodic constituent heads or edges).
         The relation between tone/accent and prosodic headedness in Tokyo Japanese that we have discussed so far involved the constraint Hdμ(ω):Tone. It was taken to be the force behind tonal epenthesis (the presence of 'accent') on the antepenultimate head syllable of the PWd in the phonology of loanwords. It was also taken to be the force behind the shift of lexical tone/accent to the antepenultimate

locus of PWd-head in accented verbs and nouns of the native vocabulary. It remains to be seen if this is the sole type of constraint on the prosodic head-tone relation in Tokyo Japanese as well as crosslinguistically. Might there be motivation as well for a constraint in the other direction, requiring that a tone be associated to a prosodic head, e.g. Tone:Hdμ(ω)? I&M do indeed suggest early on in their paper (p. 485) that such a constraint is needed for Japanese.

Perhaps a constraint Tone:Hdμ(ω) is needed for an account of the exceptional surface locations of lexical accent in native nouns in Japanese that are neither in the antepenultimate location of the head syllable of prosodic word, e.g. *kokóro* 'heart', nor even in the position of a head (light) syllable of a foot, e.g. *atamá* 'head', *hashí* 'bridge'. What is it that accounts for the lexical tone remaining in situ in these cases? Might it be that, if the tone cannot come to the prosodic head, the prosodic head comes to the tone, and so arrives in an exceptional position? A constraint Tone:Hdμ(ω), accompanied by appropriate ranking of tonal faithfulness constraints, could indeed force this to happen.[8]

But before assuming that the existence of this additional constraint on the tone-head relation is motivated by exceptional accenting in the native nouns of Tokyo Japanese, one should also consider an alternative proposal. Along the lines of Smith (2001), could a higher ranking of faithfulness constraints in native nouns account for the lack of tonal accent shift to the 'normal' antepenultimate position of prosodic heads that is seen in native native verbs and adjectives? For native nouns, could it be that Hdμ(ω):Tone and the tonal faithfulness constraints Max(Tone), Max(Assoc) and Dep(Assoc), ranked in (16), are all higher ranked than the prosodic constraints in (7) which, appropriately ranked among themselves, would call for the prosodic head of the word to fall in antepenultimate position? Such a proposal would be in the spirit of the Ito and Mester (2002, 2009) theory of lexical stratum-specific ranking for faithfulness constraints. But it is not for us to pursue that question.

In the sections that follow on tonal accent and its relation to prosodic headedness, we look at Standard English and Northen Bizkaian Basque. We suggest that there is further motivation for constraints of the Hdμ(π):Tone variety (where 'π' stands for any constituent of the prosodic hierarchy), but no evidence for the Tone:Hdμ(π) variety. We also will see additional evidence for violable prosodic markedness constraints of the π:Head variety, in the spirit of I&M's contribution to our understanding of this issue.

3 Standard British and American English

In Standard British and American English tonal "pitch accents" are not lexical properties of the words themselves or of any of the word's component morphemes.[9] There are meaning-bearing "intonational" pitch accents (see e.g. Pierrehumbert and Hirschberg 1990), which on their own should be understood as morphemes consisting only of tone. These will not concern us here. It is the non-meaning-bearing, phonologically predictable, H tone pitch accent of Standard American and British English (typically written H*) that is of most direct relevance here. The central generalization, illustrated in (18c), is that, in a sentence which is pragmatically neutral in its utterance context and whose constituents are all discourse-new, a surface H tone necessarily appears on a syllable that is the head of a prosodic word (ω) that is moreover the head of a phonological phrase (φ).

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[8] Several authors have proposed constraints with a somewhat familiar flavor, calling for an accent (or tone, in our terms) to be associated to the head of a phonological word or phrase. Basically, "if accented, then head of ω or φ" (Yip 2002; de Lacy 2002; Hellmuth 2006; Selkirk & Elordieta 2010; Selkirk 2011, 2014; Bennett and Henderson 2013; Elordieta 2015; Ito and Mester *in press*, among others). Although such constraints are not framed in the same model that we are proposing here, they point to the existence of a family of constraints which would require that a tone be associated to a head (at some level).

[9] Most of the repertoire of pitch accents of Standard English (see Pierrehumbert 1980, for example) should be understood as tonal morphemes, morphemes whose underlying phonological representation consists only of tone. Plausibly a variety of discourse particles, these tonal morphemes carry meanings that relate to the pragmatic force of a sentence in particular discourse circumstances (see e.g. Ladd 1980; Pierrehumbert and Hirschberg 1990; Bartels 1999; and especially Constant 2014). The surface distribution of these tonal morphemes in the sentence would be in part determined by their place in the morphosyntactic representation of the sentence, where they contribute to the semantic/pragmatic interpretation of the sentence.

This generalization, due to Ladd (1996/2008), Truckenbrodt (2006), Féry and Samek-Lodovici (2006) and others,[10] can be accounted for if it is assumed that the phrasal constituent structure of the sentence along with prosodic-headedness-related phonological constraints of the sort discussed in the preceding section are at play in determining the tonal properties of the "intonational contour" of neutral all-new sentences in Standard English.

A simple case is that of the all-new declarative SVO sentence with the syntactic representation in (18a). This merely all-new sentence lacks any constituent that is morphologically marked as a contrastive FoCus or as Given in the discourse; there is, moreover, no morphological marking of newness or "information focus" (see Kratzer and Selkirk 2018/submitted). The syntactic phrases and words of (18a) that are headed by lexical items — namely noun, adjective, verb — are given expression as phonological phrases (φ) in the corresponding underlying phonological representation (18b) by Match constraints on the interface between syntactic and phonological constituency (see Selkirk 2009, 2011, 2017; Elfner 2015; Selkirk and Lee 2015; Bennett, Elfner and McCloskey 2016, among others). The syllable and foot structure of (18c) is determined by a language-particular ranking of constraints on the output representation, while the higher order constituency is inherited from the input due to prosodic structure faithfulness constraints, which are unviolated in this particular case. (In the surface phonological representation (18c), for clarity, the prosodic constituent structure is represented as a tree instead of the equivalent labeled bracketing given in (18b)).[11]

As the underlying and surface phonological constituency in (18b) and (18c) show, we are considering a two-step derivation from surface to prosodic constituency, following Selkirk and Lee (2017) and Kratzer and Selkirk (2018/submitted). In a first step, the surface syntactic structure derived as the output of syntactic operations of merge and move serves as the input to the mapping to the underlying phonological representation, which contains all idiosyncratic segmental and tonal properties of the morphemes in the syntactic structure as well as a prosodic structure. This prosodic structure is obtained from the application of the set of Match constraints that are proposed as correspondence constraints in the theory of the mapping between syntactic and prosodic constituents known as Match Theory: Match-Word, Match-Phrase and Match-Clause (Selkirk 2009, 2011). In a second step, the underlying phonological representation serves as input to a surface phonological representation which is the winning candidate among a series of candidates that converge or diverge with respect to the underlying representation in different ways and that are evaluated by ranked faithfulness and markedness constraints. It is in this second step that segmental and prosodic phonology *per se* occurs (sandhi phenomena, tonal spreading and shifting, insertion of boundary tones, etc.). Thus, after the mapping from syntactic to prosodic constituency, the relationship is between input and output phonological representations, with blindness to syntactic representation. Match constraints have the generative role from syntactic to prosodic structure devised in Match Theory, and do not operate at the phonological level per se.

This serial view of the derivation between surface syntactic structure and surface prosodic structure departs from previous assumptions in Match Theory itself, in which the derivation takes place in just one step. Match constraints evaluate output prosodic structures from an input syntactic structure together with phonological faithfulness and markedness constraints (Selkirk 2009, 2011; Elfner 2012, 2015; Ito and Mester 2013; Elordieta 2015; Bennett et al. 2016). Following Selkirk and Lee (2017), and also Kratzer and Selkirk (2018/submitted), we believe it is theoretically more appropriate to treat Match constraints as generators of underlying prosodic representation from syntactic representation rather than as faithfulness constraints. In phonology proper, there are prosodic faithfulness constraints such as Max(π) and Dep(π) that govern the correspondence between input and output prosodic structure.

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[10] These works show that Selkirk (1984, 1995) and Gussenhoven (1983) were wrong in bypassing syntactic structure as the basis for generalizations concerning the distribution of pitch accents.

[11] We follow the commonly held assumption that function words are not parsed phonologically as prosodic words, and that function word-headed phrases do not have the status of phonological phrases in the phonology. Thus, a function word like 'the' will be incorporated into the prosodic constituent of the sentence adjoining to the ω to its right or directly to the φ above it, to satisfy language-specific phonological constraints on surface phonological representation (Selkirk 1996). We leave open at this point just where the determiner is located in the tree in (18c).

(18)   *Syntax*

    a.   [[[Sarah]$_N$]$_{NP}$ [[mailed]$_V$ the [[caramels]$_N$]$_{NP}$]$_{VP}$]

    Phonology

    b. Underlying   (((Sarah)$_\omega$)$_\varphi$ ((mailed)$_\omega$ the ((caramels)$_\omega$)$_\varphi$)$_\varphi$)$_\iota$

    c. Surface

Sarah mailed the caramels
H* L-   H*   L-
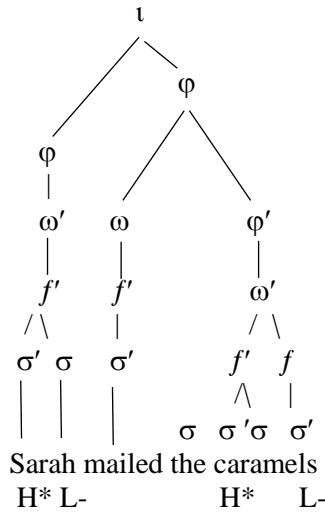
        As a consequence of Match constraints on the syntax-phonology interface and a language-particular ranking of a variety of familiar types of phonological constraints discussed in the preceding section, it is predicted that a H pitch accent necessarily falls just on the head mora of the φ that correspond to the subject and object phrases. A H tone does not obligatorily fall on the verb, which is not itself a φ in this sentence.

        Phonological markedness constraints of the π:Head family — namely φ:Head, ω:Head, *f*:Head — are responsible for the head status of a prosodic constituent. Headedness is represented by prime symbols in the surface representation (18c).[12]

        As for the surface tones, the markedness constraint Hdμ(φ):Tone can be held responsible for the appearance of a H tone in association with the (head mora of) the head syllable of the head foot of the head prosodic word of a φ in (18c), a tone typically referred to as a 'pitch accent' in the literature on English intonation. Since the appearance of a H tone on the head syllable of a phonological phrase is necessary in Standard English, a markedness constraint such as Hdμ(φ):Tone (19) must provide pressure for this epenthesis, and it must dominate the tonal faithfulness constraint Dep(Tone). Thus, Hdμ(φ):Tone >> Dep(Tone).

(19) Headμ-of-φ:Tone   [= Hdμ(φ):Tone]

        The head mora of a φ must be associated with a tone.

        The related constraint Hdμ(ω):Tone, which we suggested above is responsible for the epenthesis of accentual tone in Tokyo Japanese loanwords must be lower ranked than Dep(Tone) in Standard

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[12] To account for the assignment of head status to the φ daughter of φ within the recursive φ structure corresponding to the recursive LexP structure of the VP, Kratzer and Selkirk (2018/submitted) propose a constraint Unequal Sisters Prominence, which favors headship for whichever daughter is higher in the hierarchy of prosodic categories.

English. This is because in Standard English it is not necessary for a prosodic word which is *not* the head of φ to have a tonal accent associated with its head syllable:[13]

(20)   Standard English

Hdμ(φ):Tone >> Dep(Tone) >> Hdμ(ω):Tone

The generalization that a tonal pitch accent appears on the head of every phonological phrase (φ) of an all-new sentence of Standard English (one where no constituent is Given) is underscored by the systematic appearance of H* on the head of phonological phrases that are medial in a sentence, both nonfinal and post-verbal. The post-verbal direct object phrase and the sentence-final indirect object in an all-new sentence like (21) both systematically appear with H* pitch accents.[14]

(21)   Syntax: [I've [[sent]$_V$ my [[payment]$_N$]$_{NP}$ to the [[doctor]$_N$]$_{NP}$]$_{VP}$]

Phonology:

UR   (I've ((sent)$_ω$ my ((payment)$_ω$)$_φ$ to the ((doctor)$_ω$)$_φ$)$_φ$)$_ι$

SR   (I've ((sent)$_ω$ my ((payment)$_ω$´)$_φ$ to the ((doctor)$_ω$´)$_φ$´)$_φ$)$_ι$

                      <H>   H*   L-   H*   L-

Details of the syntax of the double object constraint, in which the objects are co-constituents of a "small clause" phrase will not concern us here.[15] What is important is that each of the two objects necessarily has a H tone on the head syllable of the φ that it corresponds to in phonological representation.

Turning now to the L- boundary tone that, by default, follows the H* tone associated with the right edge of a phonological phrase (φ), as seen in the sentences (18) and (21), it too can be understood as epenthetic. A phonological markedness constraint like (22) that calls for the right edge of a phonological phrase to be "demarcated" by a tone plausibly has responsibility for the surface presence of the L edge tone. It too would outrank Dep(Tone).

(22) R-Edgeμ-of-φ:Tone   [= R-Edgeμ(φ)]

A mora that lies at the right edge of a φ must be associated with a tone.[16]

It should be said that neither the constraint R-Edgeμ-φ:Tone, nor the Hdμ(φ):Tone constraint, specifies the quality (H or L) of the required tone. We assume that there are independent markedness constraints that make H the natural choice for a head-associated tone, or that make a L the natural choice for an edge tone of φ if the head tone of φ is H, and so on (see Hayes and Lahiri 1991, de Lacy 2002, Selkirk 2007 on such questions).

To complete the account of the tones that constitute the phonological representation of the intonational contour of all-new pragmatically neutral declarative sentences like (18) and (21) in Standard

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[13] The case of optional H tone accent on the verb in the sentence in (21) will be discussed below.

[14] See experimental evidence on this point in Katz and Selkirk (2011).

[15] See Harley (1995, 2002) on the syntactic analysis of double object constructions in English.

[16] In the earlier work by Pierrehumbert (1980) and Beckman and Pierrehumbert (1986), the prosodic phrase edge at which the L-boundary tone appears was identified as an Intermediate Phrase (as opposed to the lower-level Accentual Phrase). Ito and Mester (2013) have subsequently demonstrated that a single phonological phrase type φ suffices to represent presumed contrasts between the Intermediate and Accentual phrase in Tokyo Japanese, if the assumption is made that φ-structure is recursive. An Accentual Phrase would be a φ that immediately dominates no other φ, whereas the Intermediate Phrase might be a φ that is either nonminimal or maximal in the recursive structure. When it comes to English, simply referring to the right edge of as a φ is adequate for the characterization of the distribution of the post-H* L- boundary tone.

English, we must explain the optional presence of H tone on the verb in such cases, which is indicated by the < > brackets in (21). Our hypothesis is that this is an optional phrase-initiality effect, due to a constraint that combines both a prosodic edge condition and a prosodic head condition:

(23) Headµ-of-ω@L-Edge-of-φ:Tone   [= Hdµ(ω)@L-Edge(φ):Tone]

       The head mora of a ω at the left edge of φ must bear a tone.

This constraint would belong to the same constraint family that includes the constraint responsible for the surface presence of the LH edge-head tone of Modern Irish. According to Elfner (2012, 2015) and Bennett et al. (2016), this LH tone falls on the head mora of the prosodic word that lies at the left edge of a nonminimal φ.[17] In Irish, the relevant constraint appears not to be violated. The optionality of the edge-head H tone in Standard English indicates that the ranking of the edge-head tone markedness constraint with respect to the Dep(Tone) faithfulness constraint in Standard English is subject to variation.

       In summary, the tonal patterning in surface phonological representations of pragmatically neutral sentences of Standard English is predictable on the basis of prosodic constituency, the reliable headedness of prosodic constituents, and unviolated markedness constraints of various types that govern the relation between tone and prosodic constituent heads and/or edges. The constraint system predicts where epenthetic tones will appear in the sentence, in cases like pragmatically neutral declaratives, where no morphemic tones are at issue.

       Our proposal in this paper is that tonal markedness constraints like Hdµ(φ):Tone and Hdµ(ω):Tone, which require that a prosodic head be associated with a tone, play a central role in the "pitch accent languages" Tokyo Japanese and Northern Bizkaian Basque (see section 3) as well as in "intonational", "stress accent" languages like English. And so do tonal faithfulness constraints like Dep(Tone). The different language-particular rankings of phonological constraints in the grammars of these different language types should make a significant contribution to a cross-linguistic theory of tonal patterning. In an explanatory phonological theory of tonal typology, these language-particular grammatical constraint rankings would combine with language-particular differences in whether tone may be "lexical" (a meaningless contrastive phonological property of morphemes with segmental content), "morphemic" (the sole phonological expression of a morpheme), or epenthetic (having no place in the phonological expression of morphemes in the input representation).

       Where does "stress" fit into the typological picture that is being sketched here? If "stress" is itself not a phonological property, but rather a particular set of phonetic properties that interpret the headedness of a prosodic constituent, then it might be expected that the phonological property of a head's bearing a "pitch accent" (tone) should *not* preclude the phonetic interpretation of that head with the various "stress"-related properties of duration, intensity, spectral tilt and so on. This is indeed what we see in Standard English. A number of studies have shown, for example, that vowels bearing the "primary stress" of a word are longer than vowels bearing the "secondary stress" of a word, and have shown, moreover, that the same is true whether or not the primary stress bears a tonal accent or not (Huss 1978; Sluijter and van Heuven 1996; de Jong 2004; Okobi 2006; Sugahara 2012). Bearing tonal accent in Standard English means that the tone-bearer is the head of a phonological phrase. Moreover, the amount of phonetic "stress" effects like duration increases with the degree of phrasal prominence (i.e. the level of prosodic headedness) of a tonal-accent-bearing syllable (Katz and Selkirk 2011). Understanding "stress" to be a phonetic property whose "degree" varies according to level of prosodic headedness makes it difficult to see the presence or absence of tonal accent, which is a categorical property of phonological representation, through the same typological lens as "stress accent". In our account of the distribution of

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[17] Additional cases of head-edge default tones come from Frota's (2000) study of the tonal properties of sentences in European Portuguese, where, for example, a tonal pitch accent is always associated with the head of the final prosodic word of an intonational phrase, even in cases where that word is discourse-given and follows a contrastive FoCus word bearing greatest prosodic prominence. Myrberg (2010) makes a similar case from standard Swedish, where the initial word of an intonational phrase will systematically bear a tonal pitch accent on the prosodic head of the word.

default, epenthetic, tonal "pitch accent" in Standard English, no appeal has been made to the notion "stress". As in Tokyo Japanese and as will see next in Lekeitio Basque, in Standard English it is constraints referring only to the abstract property of prosodic headedness that contribute to determining the presence and distribution of "pitch accent" tones in surface phonological representation.

4 Northern Bizkaian Basque

In this section we will analyze the prosodic phrasing pattern of unaccented words in Northern Bizkaian Basque (NBB) within the system of constraints related to prosodic headedness and the association of tones to prosodic heads presented and discussed in this paper. As already reported in the literature, unaccented words in NBB cannot form independent φs by themselves. A φ with an unaccented word must contain at least one accented word in addition (Elordieta 1997, 1998, 2007a, 2007b; Jun and Elordieta 1997; Gussenhoven 2004; Elordieta and Hualde 2014, among others). But a principled explanation for the existence of such a pattern is still missing. In this section we will see that the interaction between prosodic markedness constraints such as φ:Hd and Hdμ(φ):Tone and prosodic faithfulness constraints such as Dep(Tone) and Max(φ) provide an explanation for the prosodic behavior of unaccented words within sentences in NBB.

As documented in the references above (among others), in NBB, there is a lexical contrast between accented and unaccented words, like in Tokyo Japanese. Accented words are traditionally called so because they surface with prosodic prominence in one of their syllables, whereas other words do not; these are the unaccented words (cf. the references above). Accented words have at least one morpheme (root or affix) that is responsible for this "accent", hence the term "accented morpheme" to refer to these morphemes. The lexical property of accent is plausibly represented with the HL tone that manifests itself in the surface position of prosodic prominence, though no accounts before this one have assumed this lexical tonal representation of accent.

In the particular variety of NBB on which we will base our analysis (the one of Lekeitio), main prosodic prominence is always found on a fixed syllable in an accented word, regardless of the location of that syllable with respect to the accented morpheme. This syllable is the penultimate of the whole word, which may consist of a bare root with no overt affix or a root plus one or more affixes. A falling accent HL surfaces on this penult syllable. What this shows is that there is a designated position for the surface association of the lexical accentual tone.

A full paradigm of word-level accentuation and lack of accentuation is found in (24). UR stands for 'underlying representation' and SR stands for 'surface representation'. An apostrophe before a root or affix in UR indicates that it is lexically accented, i.e. it has a lexical HL accent. The location of the HL accent in SR is indicated with an acute accent mark over the prominent syllable. (24a-f) illustrate the following combinations of accented and unaccented morphemes: bare accented root (24a); bare unaccented root (24b); accented root + accented suffix (24c); unaccented root + accented suffix (24d); accented root + unaccented suffixes (24e); unaccented root + unaccented suffixes (24f).

(24) a. UR: *'liburu*   SR: *libúru* 'book'
                     HL

b. UR: *lagun*   SR: *lagun*   'friend'

c. UR: *'liburu-'ari*   SR: *liburuári*   'to the books'
                     HL   HL -dative pl.

d. UR: *lagun-'ari*   SR: *lagunári*   'to the friends'
                     HL -dative pl.

e.   UR: *'liburu-a-n*   SR: *liburúan*   'in the book'
                HL   -det.-ines.

f.   UR: *lagun-en-a*   SR: *lagunena*   'of the friend'
                -gen.sg.-det.sg.

We take the fact that the lexical accent of accented words always appears on the penultimate syllable regardless of its location in underlying representation to be evidence in support of the idea that accented words have a prosodic/phonological head. That prosodic head is the mora that is the head of the syllable that is the head of a trochaic foot that is the head of the word, in a prosodic structure represented schematically as (… (σ′ σ) ′)ω. The head mora of this word hosts the accentual HL tone in the surface.

As for whether unaccented words lack such a ω head, there is no evidence from Lekeitio Basque pointing directly to the absence of ω-headedness that is comparable to the evidence from Tokyo Japanese loanwords. In the loanword subset of the Tokyo Japanese vocabulary, unaccentedness is limited to four mora words (in the subset where only words with light syllables are at issue). I&M argue that these are prosodically analyzed as consisting of a two-foot sequence which violates no constraint on word-internal prosodic structure except for the requirement for ω-headedness (WordAccent), which is low ranked, and violated in these words. Thus, I&M show, lack of ω-headedness means lack of tonal accent in loanwords, while presence of a ω-head entails presence of accent. What we seek to show in this section is that, by assuming that unaccented words in Lekeitio Basque do indeed lack a prosodic head (though not for the same reasons as in Tokyo Japanese), we have an important part of the answer to the question why a phonological phrase φ may not consist solely of unaccented words.

It should be pointed out that, given the constraint system that we have been exploiting up to now in this paper, it is virtually a trivial matter to derive the absence of ω-headedness in unaccented words in Lekeitio Basque. Hdμ(ω):Tone requires the head mora of a prosodic word to bear a tone; if the word has no lexical tone, one could be epenthesized, in principle. But Dep(Tone) plays a crucial role: the lexical property of being toneless (unaccented) is preserved by Dep(Tone) in the surface representations of words consisting only of lexically toneless morphemes, as we saw above. What then about the headedness of an unaccented prosodic word? If the constraint ω:Hd were ranked below both Hdμ(ω):Tone and Dep(Tone), the candidate that lacks ω-headedness would be optimal, as seen in the tableau in (25). In the absence of direct evidence against foot construction in unaccented words, we will assume that unaccented words also have feet which are trochees, as with accented words. Since Hdμ(ω):Tone requires that the head mora of a word must bear a tone, and since Dep(Tone) bans the insertion of a tone, the best candidate is one in which the prosodic word does not have a head. That is candidate (c) in (25). The absence of a head is indicated by the absence of an apostrophe at the right edge of the ω. In Lekeitio Basque, then, the absence of any lexical tone in a ω results in the absence of the prosodic word head.[18]

(25)

(CVCVCVCV)ω	Dep(Tone)	Hdμ(ω):Tone	ω:Hd
a. ((σ′ σ) (σ′ σ)′)ω HL	*!		
b. ((σ′ σ) (σ′ σ)′)ω		*!	
➔ c. ((σ′ σ) (σ′ σ))ω			*

---

[18] The source of the lack of ω-headedness in NBB is different from that of Tokyo Japanese loanwords, where none of the accents is lexical, but is epenthesized by default. Since Dep(Tone) must therefore be low-ranked in the subgrammar for loanwords, the absence of accentual tone (and of headedness) in a word must have another source in the grammar. I&M attribute it to a ranking of constraints on the internal prosodic structure of words over the constraint calling for ω-headedness, which result in the lack of prosodic headedness in the particular case of four-light-syllable loanwords.

We argue in what follows that the presence or absence of a prosodic head in words in NBB is directly responsible for the difference in phonological phrasing between accented and unaccented words in the language. The idea is that, in NBB, a φ that exclusively dominates unaccented word(s) lacks a head daughter ω, on principled grounds, because, in NBB, an unaccented prosodic word is not itself headed. Given the Head Chain Condition in (4), a particular ω cannot be the head of a φ if that ω does not itself have a head. There must be "heads all the way down".

Consider the prosodic structure analysis of a simple nominal construction in which an unaccented word is a syntactic phrase located in the specifier of a Determiner Phrase (DP), followed by an NP complement of the Determiner that consists of an accented word. This would be the surface syntactic structure of such constructions:

(26) a.   DP[DP[lagunen]   NP[amúma]]
            friend-gen.sg.   grandmother
          'the friend's grandmother'

b.

```
                        DP
         DP                        D'
              D'              NP         D
        NP        D                N'      |
             N'      -en          |       -ø
        N               N
        |               |
        lagun         amúma
```
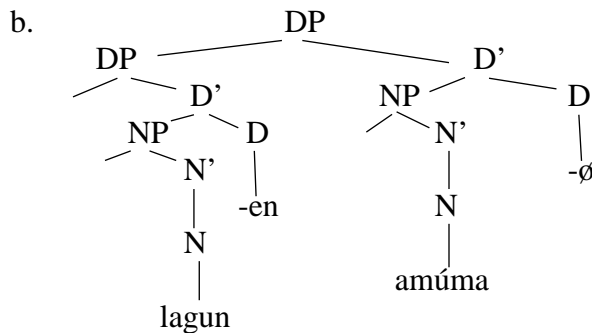
At Spell-Out, the mapping from the surface syntactic structure to the input phonological structure would give the prosodic structure in (27), after the application of Match-Phrase, which maps each syntactic maximal projection (XP) onto a phonological phrase (φ). As in Elordieta (2015), we assume that in NBB all XPs, lexical or functional, are mapped as φs, and we assume with Elfner (2012, 2015) that only XPs that exhaustively dominate overt terminal elements will be mapped. The DP in the specifier position does not get mapped as a φ because it does not dominate any overt terminal element that is not also dominated by NP. On the other hand, the genitive case marker *-en* is attached as an enclitic to the base to its left, the root *lagun*:

(27)   UR   φ
                    φ   φ
                    ω   ω
                 lagunen   amúma
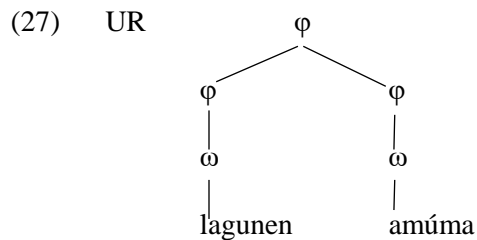
However, the observed output for that structure type in NBB does not retain the structure in (27) in surface representation. Rather, the unaccented word appears to be grouped in a single φ with the following accented word. (28) shows the pitch contour of a phrase of the type in (27).

(28)

```
        ‿‿‿‿‿‿‿‿‿‿
        σ σ σ σ    σ σ σ σ
      unaccented   accented
```
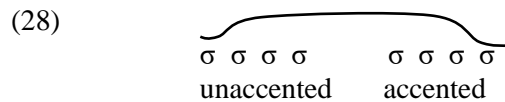
It begins with a pitch rise, then a high pitch plateau is observed from the beginning of the unaccented word until a pitch fall is realized on the syllable with the accentual HL tone. The LH rise is analyzed by Elordieta (1997, 1998) as a L boundary tone appearing at the left edge of a phonological phrase and a phrasal H tone, in a similar vein to the sequence found in Tokyo Japanese (Pierrehumbert & Beckman 1988). If the accented word were itself a φ, as expected on the basis of the underlying (27), then a LH rise should appear at its left edge. But it does not. Elordieta (1997, 1998, 2007a, 2007b), Jun and Elordieta (1997) and Elordieta and Hualde (2014) have assumed that the unaccented word forms one prosodic constituent together with the following word. This constituent has been called an Accentual Phrase, which Elordieta (2015) re-characterizes as a minimal phonological phrase or φ$_{min}$, after Ito and Mester's (2013) convincing revision of the taxonomy of prosodic constituents. What is needed now is an explanation for why the underlying φ structure in (27) that is produced by the MatchPhrase constraint should surface as the single φ structure in (29):

(29)   SR

```
                    φ
                  /   \
                ω       ω
                |       |
             lagunen   amúma
```
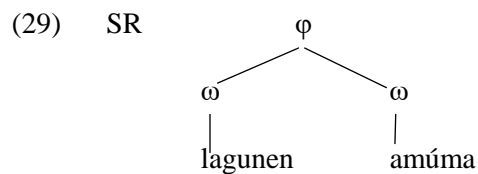
It should be noted that in a comparable DP structure with internal phrases consisting each of an accented word, the underlying dual φ structure of (27) is maintained. We see this in the surface representation (30) of the phrase *alában liburúak* 'the daughters' books'

(30)   SR

```
                    φ
                  /   \
                φ       φ
                |       |
                ω       ω
                |       |
             alában   liburúak
```
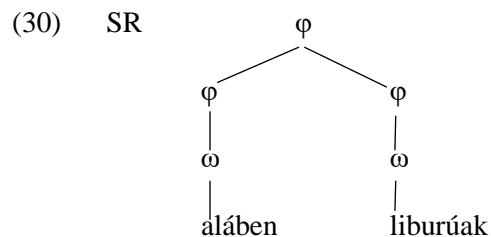
What is clear is that the unaccented status of the initial word in (27) is driving the change in φ structure seen between (27) and (29).

How can we explain the surface loss in (29) of the underlying φ which dominates the unaccented word *lagunen* in (27)? Our strategy is to adopt the assumption we introduced above that in NBB an unaccented prosodic word lacks a head in surface representation. This was seen to be the consequence of the ranking of Dep(Tone) and Hdμ(ω):Tone over ω:Hd in (25). Because it is the violation of the constraint ω:Hd that is crucial to the our proposal concerning the loss of φ status in unaccented words, we will not have to take the higher ranked Dep(Tone) and Hdμ-ω:Tone into consideration below.

Given our assumption that the prosodic constituents φ and ω form part of the underlying representation as a consequence of the constraints MatchPhrase and MatchWord (cf. section 3), the surface loss of the underlying φ dominating the unaccented ω in (29) constitutes a violation of an input-output faithfulness constraint (McCarthy and Prince 1995). This would be the prosodic constituent faithfulness constraint Max(φ):

(31) Max(φ):   A phonological phrase φ of input representation must correspond to a phonological phrase of the output representation.

Max(φ) is violated in the output representation of the unaccented word in (29). Our hypothesis is that Max(φ) is violated because it is lower ranked than the constraint φ:Hd, which calls for φ to be headed.

There is a second loss of φ in the case of (29), namely the loss of the φ which dominated the accented word in underlying representation. This loss, we would argue, is due to the constraint Strong Start (Selkirk 2011, Elfner 2012, 2015, Bennett et al. 2016), which is violated by a prosodic structure configuration where the initial daughter of a constituent is of a category lower in the prosodic hierarchy than that of the constituent that follows it. Simply eliminating at the surface the φ corresponding to the φ-initial unaccented word in (27) would create an ungrammatical, non-optimal, structure for the surface representation of the whole DP, one in which the unaccented prosodic word ω would be sister to and followed by a φ that dominates the accented word that follows:

(32)   * φ
          / \
         ω   φ

Thus, StrongStart must also be ranked higher than the faithfulness constraint Max(φ). It is the constraint-ranking ω:Hd, φ:Hd, StrongStart >> Max(φ) which derives the result that the underlying prosodic structure (27) consisting of a φ dominating a daughter sequence of underlying unaccented φ followed by accent φ surfaces as a single φ immediately dominating a sequence of unaccented and accented words. In the tableau in (33), for the sake of convenience, we have used the symbol U to stand for "a prosodic word which contains no lexical accent, and hence is not headed", while the symbol A stands for "a prosodic word which contains a lexical (and surface) accent, and hence is headed". The prime symbols at the right edges of the φs indicate that the φ in question is headed.

(33)

φ(φ(U) φ(A)) HL	ω:Hd	φ:Hd	StrongStart	Max(φ)
a. φ(φ(U ′) φ(A ′) ′) HL	*$_U$	*$_U$!		
b. φ(φ(U) φ(A ′) ′) HL	*$_U$	*$_U$!		
c. φ(φ(U φ(A ′) ′) HL	*$_U$		*!	*$_U$
➜ d. φ(φ(U A ′) ′)	*$_U$			*$_U$ *$_A$

It was hypothesized earlier in this section that ω:Hd is violated in the case of unaccented words in Lekeitio Basque, due to the particular ranking of constraints in (25). The tableau in (33) incorporates this assumption about the non-headedness of an unaccented word, and shows the consequences for the dephrasing of an underlying U-only φ. The constraint ω:Hd is included in this tableau simply in order to show that none of the unaccented words U are headed. What is crucial is that when a U also has the status of a φ, there is a violation of φ:Hd in any candidate where that U is parsed as a φ. In (33), candidates (a) and (b) both show the same violations of ω:Hd and φ:Hd, despite the difference in the marking of φ-head for (U ′) in (a) and the absence of that φ-head marking (U) in (b). They show the same violations of φ:Hd because in both (a) and (b) the assumption is made that ω:Hd is violated, i.e. that the U itself has no head. According to the Head Chain Condition stated above, for a φ to be headed, it must contain a ω that is its head, but this ω cannot be a U, which is not headed itself. Since this is not the case, by assumption, candidate (a) violates φ:Hd for the same reason that (b) does. It is headless, despite the (illicit) head-marking of φ(U ′). As for the two candidates (c) and (d) where the U does not have the status of a φ, Strong Start rules out the candidate where the A word retains its φ status. So what emerges as optimal is the candidate where U and A are sisters within a φ, and both have lost their underlying φ status.

In the last part of this section, we will consider the behavior of unaccented words when they constitute syntactic phrases independent of the phrase containing the word that follows. We will present two sentence types with three arguments preceding the verb, with the order Subject-Indirect Object-Direct Object-Verb. In the first type, the subject is composed of two accented words, the indirect object is a single unaccented word, and the direct object has one accented word. This is one of the sentence types examined in an experimental investigation of the prosodic behavior of unaccented words at the sentential level that is reported in Elordieta and Selkirk (2016). An example is illustrated in (34):

(34) CP/FinP[DP[DP/NP[Mirénen] NP[amúmak]]   ApplP[DP/NP[amari] vP[DP/NP[liburúak]]]   emon dotzoz]
        Miren-gen   grandmother-erg.sg.   mother-dat.sg. books-abs.pl. give aux
        'Miren's grandmother has given the books to the mother'

The subject contains two accented words (*Mirénen amúmak* 'Miren's grandmother'), the indirect object contains the unaccented word *amari* 'to the mother', and the direct object contains an accented word (*liburúak* 'the books'). The verb is *emon dotzoz* 'has given', with the participial verb *emon* 'give' and an auxiliary inflected for person, number and tense. The crucial aspect of this sentence is that the unaccented word is now in a different syntactic argument from the following accented word, unlike in the simple construction presented above in (26b) where the unaccented word is a genitive phrase within a DP containing the NP with the accented word.

In syntax, the indirect object is in a higher projection than the direct object, but they are both dominated by the same phrase (see references cited in in Elordieta 2015). In this paper we are going to assume that the verb is not in the same phrase with the two objects (departing from Elordieta 2015). Schematically, the syntax of these sentences is represented as in (35).

(35)   [[[A] [A]] [[U] [A]] Verb]

(36) represents the mapping from the syntactic structure in (35) to an input prosodic structure, with Match Phrase operating on the mapping, as well as the observed surface prosodic structure. For reasons of simplicity, we are only including XPs that matter to us, which are those that contain the unaccented and accented words, as well as the preceding subject. In surface phonological representation, we leave the φ corresponding to the subject as ₍φ₎(…..), and we ignore the verb.

(36)   Syntactic surface representation: [[[[A] [A]]   [[U] [A]]]   Verb]
       Underlying prosodic representation: ɩ(φ(φ(φ(A) φ(A)) φ(φ(U) φ(A))) Verb)
                                                          HL   HL   HL
       Surface representation: φ(…..) φ(U A′)

Elordieta and Selkirk (2016) show that, as with Us within a same argument, the observed output is one in which the U word in the indirect object φ groups in a single φ with the A word realizing the direct object. That is, the unaccented word does not form an independent φ but is grouped in the same φ with the word that follows, even if it is in a different argument. The head of the φ containing U and A in surface phonological representation is the A word, which is headed (i.e. it has a head foot, with a head syllable and a head mora). The pattern that is observed is the same as the one for UA sequences in one argument, above in (28).

The reason for not positing a φ boundary between the U and the A word is that there is no initial intonational rise from the initial to the second syllable in the A word, similar to the sequences of an unaccented word and an accented word in a single argument reviewed above. That is, given the absence of a LH rise at the left edge of the A word, there is no evidence for positing a φ boundary at the left edge of A.

The observed output incurs in two violations of Max(φ), as φ(U) and φ(A) are lost from the input, but Max(φ) is crucially lower ranked than the other constraints. For reasons of space, we will not run a

detailed review of all the candidates and their performance with respect to the set of ranked constraints relevant in this paper. We leave this for our upcoming paper Elordieta and Selkirk (in preparation).
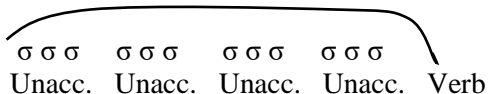
The last sentence type we look at briefly constitutes a particularly interesting case. Unamuno and Elordieta (2015) carried out an experimental investigation of sentences composed entirely of unaccented words. One of the sentence types has four unaccented words before the verb, divided in two arguments. That is:

(37)   [[[U] [U]] [[U] [U]] Verb]

The underlying prosodic representation, after the application of Match Phrase, would have φs corresponding to each syntactic phrase:

(38)   Underlying representation: ι(φ(φ(U) φ(U)) φ(φ(U) φ(U))   Verb)

However, the prosodic output observed by Unamuno and Elordieta (2015) is one where there is a pitch rise observed at the left edge of the whole sequence, signaling the beginning of a φ, and there is a high tone plateau until the right edge of the last U word, where the pitch level drops, right before the verb. There are no LH boundary tones at the left edge of any of the U words. That is, there is no LH boundary tone at the left edge of any of the non-initial φs in (38):

(39)

σ σ σ   σ σ σ   σ σ σ   σ σ σ
Unacc.   Unacc.   Unacc.   Unacc.   Verb

This prosodic contour indicates that the four U ωs are grouped in one φ. Such an output constitutes a dramatic departure from the underlying prosodic representation in (38):

(40)   Surface representation: (φ(U U U U) Verb)

As with the example of the sentence type in (36), our intention in this paper is not to provide a detailed analysis of the syntactic organization of the argument phrases in sentences of type (37). Nor do we undertake to show just how the surface prosodic structure of the preverbal arguments in (39) derive from an underlying phonological representation like (40). That is beyond the scope of this paper, but will be treated in an upcoming paper.

In the grand scheme of things, the observed "dephrasing" in Lekeitio Basque of underlying phonological phrases that consist only of lexically unaccented words provides eloquent testimony to the effects of properly phonological markedness constraints on the surface representation of prosodic structure. That surface prosodic structure is dramatically nonisomorphic to the syntactically grounded phonological phrase structure produced by MatchPhrase and MatchWord constraints in underlying representation. This nonisomorphism is the result, in part, of a phonological constraint ranking in which the prosodic markedness constraint φ:Hd that calls for a φ to be headed outranks the prosodic faithfulness constraint Max(φ), that calls for an underlying φ (one that matches an interfacing syntactic phrase).

5   Summary and looking ahead

Our purpose in this paper has been to argue for two classes of violable prosodic-headedness-sensitive markedness constraints: the family π:Head of constraints calling for a prosodic constituent π to be headed and the family Hdμ(π):Tone that calls for the head mora of a π to be associated with some tone. In the first section on Tokyo Japanese, we reviewed and concurred enthusiastically with Ito and Mester's (2016) argument that words in Tokyo Japanese that lack tonal accent in surface representation are words that are

not prosodically headed in surface representation. In the final section on Lekeitio Basque, also a "pitch accent language", the lack of prosodic headedness in lexically toneless, unaccented, words is held responsible for the surface absence of phonological phrases which consist only of such unaccented, unheaded words. This is not a surprising finding, given the interconnectedness of prosodic constituency, prosodic headedness and tone that is embodied in the constraint families π:Head and Hdμ(π):Tone. In the medial section on the "intonational language" Standard English, we saw that satisfaction of prosodic headedness requirements at both the φ and the ω level, complemented by the necessary satisfaction of the constraint that a φ-head be associated with a tone, provides an account of the distribution of default pitch accenting in pragmatically unmarked sentences in the language. It does seem then that giving constraints on prosodic headedness and on the head-tone relation a central place in accounts of tonal distribution might open up a promising avenue to an insightful typology of tonal patterning in the words and sentences of the languages of the world.

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PROSODIC RECURSION AND PSEUDO-CYCLICITY IN DANISH COMPOUND STØD*

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We analyze the contextually determined realization of Danish compound stød in terms of Match Theory with recursive prosodic words. The analysis makes predictions for long compounds, which a preliminary investigation has shown to be correct. We present a factorial typology where Danish is midway between languages with perfectly matching compound prosody, and languages that prosodically flatten underlying morphosyntactic structure. The analysis has consequences for the proper formulation of binarity constraints. While a binarity constraint counting branches yields the correct results for Danish, a binarity constraint counting leaves does not.

Keywords: Danish stød, compound prosody, Match Theory, binarity constraints

1 Introduction

Prosodic structure reflects syntactic structure, but only imperfectly. This imperfect correspondence finds a natural expression in the framework of Optimality Theory (Prince and Smolensky, 1993/2004), whether the correspondence is expressed as a requirement that the edges of prosodic constituents are aligned with syntactic constituents (Align/Wrap Theory: Truckenbrodt, 1995; 1999), or a requirement that prosodic and syntactic constituents match each other (Match Theory: Selkirk, 2011). Recent work on the syntax-prosody interface (e.g. Selkirk, 2011; Ito and Mester, 2013; Selkirk and Lee, 2015) argues for a limited crosslinguistic hierarchy of prosodic categories: the intonational phrase (ι), corresponding to the complementizer phrase (CP) in syntactic structure; the phonological phrase (φ), corresponding to other syntactic maximal projections (XPs); and the phonological word (ω), corresponding to the syntactic word (X^0).

Further distinctions between prosodic nodes, previously taken as evidence for a richer inventory of prosodic categories, have been subsumed under the rubric of prosodic recursion, where a node may dominate another node of the same prosodic category. Match Theory predicts that imperfect correspondence can occur at all levels of the prosodic hierarchy. However, most existing work focuses on the phonological phrase, to the neglect of the intonational phrase (an exception is Myrberg 2013) and phonological word (but see also Ito and Mester 2007 on Japanese). In this paper, we examine an instance of imperfect correspondence at the level of the (prosodic/syntactic) word, with a case study of Danish compound words, using the Danish glottal accent as the diagnostic for the prosodic word.

In Danish, words are lexically specified as able or unable to bear the glottal accent, known as *stød*. The host for stød must be a sonorous second mora (Basbøll, 2003; 2005). Ito and Mester (2015) argue that the distribution of stød is largely predictable on the basis of the word's prosodic

shape: stød is favored by a culminativity constraint WORDACCENT, but disfavored when it is not in a word-final stressed syllable. Hence, the presence of stød indicates the right edge of the prosodic word, and its absence from an otherwise eligible syllable indicates a misalignment with the right edge of the word. This alignment requirement can be seen in compound words (Ito and Mester, 2015). In monosyllabic compound-initial words, stød (marked with a superscripted glottal stop) disappears (1), but in longer compound-initial words it is retained (2).

(1) *Stød lost on short first word*
   a. /ruːˀg+brøːˀd/   →   [ruːg+brøːˀd]   'rye bread'
   b. /toːˀg+passageːˀr/   →   [toːg+pasasgeːˀr]   'train passenger'

(2) *Stød retained on long first word*
   a. /passageːˀr+toːˀg/   →   [passageːˀr+toːˀg]   'passenger train'
   b. /mediciːˀn+industriːˀ/   →   [mediciːˀn+industriːˀ]   'medicine industry'

As suggested by Ito and Mester (2015), the pattern in (1–2) can be accounted for if we admit prosodic recursion, and if short compound-initial words do not project their own prosodic word node. On this analysis, the syntactic compound word (e.g., [passageːˀr + toːˀg]) is always mapped to a matching prosodic word. Long compound members are also always mapped to a perfectly corresponding prosodic word. As a result, the final syllable of a long word like [passageːˀr] always receives stød, because it is always final in a prosodic word. But short syntactic words do not receive their own prosodic word when embedded in compounds, so that a word like [toːˀg] 'train' bears stød in isolation and when final in the compound, but loses stød when it is initial in the compound, as in [toːg + passageːˀr] 'train passenger', since it is no longer aligned with the right edge of any prosodic word.

Stød in Danish compound words, then, provides an example of imperfect mapping at the level of the word. In the interest of better exploring the range of possible syntax-prosody mappings at the word level, we extend Ito and Mester's (2015) analysis of stød to compounds like (1–2). We establish a ranking using Match Theory, which derives words of the appropriate prosodic shape by ranking a BINARITY constraint over NONRECURSIVITY, and NONRECURSIVITY over a MATCH constraint (Section 2). This ranking predicts that three-member compounds will be parsed pseudo-cyclically; the behavior of stød in a pilot experiment supports this prediction (Section 3). In Section 4, we show that the binarity constraint must count branches, rather than dominated feet ("leaves") to derive the partial-matching effect seen here. Finally, we explore the predictions of the resulting Optimality–Theoretic analysis for the typology of compound word prosodies (Section 5).

2 Analysis of two-word compounds

To obtain the correct prosodic structure for each of the compound types in (1–2), we posit only three constraints, all of which are well-established in the syntax-prosody literature. (We abstract away from constraints on metrical parsing, on which see Ito and Mester (2015)).

(3) BINMAX(ω,Branches)   (BINMAX-BR)
   Assign a violation for every ω which immediately dominates more than 2 nodes.

(4) NONRECURSIVITY   (NONREC)
   Assign a violation for every ω dominated by another ω.

(5) MATCH(X^0,ω)   (MATCH-X^0)
    Every syntactic word X^0 must be matched by a prosodic word ω.

We assume that righ-headed compounds Y^0+X^0 have the form in (6a).

(6) a. *Compound syntax*   b. *Perfect match*
       X^0 ω^{Max}
      ⟋＼   ⟋＼
    Y^0 X^0 ω^{Min} ω^{Min}

Since MATCH(X^0,ω) favors a recursive word structure (6b), it comes into conflict with NON-RECURSIVITY in all compounds. The relation between a prosodic structure like (6b) and the realization of stød is based on the following proposal from Ito and Mester (2015):

(7) *Stød Alignment* (Ito and Mester, 2015)
    A possible stød site is only realized with stød when it is final within some ω.

Crucially, (7) does not differentiate between ω^{Min}, ω^{Max}, or other levels of prosodic recursion. For an OT implementation of (7), see Ito and Mester (2015). Here, we simply take (7) as a diagnostic for the right edge of ω, rather than attempting to derive it.
    A consequence of (7) is that a possible stød-bearing syllable will lack stød if it is not final within some ω. In a compound composed of two monosyllabic words, such as *ruːg+brøːˀd* 'rye bread', stød is lost on the first word but retained on the second. This follows if *ruːg* does not project its own minimal ω, but is merely a foot contained within the maximal ω comprising the entire compound. (In the candidates below, the final word always keeps its stød due to its finality within the ω^{Max}, so whether it projects an ω^{Min} is irrelevant.)

(8) *Tableau for Short-Short compound*

N₂ ⟋＼ N₁ N₂ (ruːg) (brøːd)	BINMAX-BR	NONREC	MATCH
a. → ω ⟋＼ F F ruːg brøːˀd			**
b. ω ⟋＼ ω F F ruːg brøːˀd	e	*W	*L

c.	(ω tree: ω → F F; ru:ˀg brø:ˀd)	e	*W	*L
d.	(ω tree: ω ω → F F; ru:ˀg brø:ˀd)	e	**W	L

In (8a), placing each foot directly below ω^{Max}, with no intervening ω^{Min}s, results in a structure [$_\omega$ FFˀ] which fully satisfies BINMAX-BR and NONREC. Candidates (b–d), which each contain at least one ω^{Min} or ω^{Max}, fare worse than (a) according to NONREC, but better according to MATCH. We therefore obtain an Elementary Ranking Condition (ERC) establishing the partial ranking NONREC ≫ BINMAX-BR (Prince, 2002; Brasoveanu and Prince, 2011).

A nearly identical scenario ensues for S+L compounds like *to:g+passage:ˀr* 'train passenger'. Here too, if the first word projects an ω^{Min} to form [$_\omega$ [$_\omega$ Fˀ] [$_\omega$ FFˀ]], and thereby preserves its stød, it incurs a fatal violation of NONREC not shared by a candidate with one less ω^{Min}, [$_\omega$ F [$_\omega$ FFˀ]].

(9) *Tableau for Short-Long compound*

		BINMAX-BR	NONREC	MATCH
	N₂ tree: N₁ N₂; (to:g) (passa)(ge:r)			
a. →	ω tree: F ω(F F); to:g passa ge:ˀr		*	*
b.	ω tree: ω(F) ω(F F); to:ˀg passa ge:ˀr	e	**W	L

c.	ω ├─ ω │ └─ F (to:$^{?}$g) ├─ F (passa) └─ F (ge:$^{?}$r)	*W	L	**W
d.	ω ├─ F (to:g) ├─ F (passa) └─ F (ge:$^{?}$r)	*W	*e	*e

When the first word is monosyllabic, failure to project an ω^{Min} does not in itself cause a violation of BINMAX-BR; whether the first daughter of ω^{Max} is of category Ft or ω has no relevance for binarity, which counts nodes (or equivalently, branches) but does not inspect their category. Consider now compounds in which the first member is more than a single foot, such as *passage:$^{?}$r+to:$^{?}$g* 'passenger train'.

(10) *Tableau for Long-Short compound*

N$_2$ ├─ N$_1$ (passa)(ge:r) └─ N$_2$ (to:g)	BINMAX-BR	NONREC	MATCH
a. → ω ├─ ω │ ├─ F (passa) │ └─ F (ge:$^{?}$r) └─ F (to:$^{?}$g)		*	*
b. ω ├─ ω │ ├─ F (passa) │ └─ F (ge:$^{?}$r) └─ ω └─ F (to:$^{?}$g)	e	**W	L
c. ω ├─ F (passa) ├─ F (ge:r) └─ F (to:$^{?}$g)	*W	L	**W

d.	ω tree: F F [ω F] — passa ge:r to:ˀg	*W	*e	*e

In (10), the first morphosyntactic word consists of two feet. When it projects its own ω^{Min} and keeps its stød, as in (a–b), the ω^{Max} is perfectly binary, satisfying BINMAX-BR. Unlike in compounds with a short first member, embedding the two feet of *passage:ˀr* 'passenger' directly under the ω^{Max} node, as in (c–d), results in a ternary-branching structure $[_\omega \text{FFF}^{?}]$ or $[_\omega \text{FF} [_\omega \text{F}^{?}]]$, in a violation of BINMAX-BR. The fact that *passage:ˀr* projects an ω^{Min} here therefore establishes the ranking BINMAX-BR ≫ NONREC.

The same holds for Long+Long compounds, *mutatis mutandis*:

(11)   *Tableau for Long-Long compound*
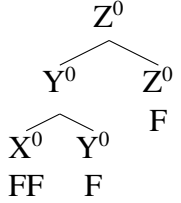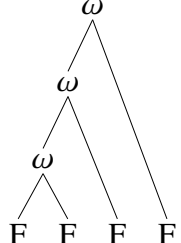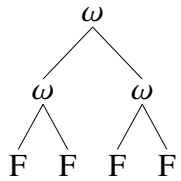
N₂ tree: N₁ (medi)(ci:n) N₂ (indu)(stri:)	BINMAX-BR	NONREC	MATCH
a. → [ω [ω F F] [ω F F]] — medi ci:ˀn indu stri:ˀ		**	
b. [ω F F [ω F F]] — medi ci:n indu stri:ˀ	*W	*L	*W
c. [ω [ω F F] F F] — medi ci:ˀn indu stri:ˀ	*W	*L	*W
d. [ω F F F F] — medi ci:n indu stri:ˀ	*W	L	**W
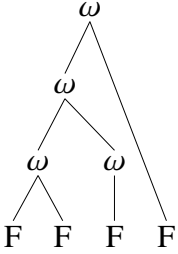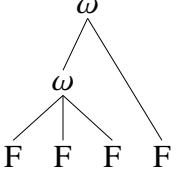
In sum, the first morphosyntactic word of a two-member compound does not always project its own ω^{Min} in Danish. The drive to perfectly match morphosyntactic structure cannot in itself override the anti-recursion imperative, so structure is minimized when possible. But as usual in OT analyses, the "when possible" caveat here is crucial, and is reliant on evaluation by an even higher-ranked constraint, in this case BINMAX-BR. On this analysis, an ω^{Min} will only be projected if the ω^{Max} above it would otherwise have more than two branches.

3 Analysis of three-word compounds

The above constraint ranking (BINMAX-BR $\gg$ NONREC $\gg$ MATCH(X^0,ω)) also makes predictions for the prosody of three-word compounds in Danish—namely, that two-word sub-compounds embedded inside three-word compounds receive the same prosody that they would if they occurred in isolation. That is, the prosody of larger compounds is what would be predicted if the compound prosody had been determined cyclically: first building the prosodic structure of the embedded two-word compound, then adding additional prosodic structure to incorporate the outer third word of the compound. For example, the three-word [[LS] S] compound contains the two-word [LS] compound (bolded throughout the tableau in (12)), which is parsed as [$_\omega$ [$_\omega$ L] S] whether it appears by itself, or embedded in a three-word compound (12a). Other candidates that do not parse pseudo-cyclically fare worse. (12b) deviates from pseudo-cyclic parsing by not matching the embedded two-word compound [$_\omega$ LS] to a prosodic word, incurring a fatal violation of MATCH. Candidates (12c) and (12d) avoid that MATCH violation, but parse the internal structure of the two-word compound with too much recursive structure (12c) or too little (12d), and lose to (12a).

(12)   *Example of pseudo-cyclicity in a three-word compound*

	BINMAX-BR	NONREC	MATCH-X^0
a. →		**	**
b.	e	**e	***W

c.	[tree: ω → ω → (ω, ω) → F F F F]	e	***W	*L
d.	[tree: ω → ω → F F F F]	*W	*L	***W

This pattern shows the interaction of BINMAX-BR and MATCH-X^0. High-ranking BINMAX-BR compels the optimal output to be subdivided into binary-branching constituents. Although binarity has no preferences regarding the placements of these prosodic subdivisions, NONREC and MATCH-X^0, exert the same pressures on sub-trees as they do on the tree as a whole: MATCH-X^0 selects the binary-branching prosodic constituency that best corresponds to the syntactic constituency, and NONREC prevents the building of excess prosodic words at any level of the tree.

This constraint set and ranking predicts analogous pseudo-cyclicity for all three-member compounds, which we verified using the JavaScript application SPOT (Bellik, Bellik, and Kalivoda, 2018) and the Excel extension OTWorkplace (Prince, Tesar, and Merchant, 2018). The predicted parsings of left-branching compounds are shown in (13). Right-branching compounds are predicted to be mirror images of these. (Here, 'S' means 'short word' (= 1 foot) and 'L' means 'long word' (= 2 feet).)

(13) *Predictions for three-word compounds in Danish*

Syntax	*Prosody*	*Syntax*	*Prosody*
[[S S] S]	[[S S$^?$] S$^?$]	[[L S] S]	[[[L$^?$] S$^?$] S$^?$]
[[S S] L]	[[S S$^?$] [L$^?$]]	[[L S] L]	[[[L$^?$] S$^?$] [L$^?$]]
[[S L] S]	[[S [L$^?$]] S$^?$]	[[L L] S]	[[[L$^?$] [L$^?$]] S$^?$]
[[SL] L]	[[S [L$^?$]] [L$^?$]]	[[L L] L]	[[[L$^?$] [L$^?$]] [L$^?$]]

To test these predictions, we recorded a Danish speaker reading a list of three-member compounds. These were both left-branching and right-branching. Subwords were selected that bear stød in isolation, allowing us to observe whether that stød appears or not in various compound positions. Recordings were examined in Praat (Boersma and Weenink, 2017). Stød was identified by glottalization and/or pitch drop during the second mora of a syllable (Fischer-Jørgensen, 1989). Our results were in line with the prediction of pseudocyclicity laid out above.

(14) *Left-branching*
   a. [$_ω$ [$_ω$ [$_ω$ passa ge:$^?$r] **to:$^?$g**] vra:$^?$g]   'passenger train wreck'
   b. [$_ω$ [$_ω$ **ru:g brø:$^?$ds**] to:$^?$g]   'rye bread train'
   c. [$_ω$ [$_ω$ **da:g bo:$^?$g**] [$_ω$ tera pi:$^?$]]   'diary therapy'

The fact that stød is present on *toːˀg*, *brøːˀds*, and *boːˀg* in (14) indicates that these words are ω-final, as predicted. Our analysis also correctly predictis the absence of stød on *ruːg* and *daːg*. Our consultant judged many right-branching compounds as degraded, but while they found the following awkward, they crucially pronounced them without stød on the second subword:

(15)   *Right-branching*

    a.   [$_\omega$ [$_\omega$ industriːˀ] [$_\omega$ **foːd** [tera piːˀ]]]　　　　　　　　'industry foot-therapy'

    b.   [$_\omega$ [$_\omega$ fanta siːˀ] [$_\omega$ **sneː** storːˀm]]]　　　　　　　　'fantasy snowstorm'

Although these are constructed examples with unusual meanings, the lack of stød on *foːd* 'foot' and *sneː* 'snow' suggests that these words are not ω-final. This can be explained on a cyclic account of ω-construction, or on the pseudo-cyclic but fully parallel analysis we provide using forms of MATCH-X^0, NONREC, and BINMAX-BR.

4 Counting branches, not leaves

To derive the partial-matching and pseudo-cyclic effects seen above, the undominated binarity constraint must be satisfied by the building of additional prosodic structure. This is only possible with certain implementations of binarity. While binarity is a commonly-used prosodic well-formedness constraint-type (Ito and Mester, 2003; Sandalo and Truckenbrodt, 2002; Prieto, 2007; Selkirk, 2011; Elfner, 2012), different analyses have employed significantly different implementations. Broadly speaking, these can be divided into two types: branch-counting and leaf-counting. When only binary or ternary-branching nodes are considered, branch- and leaf-counting binarity often make the same predictions. However, when recursive structures and supra-ternary branching structures are taken into account, the two types of binarity make different predictions: branch-counting binarity can compel the building of recursive structure, but leaf-counting cannot. This section unpacks the differences between these two different implementations of binarity.

    Branch-counting binarity requires a node to branch into two children. A violation of BINMAX-BR is incurred only by a node that branches into three or more children. The total number of dominated nodes (e.g., both its children and its more distant descendants) is irrelevant, as is their category. Consequently, a violation of branch-counting binarity can be avoided by building additional layers of prosodic structure, in which each node immediately dominates only two children. Branch-counting binarity has been employed in analyses of phrasing in Irish (Elfner, 2012), Kinyambo (Bellik and Kalivoda, 2016), and several langugaes in Kalivoda (2018), and we employ it here for the analysis of Danish compound word prosody.

    Leaf-counting binarity, on the other hand, counts the number of nodes of the next-lower prosodic category that are dominated by a node. In the case of φ, leaf-counting constraints are concerned with the total number of dominated ωs, while any intermediate φ structure is irrelevant. A four-word phrase ($_\varphi$ ($_\varphi$ ω ω) ($_\varphi$ ω ω)) violates leaf-counting binarity despite maintaining strict binary branching. Conversely, a phrase ($_\varphi$ σ ω ω) violates branch-counting binarity, but satisfies leaf-counting binarity. Leaf-counting binarity constraints at the φ-level have been employed by Selkirk (2000), Sandalo and Truckenbrodt (2002), Prieto (2007), and Ito and Mester (2013).

    Importantly for our purposes, leaf-counting binarity is not satisfied by building additional recursive structures, and consequently cannot derive the partial-matching results seen above for Danish compound words. We illustrate this difference between leaf-counting and branch-counting in (16).

(16)   *Branch-counting versus leaf-counting*

	BINMAX-BRANCHES	BINMAX-LEAVES
a. → φ_1 [φ_2 [ω_1 ω_2], φ_3 [ω_3 ω_4]]		*
b. φ_1 [φ_2 [φ_3 [ω_1 ω_2], ω_3], ω_4]	e	**W
c. φ_1 [ω_1 ω_2 ω_3 ω_4]	*W	*e

All candidates in (15) contain four prosodic words. However, their phonological phrasing differs, with the result that the two types of binarity prefer different candidates. Under branch-counting binarity, candidates (a) and (b) are perfect, since every φ in those prosodic trees branches into exactly two children. Candidate (c), however, incurs one violation of BINMAX-BRANCHES, since its φ_1 branches into four children.

In contrast, under leaf-counting binarity, every candidate incurs at least one violation, since all trees are rooted in φs that ultimately dominate four (>2) prosodic words. Candidates (a) and (c) only contain one such φ, but candidate (b) contains two (φ_1, φ_2). Notice that the two forms of Binarity group different candidates together. Under branch-counting binarity, all violations can be eliminated by articulating the φ-structure sufficiently, as in (a) and (b), while under word-counting binarity, this escape is not available. Adding more layers of structure does not eliminate the fact that somewhere in the tree, more than two prosodic words are being grouped together. (In fact, unlike branch-counting binarity, leaf-counting has a potentially unbounded search space.) Thus, branch-counting binarity motivates the building of prosodic structure, and hence prosodic recursion, but leaf-counting binarity does not.

In our analysis of Danish compound words, we derived the partially-matching prosody found in Danish with a low-ranked MATCH-X^0 that is complemented by a high-ranked BINMAX-BR, with NONREC ranked in between. NONREC can be overridden in order to avoid a BINMAX-BR violation. If BINMAX-BR is replaced by BINMAX-LEAVES, partial matching is no longer motivated, and a flat structure wins instead. This is shown in the tableau in (17). The intended winner is candidate (a), which is perfectly binary in terms of its branches, thanks to its recursive structure, but which incurs a violation of BINMAX-LV because the topmost prosodic word dominates three (> 2) feet. In fact, all candidates incur one violation of BINMAX-LV, so the decision is made instead by NONREC. Consequently, (a) loses to (c), which has no recursive

structure. Moreover, the desired optimum (a) also ties with (d), where the shorter X^0 receives its own prosodic word but the longer one does not.

(17)   *Ineffectiveness of leaf-counting in Danish*

N_2 — N_1 (toːg) N_2 (passa)(geːr)	BINMAX-LEAVES	NONREC	MATCH-X^0
a. → ω ... F F F toːg passa geː$^?$r	*	*	*
b. ω ... F F F toː$^?$g passa geː$^?$r	*e	**W	L
c. ω ... F F F toːg passa geː$^?$r	*e	L	**W
d. ω ... F F F toː$^?$g passa geː$^?$r	*e	*e	*e

In modeling Danish compound prosody, then, binarity must count branches (immediate children), rather than leaves (all descendents). Only branch-counting binarity derives the partial-matching effect seen in Danish words; leaf-counting cannot motivate ω-recursion.

5 Typological predictions

The proposed partial-matching analysis of Danish compounds gives a non-uniform account, where sometimes compounds are recursive and sometimes they are not. This is novel and somewhat unusual in the treatment of compounds. What does this set of constraints predict for the typology of compound prosodies? We address this question using the JavaScript application SPOT (Bellik et al., 2018) and the Excel extension OTWorkplace (Prince et al., 2018). We used SPOT to generate a comprehensive violation tableau for the OT system in question. The constraint set for the system

was CON = {MATCH-X^0, BINMAX-BR, NONREC}, as above. The space of syntactic inputs consisted of 16 binary branching compounds, comprised of three L or S syntactic words, as well as the four two-word compounds shown in Section 2. GEN was a function that yields all Weakly Layered prosodic trees that were rooted in a prosodic word and did not contain vacuous recursion. The resulting violation tableau was entered into OTWorkplace to calculate a factorial typology of compound prosodies.

The resulting factorial typology contained three languages, shown in Table 2, with different degrees of faithfulness in the syntax-prosody mapping. The most faithful mapping occurs in L1, which represents languages where compound prosody exactly matches input syntax (Perfect Match), because MATCH-X^0 outranks BINMAX-BR and NONREC. English instantiates an L1-type language, since English compound prosody is essentially perfectly matching (Liberman and Prince, 1977; Cinque, 1993). At the other end of the spectrum of syntax-prosody correspondence, L3 represents languages where recursive syntactic words become prosodically flat. This unfaithful mapping of compound structure occurs because NonRecursivity outranks both MATCH and BINMAX-BR. Such flat compound structure has been reported for Greek (Nespor and Vogel, 1986), where a compound constitutes a single stress domain. Intermediate between Perfect Matching L1 and Flat L3 is Partial Matching L2. In L2, recursive structures occur only where they eliminate violations of BINMAX-BR, as seen above for two-word compounds in Danish. Although MATCH is too low-ranked to drive recursive structure-building, high-ranked BINMAX-BR performs this function, and MATCH motivates the choice of how to group the terminals.

(18)   *Factorial typology of compound prosodies*[1]

		L1 Perfect Match M ≫ NR	L2 Partial Match B ≫ NR ≫ M	L3 Flat NR ≫ M, B
a.	[[F] [F]]	[[F] [F]]	[FF]	[FF]
b.	[[F] [FF]]	[[F] [FF]]	[F [FF]]	[FFF]
c.	[[FF] [F]]	[[FF] [F]]	[[FF] F]	[FFF]
d.	[[FF] [FF]]	[[FF] [FF]]	[[FF] [FF]]	[FFFF]
e.	[[[F] [F]] [F]]	[[[F] [F]] [F]]	[[FF] F]	[FFF]
f.	[[[F] [F]] [FF]]	[[[F] [F]] [FF]]	[[FF] [FF]]	[FFFF]
g.	[[[F] [FF]] [F]]	[[[F] [FF]] [F]]	[[F [FF]] F]	[FFFF]
h.	[[[F] [FF]] [FF]]	[[[F] [FF]] [FF]]	[[F [FF]] [FF]]	[FFFFF]

---

[1]The analysis also considered right-branching structures, which we omit here since they behave identically to left-branching structures.

i.	[[[FF] [F]] [F]]	[[[FF] [F]] [F]]	[[[FF] F] F]	[FFFF]
j.	[[[FF] [F]] [FF]]	[[[FF] [F]] [FF]]	[[[FF] F] [FF]]	[FFFFF]
k.	[[[FF] [FF]] [F]]	[[[FF] [FF]] [F]]	[[[FF] [FF]] F]	[FFFFF]
l.	[[[FF] [FF]] [FF]]	[[[FF] [FF]] [FF]]	[[[FF] [FF]] [FF]]	[FFFFFF]

This constraint set was able to derived the novel result of non-uniform matching in compound prosody while also predicting uniform results when other constraint rankings obtain. In addition, all three languages in the factorial typology are attested. Thus, while the non-uniform, partial-matching prosody in our account of Danish may seem unusual, it can be predicted using a small set of conventional constraints, which does not affect the predicted typology adversely.

6 Phrasal compounds

All the compound prosodies predicted by the typology above are attested in real languages. However, not every attested compound prosody is predicted by our OT system. For example, in the investigation of compound prosodies above, we require every maximal X^0 map to a prosodic word. However, cross-linguistically, the maximal X^0 in a compounds can map to a phonological phrase. Ito and Mester (2007) discuss facts in Japanese which argue in favor of non-uniform, size-dependent compound prosody. On the basis of rendaku voicing, junctural accent, and other diagnostics, they argue that Japanese compounds can have at least the following forms:

(19) *Shapes of Japanese compounds* (Ito and Mester, 2007)
  a. $[_\omega [_\omega \omega \omega] \omega]$ *hoken-gaisha bánare*   'movement from insurance cos.'
  b. $[_\omega \omega [_\omega \omega \omega]]$ *genkin fúri-komi*   'cash transfer'
  c. $(_\varphi \omega [_\omega \omega \omega])$ *hatsu kao-áwase*   'first face-to-face meeting'
  d. $(_\varphi(_\varphi \omega)(_\varphi [_\omega \omega \omega]))$ *zénkoku kaisha-ánnai*   'nationwide corporate guide'

The within-word recursion seen in (19a–b) is similar to what we have observed in Danish, but phrasal compounds like those shown in (19a–b) were not considered as candidates in our system. What we've developed here may be a slice of larger typology, for a system in which GEN may map the maximal X^0 to a φ instead of an ω. This relaxation of GEN could be compensated for with a violable constraint MATCH($X^{0\,\text{Max}}, \omega^{\text{Max}}$), following Ishihara's (2014) formulation of a phrase-level equivalent:

(20) MATCHPHRASE-MAX (Ishihara, 2014)
  A maximal lexical projection in syntactic constituent structure (a lexical XP that is not immediately dominated by another lexical XP) must be matched by a corresponding maximal prosodic constituent in phonological representation (a PPhrse that is not immediately dominated by another PPhrase, φ^{Max}).

We leave the study of this larger system for future work, but the languages in (18) will be present when MATCH($X^{0\,\text{Max}}, \omega^{\text{Max}}$) is undominated.

7 Conclusion

In this paper, we have followed up on a proposal made by Ito and Mester (2015), namely that the prosodic structure of Danish compounds determines the context-sensitive presence or absence of stød. A simple OT system involving three constraints, MATCH(X^0,ω), NONRECURSIVITY, and BINMAX-BRANCHES derives the prosodic structures diagnosed by disappearing stød. The constraint ranking for Danish, BINMAX-BR $\gg$ NONREC $\gg$ MATCH-X^0, ensures that prosodic structure will be non-recursive, contra MATCH, unless the absence of recursive structure results in a ternary-branching structure.

The analysis presented here underscores the importance of carefully defining binarity constraints. In Danish, replacing BINMAX-BRANCHES with BINMAX-LEAVES does not derive the observed partial matching effect. However, evidence from phenomena in other languages points toward several co-existing formulations of binarity. For example, Japanese phrasal compounding, as well as Japanese phonological phrasing, seem to require some form of leaf-counting binarity (Ito and Mester, 2007; 2013). In addition to the leaf-counting vs. branch-counting distinction and the categorical vs. gradient distinction, there are a number of subtle variations on the same theme. Elordieta (2006) has proposed a binarity constraint concerned only with the leftmost φ in ι. Reversing this, Prieto (2007) argues for a leaf-counting binarity constraint on the head φ of ι, which in Spanish is the rightmost in ι. In addition, Shinya, Selkirk, and Kawahara (2004) have investigated the moraic length of phonological phrases, and found a prosodic distinction between the behavior of, e.g., 5μ and 7μ words in certain φ-environments, and Selkirk (2011) cites several studies positing "prosodic size effects [. . .] that appear to depend on brute syllable count and are not reducible to prosodic binarity". Whether such finer-grained effects can be assimilated to some form of binarity constraint family remains to be seen.

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ASYMMETRIC CRISP EDGE*

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CRISPEDGE constraints provide a means for limiting harmony by penalizing features that stray beyond a particular domain. Usually this constraint is bidirectional: it penalizes features that cross the relevant domain's left and right edges equally. But harmony in the Romance variety of Tudanca Montañés provides evidence for an asymmetric version of CRISPEDGE. Regressive harmony originates with the final vowel and extends beyond the stressed syllable only under limited circumstances. Asymmetric CRISPEDGE, which penalizes features spreading beyond the stressed syllable's left edge but not its right edge, provides the only satisfactory account of this restriction.

Keywords: CRISPEDGE, Harmonic Grammar, Positional Licensing, Tudanca Montañés

1 Introduction

The observation that the edges of different phonological domains—say, different levels of prosodic or segmental representations—are often aligned is a common theme in the phonological literature. Perhaps the two most obvious domains in which this coordination is asserted are the syntax/phonology interface, where prosodic constituency is determined at least in part by syntactic phrasal boundaries (see Selkirk (2011) for an overview), and prosodic morphology, wherein morpheme shape and placement are often tailored to meet specific prosodic desiderata (e.g. McCarthy and Prince 1993; 1995).

A handful of constraint formalisms exists to enforce this coordination. Ito and Mester (1999) contribute to this body of work by developing the CRISPEDGE family of constraints, which rules out "[m]ultiple linking between prosodic categories" (208): for each prosodic category PCat, there exists a constraint CRISPEDGE[PCat] that is violated if some element is linked to multiple units of type PCat. For example, CRISPEDGE[σ] effectively blocks gemination by prohibiting elements from maintaining membership in two different syllables.

Walker (2001) elaborates on this formalism by positing a second argument in each CRISPEDGE constraint that specifies which particular phonological elements may not have membership in multiple PCats. (Kawahara (2008) makes a similar proposal.) For example, CRISPEDGE([Round], σ) penalizes [Round] features that are linked to multiple syllables; other multiply linked features are not penalized. CRISPEDGE constraints of this sort play a central role in Walker's (2011) theory of licensing-driven vocalic phenomena. In her framework, a Positional Licensing constraint LICENSE(λ, π) compels λ—which might be a feature or set of features—to appear in the position π. Other constraints, including CRISPEDGE, determine the means by which compliance with LICENSE is achieved: do unlicensed features spread to the licensor, or are they eliminated? May a feature appear in non-licensing positions in addition to the licensor? For systems in which the answer to the latter question is "no," that prohibition is enforced by CRISPEDGE. For example, unstressed high vowels delete under certain conditions in northern dialects of Modern Greek (see Walker (2011:208) for details and references). Walker treats this as the combined effects of LICENSE([+high], $\acute{\sigma}$), which requires [+high] to be linked to the stressed syllable, and CRISPEDGE([high], σ), which prohibits linking a [high] feature to multiple syllables. With [+high] unable to spread to the licensor because of CRISPEDGE, deletion is the only way to satisfy LICENSE.

Ito and Mester (1999:208) note another possible elaboration of their formalism that, to my knowledge, has not been explored: "CRISPEDGE remains to be further developed in terms of categories and L/R

edges." That is, building on Walker's formalism, we might employ CRISPEDGE([F], PCat, L/R), which is violated only when [F] has an affiliation with another prosodic unit to PCat's left or right as specified by the L/R argument. I argue here that in Harmonic Grammar (HG; e.g. Legendre, Miyata, and Smolensky 1990), this asymmetric CRISPEDGE is crucial to analyses of Positional Licensing phenomena like those studied by Walker (2011).

Evidence for this asymmetric CRISPEDGE is found in the harmony system of Tudanca Montañés, a Romance variety spoken in Spain and described by Penny (1978) (Hualde (1989) also discusses properties of the language that are of interest here). Harmony originates with a final high vowel, which centralizes (indicated with capitalization, following Hualde) and causes centralization to spread leftward up to and including the stressed syllable:

(1)   a.   pÍntU   'male calf'   cf.   pínta   'female calf'
            sekÁlU   'to dry him'   cf.   sekálo   'to dry it' (mass)

      b.   kÁrAbU   'tawny owl'
            orÉgAnU   'oregano'
            antigwÍsImU   'very old'

Under particular circumstances (see below), harmony also targets a pretonic vowel: [ehpInÁθU] 'spinal cord.' In Kaplan (2018) I argue that accounting for this "overshoot," in which harmony seems to go too far, requires a Positional Licensing formalism that encourages assimilation beyond the licensor; such a formalism must be prevented from triggering pretonic harmony in non-overshoot cases, and I argue here that asymmetric CRISPEDGE is the appropriate vehicle for doing so.

2 Tudanca's Harmony in Harmonic Grammar

This section summarizes the relevant parts of the analysis of Kaplan (2018). As we'll see, asymmetric CRISPEDGE plays a central role. The following section argues that alternatives are inferior.

Positional Licensing drives Tudanca's harmony: centralization (which I assume to be [–ATR], following Hualde (1989)) seeks the prominence of a stressed syllable by spreading to that position. The analysis in Kaplan (2018) builds on Kaplan (to appear), which develops a Positional Licensing formalism that rectifies pathological properties of standard Positional Licensing in HG. Unlike OT, constraints in HG are numerically weighted, and each constraint contributes to a candidate's harmony score; these properties change the relationship between Positional Licensing and faithfulness in ways that lead to unwanted predictions. Correcting this requires Positional Licensing to be a positive and gradient constraint. By way of illustration, the constraint necessary for Tudanca is given in (2). This constraint rewards licensed features instead of penalizing unlicensed ones, and it also assigns +1 for each non-licensor that a licensed feature is associated with. See Kaplan (to appear) for justifications of both properties.[1]

(2)   LICENSE([–ATR], $\acute{\sigma}$): assign +1 for each [–ATR] that coincides with $\acute{\sigma}$. For each such [–ATR], assign +1 for each additional position it coincides with.

One serendipitous consequence of rewarding harmony on non-licensors is that LICENSE([–ATR], $\acute{\sigma}$) provides a ready motivation for Tudanca's overshoot. This overshoot occurs just when a pretonic vowel

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[1]As discussed in Kaplan (to appear), this formalism must be implemented in a serial framework to avoid problematic predictions of positive constraints (Kimper, 2011). In the interest of simplicity, I use parallel HG here; the problems arising from positive constraints are tangential to present concerns.

is labial-adjacent.[2] Contrast the examples of overshoot in (3) with (1), where the pretonic vowels are not labial-adjacent.

(3) pIyÍhkU   'pinch'
     ehpInÁθU   'spinal cord'
     mUr̄ÍyU   'stone'
     bUhÁnU   'worm'
     mAr̄ÁnU   'pig'
     tAmbÚhU   'short and fat person'

Let us set aside the requirement of labial adjacency for the moment and focus on the fact that the possibility of overshoot requires something like LICENSE([–ATR], $\acute{\sigma}$) as defined above while overshoot's absence in (1) demands a constraint that prevents LICENSE from producing overshoot.[3]

First, (4a) shows that LICENSE([–ATR], $\acute{\sigma}$) triggers overshoot: when harmony stops at the stressed syllable, it sacrifices an additional reward from LICENSE. Of course, in cases like (4b) this is not the desired result. ((☞) marks the intended winner, and ☻ marks the incorrect winner. Here and throughout, I assume a constraint *[+ATR, +high]# that motivates centralization of final high vowels, which we might take to be a word-final weakening process (Barnes, 2006). I also assume that *[–ATR] penalizes each [–ATR] vowel, not each [–ATR] feature, contra Beckman (1999), so a single feature associated with two vowels incurs two violations.)

(4)   a.

/piyíhku/	LICENSE([–ATR], $\acute{\sigma}$) 4	*[–ATR] 3	H
a. piyíhkU		−1	−3
b. piyÍhkU	+2	−2	2
☞ c. pIyÍhkU	+3	−3	3

b.

/oréganu/	LICENSE([–ATR], $\acute{\sigma}$) 4	*[–ATR] 3	H
a. oréganU		−1	−3
(☞) b. orÉgAnU	+3	−3	3
☻ c. OrÉgAnU	+4	−4	4

Kaplan (2018) uses the constraint in (5) to block pretonic harmony in cases like (4b). This is an asymmetric CRISPEDGE constraint, which I abbreviate CRISPEDGE-L to emphasize the property that distinguishes it from symmetrical versions of this constraint. (See section 3 for a demonstration that symmetrical CRISPEDGE does not work in the current context.)

(5)   CRISPEDGE([–ATR], $\acute{\sigma}$, L): The stressed syllable's [–ATR] cannot extend beyond the left edge of that syllable.

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[2]This is related to an independent process in Tudanca whereby mid vowels centralize when adjacent to a labial even when harmony is not present: [bOnúka] 'weasel.' Labials cause non-mid vowels to centralize only as an extension of harmony—that is, as overshoot. See Penny (1978) and Hualde (1989) for discussion and Kaplan (2018) for a constraint-based analysis of the full range of labial-induced centralization.

[3]Interestingly, all examples of overshoot that I am aware of contain penultimate stress, even though antepenultimate stress is also possible in the language; see (1b). Whether this is a coincidence or not I cannot say, though I know of no data with antepenultimate stress that meet the conditions for, but do not exhibit, overshoot. There is thus no clear evidence that overshoot requires penultimate stress, a condition that might point toward a three-syllable window—i.e. a ternary foot—for harmony. Furthermore, forms like [sekÁlU] 'to dry him' (1a) indicate that harmony does not always fill such a ternary domain.

As (6) shows, the analysis now correctly produces [orÉgAnU]. *[–ATR] and CRISPEDGE-L gang up on LICENSE to block pretonic harmony. CRISPEDGE-L penalizes this harmony because it entails [–ATR] spreading beyond the stressed syllable's left edge; in contrast, it does not assign penalties when the stressed syllable shares this feature with a post-tonic vowel—this is the essence of asymmetric CRISPEDGE.[4]

(6)

/oréganu/	LICENSE 4	*[–ATR] 3	CRISPEDGE-L 2	H
a. oréganU		−1		−3
☞ b. orÉgAnU	+3	−3		3
c. OrÉgAnU	+4	−4	−1	2

Because LICENSE outweighs *[–ATR], it can produce harmony when only *[–ATR] is violated— namely in the post-tonic domain. As for the data in (3), where overshoot occurs, Kaplan (2018) posits another constraint, called here *[+lab][+ATR], requiring labial-adjacent vowels to be centralized. (I do not know of any convincing phonetic motivation for this constraint, but see Hualde (1989) for brief discussion of other languages that show similar effects.) This constraint and LICENSE gang up on *[–ATR] and CRISPEDGE-L to produce overshoot on only labial-adjacent vowels; see Kaplan (2018) for justification for, and more complete discussion of, *[+lab][+ATR]. An overshoot example is given (7).

(7)

/piyíhku/	LICENSE 4	*[–ATR] 3	CRISPEDGE-L 2	*[+lab][+ATR] 2	H
a. piyíhkU		−1		−1	−5
b. piyÍhkU	+2	−2		−1	0
☞ c. pIyÍhkU	+3	−3	−1		1

A note on representations: the discussion so far has assumed that a single [–ATR] feature extends to all centralized vowels in a form as in (8a). But what if the first vowel of *[OrÉgAnU] has its own separate [–ATR] feature distinct from the one appearing in the remaining syllables, as in (8b)?

(8)   a.   O r É g A n U
                    __\|/
                   [–ATR]

       b.   O r É g A n U
                 | _|/
              [–ATR] [–ATR]

Because the [–ATR] feature on the stressed vowel does not appear in a syllable to the left of that position in (8b), this configuration does not violate CRISPEDGE-L, unlike (8a). This is potentially worrisome: remove the CRISPEDGE-L violation from (6), and candidate (c), *[OrÉgAnU], wins. But (8a) and (8b) differ in another crucial way: in evading a violation of CRISPEDGE-L, (8b) sacrifices a reward from LICENSE because the [–ATR] feature on the stressed syllable does not appear in the pretonic syllable. Consequently, if candidate (c) from (6) represents (8b), we must also reduce the reward from LICENSE to 3. That candidate's score is reduced to 0, and it loses to candidate (b). This dual-features approach to avoiding CRISPEDGE-L violations is not viable after all, and I set it aside. Apart from CRISPEDGE and LICENSE, the constraints used here and in section 3 do not distinguish (8a) from (8b), so I henceforth assume structures like (8a), which maximize the reward from LICENSE.

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[4]It is not a winning strategy to evade the CRISPEDGE-L violation by harmonizing the pretonic vowel(s) but not the stressed vowel: LICENSE assigns no reward if the licensor does not harmonize.

One final refinement is required: it is insufficient for CRISPEDGE-L to simply assign −1 when the stressed syllable's [–ATR] also appears in the pretonic domain. It must assign one violation for each pretonic vowel that this [–ATR] appears on. The reason is illustrated in (9).

(9)

/ehpináθu/	LICENSE 4	*[–ATR] 3	CRISPEDGE-L 2	*[+lab][+ATR] 2	H
a. ehpináθU		−1		−1	−5
b. ehpinÁθU	+2	−2		−1	0
☞ c. ehpInÁθU	+3	−3	−1		1
d. EhpInÁθU	+4	−4	−2		0

Once LICENSE and *[+lab][+ATR] trigger harmony on the labial-adjacent pretonic vowel, we must stop harmony from extending to the other pretonic vowel. *[–ATR] cannot do this on its own because it is outweighed by LICENSE. We must rely on the same gang effect that blocks pretonic harmony in (6), where *[–ATR] and CRISPEDGE-L combine to block the harmony that LICENSE wants. But this is only possible if harmony on the initial vowel incurs new violations of both *[–ATR] and CRISPEDGE-L. As inspection of (9) shows, were CRISPEDGE-L to assign just one violation no matter how far harmony extends beyond the stressed syllable, candidate (d) would win. We can therefore amend CRISPEDGE-L as follows:

(10)   CRISPEDGE([–ATR], $\acute{\sigma}$, L): The stressed syllable's [–ATR] cannot extend beyond the left edge of that syllable. Assign −1 for each syllable to the left of the stressed syllable that an offending [–ATR] appears in.

This, then, is the core of the analysis of centralization in Tudanca. Normally, *[–ATR] and CRISPEDGE-L gang up on LICENSE to prevent pretonic harmony. In the post-tonic domain, CRISPEDGE-L is inactive, so LICENSE triggers harmony there. And in overshoot contexts, LICENSE and *[+lab][+ATR] gang up on *[–ATR] and CRISPEDGE-L.

Two anonymous reviewers ask about CRISPEDGE-R: does this constraint exist, and if so, what is its function? Because harmony originates at the right edge of the word, a right-edge version of (10) plays no active role in Tudanca, but a version of CRISPEDGE-R that holds for the right edge of the word rather than the right edge of the stressed syllable would prevent harmony from extending rightward from a final vowel to subsequent words. More generally, harmony driven by Positional Licensing typically extends in one direction only (Walker, 2011), and if the positive version of Positional Licensing used here is applicable more broadly, both CRISPEDGE-R and CRISPEDGE-L may be needed to prevent the source of the harmonizing feature from triggering harmony in the wrong direction.

We can now ask the following question: is CRISPEDGE([–ATR], $\acute{\sigma}$, L) the proper means of curtailing overshoot in Tudanca? In the next section I consider salient plausible alternatives and argue that each is inferior to CRISPEDGE-L. The alternatives I consider are symmetric CRISPEDGE, positional faithfulness for pretonic syllables, *[–ATR], and the positional markedness constraint *[–ATR]-pretonic.

3 Alternatives

It is perhaps most imperative to show that CRISPEDGE-L succeeds where its symmetric cousin fails. The symmetric counterpart of CRISPEDGE-L penalizes any [–ATR] feature that is simultaneously associated with the stressed syllable and some other syllable, whether that other syllable is to the right or the left of the stressed syllable. Essentially, the problem with symmetric CRISPEDGE, which I will call CRISPEDGE-S, is that it cannot distinguish pretonic harmony (which it must block) from post-tonic harmony (which it

must allow). Categorical CRISPEDGE-S assigns −1 if the stressed syllable's [−ATR] is not confined to that syllable regardless of how many other positions [−ATR] appears in. Consequently, once harmony between post-tonic vowels and the stressed syllable is established, there is no cost from CRISPEDGE-S for extending harmony to the pretonic domain. This is illustrated in (11a): all three candidates tie on CRISPEDGE-S, and with LICENSE outweighing *[−ATR], pretonic harmony cannot be stopped. If we change things so that *[−ATR] outweighs LICENSE, as in (11b), post-tonic harmony is blocked along with pretonic harmony. (The discontiguous harmony in *[orÉganU] represents a possible configuration in other licensing-driven systems and so must be allowed as a possible candidate (Walker, 2011), indicating either one [−ATR] linked to vowels in non-adjacent syllables or, as Walker treats it, two [−ATR] features in correspondence with each other. The latter differs from (8b), which did not have this correspondence relationship. In Walker's framework, if the two features in (8b) were in correspondence, the CRISPEDGE-L violation that (8b) is meant to escape would be reintroduced.) The correct form is collectively harmonically bounded (Samek-Lodovici and Prince, 1999; 2002) by *[OrÉgAnU] and *[orÉganU].

(11) a.

/oréganu/	LICENSE 4	*[−ATR] 3	CRISPEDGE([−ATR], $\acute{\sigma}$) 2	H
(☞) a. orÉgAnU	+3	−3	−1	1
� b. OrÉgAnU	+4	−4	−1	2
c. orÉganU	+2	−2	−1	0

b.

/oréganu/	*[−ATR] 4	LICENSE 3	CRISPEDGE([−ATR], $\acute{\sigma}$) 2	H
(☞) a. orÉgAnU	−3	+3	−1	−5
b. OrÉgAnU	−4	+4	−1	−6
� c. orÉganU	−2	+2	−1	−4

CRISPEDGE-S fares no better if it assigns violations gradiently, comparable to (10). Under this arrangement, CRISPEDGE-S favors [orÉgAnU] over *[OrÉgAnU], but it prefers *[orÉganU] even more. The harmonic bounding problem is exacerbated. As before, LICENSE and *[−ATR] favor *[OrÉgAnU] and *[orÉganU], respectively, over [orÉgAnU]. Additionally, now if CRISPEDGE can prevent harmony on the pretonic vowel, it can also do so for the penultimate vowel (and even the final vowel were we to consider forms like *[orÉganu]).

(12) a.

/oréganu/	LICENSE 4	*[−ATR] 3	CRISPEDGE([−ATR], $\acute{\sigma}$) 2	H
(☞) a. orÉgAnU	+3	−3	−2	−1
b. OrÉgAnU	+4	−4	−3	−2
☞bomb c. orÉganU	+2	−2	−1	0

b.

/oréganu/	*[−ATR] 4	LICENSE 3	CRISPEDGE([−ATR], $\acute{\sigma}$) 2	H
(☞) a. orÉgAnU	−3	+3	−2	−7
b. OrÉgAnU	−4	+4	−3	−10
☞bomb c. orÉganU	−2	+2	−1	−4

The same problem plagues *[–ATR], which (like CRISPEDGE-S) cannot distinguish pretonic from post-tonic positions. If it excludes harmony in one of those domains it does so in the other, too. For both CRISPEDGE-S and *[–ATR] it is possible to adopt weights that preclude both pretonic and post-tonic harmony, as in (11b) or (12), and introduce another constraint that disfavors gapped harmony domains, thereby overriding CRISPEDGE-S/*[–ATR]. But in Kaplan (to appear) I show that constraints of this sort interact pathologically with Positional Licensing, and in any case the positive version of Positional Licensing at the heart of the current analysis obviates such constraints. This treatment therefore entails a more complex and less theoretically sound analysis than one that uses asymmetric CRISPEDGE.

On the other hand, IDENT(ATR)-pretonic targets only pretonic syllables and thereby makes the distinction that CRISPEDGE-S cannot. (See Kaplan (2015) for an argument that IDENT(ATR)-pretonic is a well-formed constraint.) At first glance, this appears to do the trick:

(13)

/oréganu/	LICENSE 4	*[–ATR] 3	IDENT([ATR])-pretonic 2	H
a. oréganU		−1		−3
☞ b. orÉgAnU	+3	−3		3
c. OrÉgAnU	+4	−4	−1	2

But Richness of the Base reveals IDENT(ATR)-pretonic's limitations. When the pretonic vowel is underlyingly centralized, IDENT([ATR])-pretonic incorrectly favors retention of that centralization:

(14)

/Oréganu/	LICENSE 4	*[–ATR] 3	IDENT([ATR])-pretonic 2	H
(☞) a. orÉgAnU	+3	−3	−1	1
💣 b. OrÉgAnU	+4	−4		4

Because post-tonic harmony requires LICENSE to outweigh *[–ATR] (as we saw in (11b)), if IDENT(ATR)-pretonic (in conjunction with *[–ATR]) can prevent LICENSE from extending harmony to a pretonic /o/, it can also prevent (with help from LICENSE) *[–ATR] from decentralizing a pretonic /O/. In establishing the former gang effect, we also admit the latter.

Problems do not disappear with IDENT([+ATR])-pretonic, which preserves only [+ATR] and therefore assigns no penalties in (14) while still ruling out overshoot in (13). As long as LICENSE outweighs *[–ATR], candidate (b) in (14) still wins.

Rich-base inputs do not threaten asymmetric CRISPEDGE. Because faithfulness plays no role in the analysis developed in Section 2 (or more accurately, faithfulness is too low-weighted to affect the outcome—see Kaplan (to appear) for faithfulness's role in licensing-driven patterns in HG), input vowels' [ATR] specifications are inconsequential. The outcome in (6), e.g., does not change if the input is /Oréganu/.

Neither CRISPEDGE-S nor IDENT(ATR)-pretonic capture the generalization at hand. The former discourages feature-sharing between the stressed syllable and all other positions, not just pretonic ones, and the latter does not discourage pretonic harmony but instead discourages any unfaithfulness in pretonic positions. In contrast, CRISPEDGE-L hits the nail on the head by militating against feature-sharing between the stressed syllable and pretonic positions.

Like CRISPEDGE-L, the positional markedness constraint *[–ATR]-pretonic captures the intuition that [–ATR] should not (generally) appear to the left of the stressed syllable. Were it to replace CRISPEDGE-L in (7) and (9), the candidates' violation profiles and the outcomes of the tableaux would not change. And like CRISPEDGE-L, *[–ATR]-pretonic deals correctly with inputs containing pretonic centralized vowels. *[–ATR]-pretonic, though, is not a well-formed constraint. Typically, positional markedness bans marked

elements in weak positions; see Walker (2011), e.g., for a defense of this view. Unfortunately, pretonic positions, especially in Romance languages, show signs of strength; for example, they resist vowel reduction in some Romance varieties (Canalis, 2009). (See Crosswhite (2001), e.g., for other similar pretonic/post-tonic asymmetries.) Nor is it obvious that *[–ATR]-pretonic belongs to the family of augmentation constraints (Smith, 2005), which are markedness constraints that enhance a strong position's prominence. I conclude, then, that *[–ATR]-pretonic is illicit because it is not consistent with the typology of position-sensitive markedness constraints.

4 Conclusion

Unlike most assimilation motivated by Positional Licensing, harmony in Tudanca Montañés does not always stop at the licensor. This means two things: first, Positional Licensing must motivate overshoot, a requirement met by positive Positional Licensing. Second, positive Positional Licensing's power must be held in check lest harmony run amok. Only CRISPEDGE-L adequately fills that role. By militating against harmony that extends beyond the stressed syllable's left edge, it protects pretonic syllables while not interfering with harmony in the post-tonic domain. If positive Positional Licensing drives licensing-based harmony more generally, as I argue in Kaplan (to appear), asymmetric CRISPEDGE has a large and central role to play in confining harmony to the proper domain. Conceivable substitutes for asymmetric CRISPEDGE fail to distinguish pretonic harmony from post-tonic harmony, do not properly evaluate certain input configurations, or flout generalizations concerning well-formed markedness constraints.

CRISPEDGE belongs to a category of constraint that regulates the edges of phonological (and other) domains. Other constraints types that belong to this category, such as Alignment (McCarthy and Prince, 1993) and Anchoring (McCarthy and Prince, 1995), distinguish left and right edges, and the argument put forth here extends this functionality to Ito and Mester's own contribution to this literature. That CRISPEDGE warrants the power already granted to other constraints should not be surprising—as Ito and Mester themselves say, "general notions like 'edge,' 'left,' and 'right' are not the exclusive property of Alignment Theory" (1999:209). Perhaps what is surprising is that it has taken so long to find evidence for this.

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PERSISTENCE OF PROSODY

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Preamble

In October 2016, at a workshop held at the National Institute for Japanese Language and Linguistics (NIN-JAL),[1] Junko and Armin presented a talk in which they argued against Kubozono's (1999; 2003) proposal that VVN sequences in Japanese are syllabified as two separate syllables (V.VN) (Ito & Mester 2016a). One of their arguments involved the consequences for VNC sequences (e.g. /beruriŋkko/ 'people from Berlin'); more specifically, Kubozono's proposal would require positing syllables headed by a nasal (i.e. V.NC, or [be.ru.ri.ŋk.ko]). They argue that syllables headed by a nasal segment are "questionable syllable types", at least in the context of Japanese phonology. We are happy to dedicate this paper to Junko and Armin, in which we argue that Japanese has syllables headed by a fricative, and possibly those headed by an affricate.

1 Introduction

Segments or prosody, which comes first? This question has been an important topic in phonetic and phonological theories. A classic view in generative phonology is that input segments are given first, and syllables and higher prosodic structures are built over segments according to universal and language-specific algorithms (Clements & Keyser 1983; Ito 1986; Kahn 1976; Steriade 1982 and subsequent research). An almost standard assumption in this line of research is that syllabification does not exist in the underlying representation (Blevins 1995; Clements 1986; Hayes 1989), and this assumption reflects the view that segments come before prosody.[2] However, there are also proposals to the effect that prosodic templates are given first, and segments are "filled in" later; such is the case for patterns of prosodic morphology, such as reduplication and truncation (Ito 1990; Levin 1985; Marantz 1982; McCarthy 1981; McCarthy & Prince 1986; 1990; Mester 1990). Compensatory lengthening, in which segments are lengthened to fill "already-existing" prosodic positions (Hayes 1989; Kavitskaya 2002; Wetzels & Sezer 1986), also instantiates a case in which prosody comes first. Thus, the question of which comes first—segments or prosody—does not seem to have a simple answer in phonological theorization.

Optimality Theory (Prince & Smolensky 1993/2004) provided a third possibility—segments and prosodic structures are built simultaneously, and some explicit arguments are made for "parallel" evaluation of segments and prosodic structures (Adler & Zymet 2017; Anttila & Shapiro 2017; Prince & Smolensky 1993/2004; Rosenthall 1997). Generally, due to parallel evaluation of output wellformedness, Optimality Theory rendered moot the question of "which comes first." The question does not even arise because everything happens all at once. However, recent proposals to incorporate derivation back into Optimality Theory (e.g. McCarthy 2007; 2010) brought this question back on the table—see for example a debate between Pruitt (2010) and Hyde (2012) about whether footing should occur derivationally or in parallel. In this theoretical context, McCarthy (2008) argues that footing needs to precede syncope in some languages, and that

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[1]"Syllables and Prosody" which Shigeto had proudly co-organized with Junko.

[2]Key evidence is the observation that no languages seem to use different syllabification patterns to signal lexical contrasts (though see Elfner 2006 for a potential counterexample). In Optimality Theory (Prince & Smolensky 1993/2004), this lack of contrast can be accounted for by postulating that there are no faithfulness constraints that protect underlying syllabification (Kirchner 1997; McCarthy 2003). Given the Richness of the Base (Prince & Smolensky 1993/2004; Smolensky 1996), inputs should not be prohibited from having syllable structure, so this assumption about the lack of syllabification in underlying representations is much weakened, if not entirely abandoned, in Optimality Theory.

this analysis is possible only in a derivational version of Optimality Theory (though cf. Kager 1997). Thus the question of the derivational relationship between segments and prosodic structure—including the very general question of whether derivation exists at all in the phonological component of grammar—is still a matter of debate in phonological theory.

A similar question has been addressed in the context of speech production. There is a large body of literature suggesting that prosodic information is planned prior to phonetic specification of segments. In tip-of-the-tongue phenomena, for example, there are cases in which speakers can recall the stress patterns—hence the prosodic structures—of the words in question, even when the segments cannot be recalled (Brown & MacNeill 1966). Cutler (1980) analyzes a corpus of speech errors in English and points out that "omission or addition of a syllable can be caused by an initial error involving the misplacement of stress" (p. 68), and consequently suggests that "lexical stress errors arise at a fairly early level in the production process" (p. 71).

In the modular feed-forward model of speech production planning developed in Roelofs (1997) and Levelt, Roelofs & Myer (1999), prosodic templates including syllable counts and lexical stress position are stored in lexical entries independently from the segments of a lexical item. This aspect of the speech production model makes it theoretically possible to retrieve word prosody without segmental content. The architecture of the model is motivated as well by the implicit form priming paradigm, in which shared prosody across words, including stress position, facilitates lexical retrieval (Roelofs & Meyers 1998). However, in this model, segmental and prosodic templates of words are merged at the level of the prosodic word, a stage of planning followed by phonetic encoding and finally construction of higher level prosodic structure. The stages of the model have been criticized for not specifying enough prosodic structure prior to phonetic encoding (Keating 2003; Keating & Shattuck-Hufnagel 2002; Shattuck-Hufnagel 2006). The basic argument is that prosody must be available early in the speech planning process so that it can condition phonetic form. In other words, in speech production, it is prosody first (Shattuck-Hufnagel 2006).

More recent work has identified a possible neural basis for dissociation between segments and prosodic organization. Long, Katlowitz, Svirsky, Clary, Byun, Majaj, Oya, III & Greenlee (2016) found that perturbation of normal brain function (through focal cooling) could selectively influence speech timing or segmental content, depending on the brain region targeted. To the extent that segments dictate articulatory goals and prosody conditions timing, this result provides another converging line of evidence for, at the least, a dissociation between segmental and prosodic planning.

1.1 Consequences of vowel deletion for syllabification

In this paper we would like to address the general issue of the relationship between segments and prosody by examining the consequences of vowel deletion for syllabification. Our main empirical focus is Japanese, but before we present our analysis of Japanese, we start with a brief cross-linguistic examination in order to put our analysis in a broader perspective. Given a $C_1V_1C_2V_2$ sequence, when V_1 deletes, we can conceive of two outcomes regarding how C_1 is syllabified: (1) C_1 is resyllabified with a surrounding vowel, or (2) C_1 maintains its syllabicity. Both patterns have been claimed to be attested in the previous literature, as summarized in (1)-(9). Forms on the left are those with vowels (vowel present); forms on the right are those without vowels (vowel absent). Syllable and foot boundaries are shown only where relevant.

(1)   Resyllabification: Latvian (Karins 1995: 19)

	vowel present	vowel absent	
a.	splig.**ta**s.au.ras	spligt.sau.ras	'dazzling auras'
b.	spilg.**ti** a:.buo.li	spilg.ta:.buo.li	'dazzling apples'

(2)   Resyllabification: Leti (Hume 1997)

	vowel present	vowel absent
a.	lop**u** do	lop.d^{w}o

(3)   Syllabicity maintenance: English (Kaisse & Shaw 1985: 6)

	vowel present	vowel absent
a.	sə.p^{h}ort	s.p^{h}ort
b.	pə.t^{h}ɛɪ.rɔʊ	p.t^{h}ɛɪ.rɔʊ
c.	tə.li.dɔʊ	t.li.dɔʊ

(4)   Syllabicity maintenance (debated): French (Rialland 1986 vs. Steriade 2000)

	vowel present	vowel absent	
a.	də rôle	d.rôle	'some role'
b.	baʁə tʁuve	ba.ʁ.tʁuve	'stocking found again'

(5)   Syllabicity maintenance: Lushootseed (Urbanczyk 1996: 119)

	vowel present	vowel absent	
a.	qəsi	q.siʔ	'uncle'
b.	c'ək'apaʔ	c'.kapaʔ	'rose hips'

(6)   Syllabicity maintenance: Triqui (p.c. Christian DiCanio)

	vowel present	vowel absent	
a.	n**i**^{1}jah^3	j^1.jah^3	'when'
b.	n**a**^{2}nah^2	n^2.nah^2	'slowly'

(7)   Syllabicity maintenance: Carib (Kager 1997 based on Abbott 1991)

	vowel present	vowel absent	
a.	peʔm**a**ra	(pèʔ)(m.rá:)	'free'
b.	seepɔrɔ	(sèe)(p.rɔ́:)	'alone'

(8)   Syllabicity maintenance: Odawa (Bowers 2015 based on Rhodes 1985)

	vowel present	vowel absent	
a.	mʌ kɪzɪn	(m.ˈkɪ)(ˈzɪn)	'shoe'

(9)   Syllabicity maintenance: Québec French (Garcia, Goad & Guzzo 2016)

	vowel present	vowel absent	
a.	al**i**mãtasjɔ̃	a(l.mã)(ta.sjɔ̃)	'nourishment'
b.	kɔbine	kɔ(b.ne)	'to combine'

    From the perspective of cross-linguistic markedness, the cases of resyllabification, as in Latvian and Leti, seem more natural; syllables headed by a vowel are less marked than syllables headed by a consonant. We are thus more interested in alleged cases in which consonants maintain their syllabicity after vowel

deletion, so let us examine each case in greater detail. Especially, since syllables are often thought of as being built around high sonority segments (Dell & Elmedlaoui 1985; Selkirk 1982; 1984; Steriade 1982), it is worth considering the strength of the evidence for each analysis positing consonantal syllables.

For English, it seems reasonable to posit a syllable boundary between the two word-initial consonants after the schwa is deleted; as for (a, b), the second consonants are aspirated, a hallmark of syllable-initial consonants in English; for (c), English does not allow [tl] clusters syllable-initially (Kahn 1976; Massaro & Cohen 1983; Moreton 2002). We thus seem to have good evidence to consider that resyllabification does not occur after schwa deletion in English. However, Davidson (2006) points out that it is possible—and even likely—that schwa "deletion" in English does not involve phonological deletion, but instead that the process is better characterized as phonetic reduction. In that sense, these schwas in English are not deleted phonologically, and therefore, it may not be necessary to posit consonantal syllables in English.[3]

For French, Barnes & Kavitskaya (2003) summarize Rialland's (1986) argument as follows: "[she] observed a curious fact concerning certain instances of deletion of French schwa. Specifically, she noted that the preceding consonant, in non-postpausal contexts ostensibly resyllabified as a coda, nonetheless appears in spectrograms to retain much of the phonetic character of its corresponding onset variant, and not to lengthen the preceding vowel, as it would be expected to do were it in fact in the coda (p.41)." To account for this observation, Rialland (1986) posits an empty vocalic timing slot after schwa deletion in French, effectively arguing for consonantal syllables in French. Like Rialland (1986), Fougeron & Steriade (1997) found that consonant clusters created via schwa deletion (e.g. d'rôle 'some role') and underlying consonant clusters (drôle 'funny') behave differently. Fougeron & Steriade (1997) and Steriade (2000), however, argue against Rialland's interpretation, based on the observation that vowel deletion in French does reduce the number of syllable counts in poetry reading, suggesting instead that [d] in d'rôle keeps its underlying articulatory specification as a prevocalic consonant via phonetic analogy; crucially, however, they argue that these consonants are nevertheless resyllabified. In addition, there is a debate about whether schwas in French are entirely deleted or merely reduced (see Bürki, Fougeron & Gendrot 2007; Bürki, Fougeron, Gendrot & Frauenfelder 2011 for evidence that supports the deletion view). Overall, the existence of consonantal syllables is debatable in French.

Su Urbanczyk (p.c.) informed us that the primary reason to posit "consonantal syllables" in Lushootseed is because "there is no evidence for obstruent-obstruent complex onsets in the language, so it is unlikely that [the consonant cluster] would form a complex onset." This type of argument is recurrent when examining patterns like those in (1)-(9), and came up for the analysis of English above, and will become relevant for the case of Japanese that we will discuss in detail below. For the case of Lushootseed, there remains a question of whether vowels are entirely deleted, or whether they are merely devoiced. Unfortunately, phonetic data which would allow us to address this issue in Lushootseed is currently unavailable.

The Triqui pattern was brought to our attention by Christian DiCanio (see also DiCanio 2012; 2014). The data exemplify a process of pre-tonic (i.e. penultimate) vowel syncope (DiCanio 2012), which results in word-initial geminates. When the resulting geminates are sonorant, DiCanio suggests that they are separated by a syllable boundary, as there is tone movement across the sonorant geminates. He is not confident, however, that vowel deletion is complete in Triqui; apparent "deletion" may alternatively involve (heavy) reduction. He also informed us that when C_2 is a stop and the resulting geminate is a stop geminate (e.g. /ni^3.tah^2/ → [ttah^{32}] 'NEG.exist'), it is less clear whether C_1 is still syllabic. Evidence that the form resulting from vowel deletion remains disyllabic, for the case of initial geminate stops, is not currently available.

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[3]Kawahara (2002) made a general observation that marked structures that are otherwise not tolerated in the language can be produced as a result of an optional phonological process, like vowel deletion, the observation which he dubbed "the emergence of the marked". Kawahara (2002) did not examine the issue of whether these optional processes are indeed phonological, and hence it is important to address, for example, whether vowels are indeed deleted phonologically, rather than phonetically reduced. See below for more on this issue of establishing whether vowels are deleted phonologically (i.e. categorically).

Kager (1997) makes an interesting set of arguments for the proposal that vowel deletion in Carib preserves syllable structure in the output, and maintains that Carib does not show evidence for resyllabification after vowel deletion. Kager (1997) states that "[b]oth lengthening and vowel reduction are cross-linguistically common processes in iambic languages, increasing the durational differences which are inherent to the iamb: *a quantitatively unbalanced rhythm unit* (Hayes 1995) of a light plus a heavy syllable. From a typological perspective some analysis is preferable that expresses this connection between foot type and reduction. But then vowel reduction must crucially preserve the weak syllable in the iamb as a degenerate syllable, containing a nucleus that is void of vocalic features (p. 467; emphasis in the original)." If Kager is correct, then this is a case of "persistence of prosody"—a vowel is deleted, but its rhythmic structure is maintained. While our analysis of Japanese developed below in detail is in a very similar spirit with that of Kager, Kager (1997) also emphasizes that vowel deletion is *optional* and *gradient*. A question thus remains whether vowel deletion in Carib can be considered as complete phonological deletion, or whether it is merely heavy phonetic reduction.

For Odawa, there is evidence for vowel deletion, at least diachronically, as recent surveys have shown that speakers have lost vowel alternations once conditioned by rhythmic syncope in favor non-alternating stems that exclude the vowel (Bowers 2018). In this case, as well, it seems like higher level prosody has been preserved. Despite other fairly dramatic restructuring of stems and morphological inflection, the pattern of stressed vowels indicative of higher level prosodic structure persists. Indirect evidence against the resyllabification of consonants comes from phonotactic evidence elsewhere in the synchronic grammar for active avoidance of complex onsets (Bowers 2015).

Finally, there are many cases of rhythmic syncope in Québec French discussed by Garcia et al. (2016), who, building on Verluyten (1982), show that this deletion is conditioned by a rhythmic iambic requirement, just like in Carib and Odawa.

What is emerging from our brief cross-linguistic survey is that in order to establish the existence of consonantal syllables, two things need to be shown: (1) vowels are entirely deleted, not merely reduced or devoiced, and (2) consonants are not resyllabified. In this paper, we intend to establish both of these types of evidence for Japanese.

1.2 The case of Japanese

Japanese is well-known as a language without consonant clusters, allowing only homorganic nasal-consonant clusters and geminates (Ito 1986; 1989). In fact, not only does Japanese have no words with non-homorganic consonant clusters, Japanese speakers resort to epenthesis when they borrow words with consonant clusters from other languages; for example, the English word *strike* is pronounced as [s**u**to**r**aik**u**] when borrowed into Japanese, in which the original, monosyllabic word becomes a four-syllable word with three epenthetic vowels (Katayama 1998). The German last name *Wurmbrand* is borrowed as [ur**u**m**u**b**u**rand**o**]. This phonotactic restriction is claimed to condition perceptual epenthesis as well—Japanese listeners report hearing vowels between non-homorganic consonant clusters (Dehaene-Lambertz, Dupoux & Gout 2000; Dupoux, Kakehi, Hirose, Pallier & Mehler 1999; Dupoux, Parlato, Frota, Hirose & Peperkamp 2011). Moreover, the Japanese orthographic system is organized in such a way that each letter represents a combination of a consonant and a vowel; i.e., there is no character that exclusively represents an onset consonant. All of these observations lead to the oft-stated characterization that "Japanese is a strict CV-language".

However, Japanese is also known to devoice high vowels between two voiceless obstruents and after a voiceless consonant word-finally, which results in apparent consonant clusters and word-final consonants (e.g. [ɸus̠oku̥] or [ɸsok] 'shortage'). Some researchers argue that these high vowels are simply devoiced—not deleted—and therefore, Japanese does not have consonant clusters after all (Faber & Vance 2010; Jun & Beckman 1993; Kawahara 2015a; Sawashima 1971). Other researchers argue that acousti-

cally, there is no evidence for the presence of vowels at all; they therefore conclude that these vowels are entirely deleted (Beckman 1982; 1996; Beckman & Shoji 1984).[4] Beckman & Shoji (1984), for example, state that "[w]hen the waveform of a devoiced syllable is examined...neither its spectral nor its temporal structure indicates the presence of a voiceless vowel (p.63)." Beckman (1982) states that "devoicing" is a better term psychologically, but physically "[the term] 'deletion' is more correct, since there is generally no spectral evidence for a voiceless vowel" (p. 118). These studies are often limited in the sense that they rely on acoustic information to infer whether there remains an articulatory target for voiceless vowels or not—we independently know, however, that inferring articulation from acoustics is not always straightforward, especially when it comes to detecting the presence of a vowel (e.g. Davidson & Stone 2004; Davidson 2005; Shaw & Kawahara 2018a). The acoustic consequences of vocalic gestures can be rendered inaudible due to gestural overlap of surrounding voiceless consonants (Jun & Beckman 1993; Jun, Beckman & Lee 1998), and conversely, vowel-like acoustics can be observed, even without intended vocalic gestures, when consonantal gestures are not sufficiently overlapped (Davidson & Stone 2004; Davidson 2005; Hall 2006).

To address the issue of whether high devoiced vowels in Japanese are deleted or not in a way that is more direct than inference from acoustic data, a recent articulatory study by Shaw & Kawahara (2018c) used ElectroMagnetic Articulography (EMA) to address this issue—mere devoicing vs. wholesale deletion—by examining whether the devoiced vowels retain their lingual articulation.[5] They found that at least some devoiced tokens lack vowel height targets altogether, suggesting that these high vowels are not merely devoiced but entirely deleted (see Figure 6; see also Figures 2 and 3 for relevant EPG data). They also found that those tokens that lack vowel height targets show patterns of temporal variation consistent with consonant-to-consonant (C-C) coordination. That is, the flanking consonants appear to be timed directly to each other instead of to an intervening vowel, i.e., consonant-to-vowel (C-V) coordination, providing further evidence that there is no vowel in the surface phonological representation of these tokens. These results mean that Japanese, as a consequence of high vowel deletion, has consonant clusters (e.g. [ɸsoku]), contrary to the "CV-language" characterization often given to Japanese.

Based on this recent result reported in Shaw & Kawahara (2018c), this paper addresses how such consonant clusters, arising from high vowel deletion, are syllabified. We compare two specific hypotheses regarding this question, (1) the resyllabification hypothesis and (2) the consonantal syllable hypothesis, as anticipated in section 1.1, and present evidence for the consonantal syllable hypothesis. Our argumentation is based on two kinds of evidence. The first is a phonological consideration (section 3); we show that phonological processes that are sensitive to syllable structure, such as prosodic truncation and pitch accent placement, are unaltered by high vowel deletion. The other one is a phonetic consideration (section 4); patterns of temporal stability in speech production are inconsistent with the resyllabification hypothesis. In addition to addressing a specific question in Japanese phonology, our results bear on more general theoretical issues, including how different syllable structures manifest themselves in articulatory timing patterns (Browman & Goldstein 1988; Byrd 1995; Hermes, Mücke & Grice 2013; Hermes, Mücke & Auris 2017; Marin 2013; Marin & Pouplier 2010; Shaw & Gafos 2015; Shaw, Gafos, Hoole & Zeroual 2009), and the independence of prosodic and segmental levels of representation, as reviewed at the beginning of this paper. The convergence of the phonetic and phonological evidence also bolsters the claim that syllable structure corresponds to characteristic patterns of gestural timing in speech. Our case study also highlights the importance of integrating theoretical insights with phonetic experimentation.

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[4]Yet others argue that vowels are merely devoiced in some environments and deleted altogether in other environments (Kawakami 1977; Maekawa 1989; Whang 2017; 2018). In what environments deletion takes place, however, is still debated (see Shaw & Kawahara 2018c and Whang 2018 for recent discussion).

[5]Part of the complexity of assessing deletion based on measurement is in choosing which signal to measure, as there are many relevant options, including the neural motor control signal, the activation of muscles, individually or in ensemble, the movement of the articulators, the resulting acoustic signal, or the auditory response within the cochlea or along the auditory nerve.

2 The two hypotheses examined in the current study

We can entertain two types of hypotheses regarding the question of how consonant clusters resulting from high vowel deletion are syllabified in Japanese. These two hypotheses are illustrated in Figure 1. The first hypothesis (H1), shown on the left side of Figure 1, is that the consonant that preceded the deleted high vowel is resyllabified into the following syllable, resulting in a complex syllable onset.[6] Kondo (1997) argues for this sort of view based on the observation that devoicing of two consecutive vowels is often prohibited (for which see a recent study by Nielsen 2015 and references cited therein). On Kondo's account, consecutive vowel devoicing is blocked by a constraint against tri-consonantal onsets (*CCC).[7] This constraint can only function to block consecutive devoicing if the devoiced vowels are also deleted.

Matsui (2017) on the other hand argues that it is possible for Japanese to have consonantal syllables, as in the right side of Figure 1. His argument is primarily based on linguo-palatal contact patterns obtained using ElectroPalatoGraphy (EPG). He found that the pattern of lingual contact typically observed for Japanese /u/ is absent in devoiced contexts, as shown in Figure 2, implying that devoiced [u̥] is actually deleted. Moreover, when devoiced /u/ is preceded by /s/, the linguo-palatal contact pattern characteristic of /s/, which is likely to be produced with tongue groove, extends temporally throughout the syllable (Figure 3). Thus, in terms of linguo-palatal contact, it appears that /u/ is replaced by a consonant. Matsui (2017) discusses this result in the context of the C/D model of articulation (Fujimura 2000; Fujimura & Williams 2015), which crucially assumes that a syllable can remain even after high vowel deletion.

Hypothesis 1 (H1): Resyllabification   Hypothesis 2 (H2): Consonantal syllable
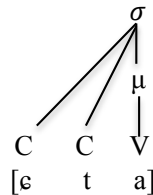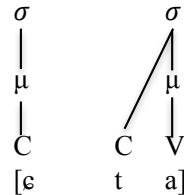
Figure 1: Two hypotheses regarding the syllabification of consonant clusters created via high vowel deletion, as in /ɕuta/ → [ɕta] .

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[6]Resyllabification does not necessarily entail loss of moras; in standard moraic theory, however, onset consonants are assumed to be non-moraic (e.g. Hayes 1989, cf. Topintzi 2008; 2010). It is nevertheless possible to assume a slightly different version of H1, in which moras of the devoiced vowels are maintained, whereas the syllables are lost. This version of H1 is not compatible with the phonological evidence discussed in section 3. What this sort of representation predicts about articulatory stability patterns is not exactly clear to us, although we suspect that it makes predictions similar to those of H1, which is not compatible with the results reported in section 4. In this paper we consider only those hypotheses for which we can master both phonetic and phonological evidence.

[7]Although this analysis deploys a constraint against a tri-consonantal cluster, other constraints might also prevent consecutive devoicing; for instance, in disyllabic words, words may be required to have at least one vocalic nucleus, or in other words, heads of metrical feet need to coincide with a prominent element (cf. de Lacy 2002).
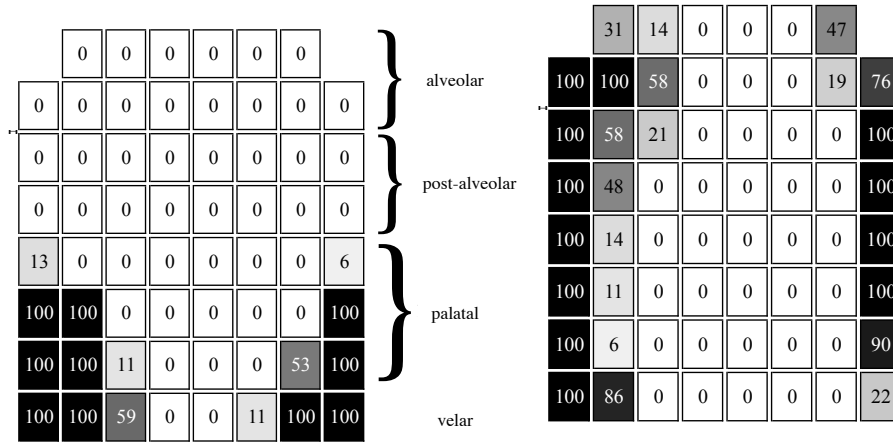
Figure 2: The linguo-palatal contact patterns of voiced [u] (left) and devoiced [u̥] in [su̥] (right). Adopted from Matsui (2017).
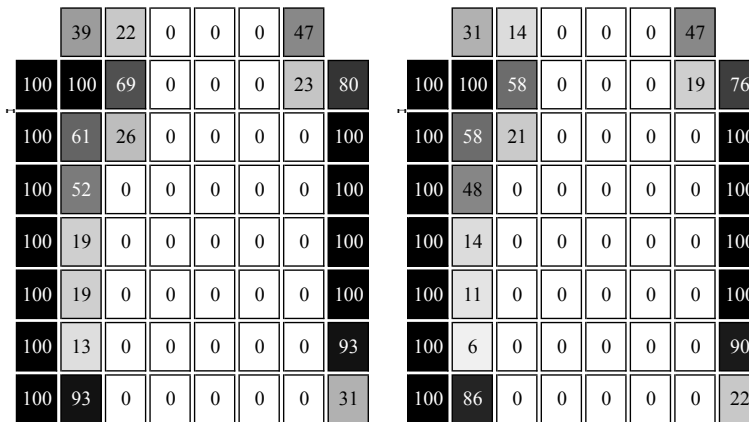
Figure 3: The linguo-palatal contact patterns of the devoiced syllable, [su̥]. The left panel is the first half of the syllable; the right panel is the second half of the syllable. We observe that lateral constriction for [s], which is likely produced with tongue groove, persists throughout the syllable. Adopted from Matsui (2017).

This paper provides further evidence for H2, drawing on a confluence of phonological and phonetic evidence.

3 Phonological considerations

We begin with phonological considerations that favor the consonantal syllable hypothesis (H2). As observed by Tsuchida (1997) and Kawahara (2015a), devoiced vowels count toward the bi-moraic requirement of some morphophonological processes. Japanese has many word formation processes that are based on a bimoraic foot (Ito 1990; Ito & Mester 1992/2003; 2015; Mester 1990; Poser 1990) and devoiced vowels count toward satisfying this requirement. The general patterns are described in (10)-(12) (the data are based on the previous works cited above, with some examples added by the first author).

(10)   loanword truncation

    a. [demonsu̥toreeɕoɴ] → [demo] 'demonstration'
    b. [rokeeɕoɴ] → [roke] 'location'
    c. [rihaasaru] → [riha] 'rehearsal'
    d. [sureddo] → [sure] 'thread'
    e. [raboratorii] → [rabo] 'lab'
    f. [opereeɕoɴ] → [ope] 'operation'
    g. [ookesu̥tora] → [oke] 'orchestra'

(11)   hypocoristic formation ([-tɕaɴ] is an optional hypocoristic suffix)

    a. [tomoko] → [tomo(-tɕaɴ)] (personal name)
    b. [sumiko] → [sumi(-tɕaɴ)] (personal name)
    c. [mariko] → [mari(-tɕaɴ)] (personal name)
    d. [wasaburoo] → [wasa(-tɕaɴ)] (personal name)
    e. [aamiɴ] → [aa(-tɕaɴ)] (personal name)
    f. [dʑuŋko] → [dʑun̥(-tɕaɴ)] (personal name)

(12)   Mimetics

    a. [buru-buru] 'shivering'
    b. [doɴ-doɴ] 'stomping'
    c. [pasa-pasa] 'dry'
    d. [kira-kira] 'twinkle'
    e. [pojo-pojo] 'bouncy'
    f. [riɴ-riɴ] 'ringing'

The following data in (13)-(15) show that devoiced vowels count toward bimoraic template patterns:

(13)   loanword truncation

    a. [su̥toraiki̥] → [su̥to] 'strike'
    b. [ripurai] → [ripu̥] 'reply'
    c. [hi̥su̥terii] → [hi̥su̥] 'Hysterie (German)'
    d. [moruhine] → [mohi̥] 'morphine'
    e. [su̥kuriiɴ-ɕotto]   [su̥ku̥-ɕo] 'screenshot'

(14)   hypocoristic formation

    a. [kumiko] → [ku̥ko(-tɕaɴ)] (personal name)
    b. [tɕi̥kako] → [tɕi̥ka(-tɕaɴ)] (personal name)
    c. [satɕi̥ko] → [satɕi̥(-tɕaɴ)] (personal name)
    d. [satsu̥ki] → [satsu̥(-tɕaɴ)] (personal name)
    e. [akira] → [aki̥(-tɕaɴ)] (personal name)

(15)   mimetics

    a. [ɸu̥ka-ɸu̥ka] 'fluffy'
    b. [su̥ka-su̥ka] 'empty'
    c. [ɕi̥to-ɕi̥to] 'rainy'
    d. [su̥ku-su̥ku] 'growing steadily'
    e. [ɕi̥ku-ɕi̥ku] 'wining'
    f. [pi̥tɕi -pi̥tɕi] 'stretched'

The patterns in (13)-(15) show that the moras of the devoiced (and possibly deleted) high vowels remain. If they did not, then the bimoraic loanword truncation for, e.g., [su̥toraiki̥] would be *[su̥tora] instead of [su̥to]; the hypocoristic for, e.g, [tɕi̥kako] would be *[tɕi̥ka:] or *[tɕi̥kka] instead of [tɕi̥ka]; and, similarly, the mimetic for 'rainy' would be *[ɕi̥tto-ɕi̥tto] or *[ɕi̥to:-ɕi̥to:] instead of [ɕi̥to-ɕi̥to].

To further corroborate this observation, Hirayama (2009) showed that moras of devoiced vowels count in *haiku*, whose rhythm is based on mora counts, in the same way as voiced vowels. To the extent that onset consonants do not project a mora (e.g. Hayes 1989, cf. Topintzi 2008; 2010), then, this observation supports H2 in Figure 1. At the very least, the patterns in (13)-(15) show that the moras of devoiced vowels remain. If these devoiced vowels are variably deleted, as in Shaw & Kawahara (2018c), then the mora must be docked to the remaining consonant, as in H2 in Figure 1.

Phonologically, some evidence suggests that syllables of devoiced vowels remain as well. Ito (1990) observes that the morphophological truncation pattern in (16) cannot result in monosyllabic outputs, and that a light syllable is appended in such cases, as in (17).[8] Ito & Mester (1992/2003) formalize this pattern as a result of a binarity branching condition at the prosodic word level; a PrWd must branch at the level of the syllable. As shown in (18), a syllable hosted by a devoiced vowel satisfies this prosodic branching requirement. If devoiced vowels in this context are also deleted, then the syllabic requirement is being satisfied by the final consonant in the word. This supports the syllabic consonant analysis, as in H2.

(16)   Bimoraic truncation

    a.   [ookesu̥tora] → [oke] 'orchestra'
    b.   [rihaasaru] → [riha] 'rehearsal
    c.   [rokeeɕoɴ] → [roke] 'location'

(17)   No monosyllabic outputs

    a.   [daijamondo] → [dai.ja] 'diamond'
    b.   [paamanento] → [paa.ma] 'permanent'
    c.   [kombineeɕoɴ] → [kom.bi] 'combination'
    d.   [ɕimpoʑium] → [ɕim.po] 'symposium'
    e.   [impotentsu̥] → [im.po] 'impotent'
    f.   [kompoonento] → [kom.po] '(stereo) compoent'

(18)   Devoiced vowels count

    a.   [maikuroɸooɴ] → [mai.ku̥] 'microphone'
    b.   [ampuriɸaiaa] → [am.pu̥] 'amplifier'
    c.   [paŋku̥tɕaa] → [paŋ.ku̥] 'puncture'
    d.   [wam.piisu̥] → [wam.pi̥] 'one piece'
    e.   [paɴɸuretto] → [paɴ.ɸu̥] 'brochure'

Another piece of phonological evidence comes from patterns of pitch accent placement. Kubozono (2011) argues that the Japanese default accent pattern, which is observed in loanwords and nonce word pronunciation, generally follows the Latin Stress Rule: (i) place the accent on the penultimate syllable if it is heavy (19), (ii) otherwise place the accent on the antepenultimate syllable (20) (see also Kawahara 2015b).[9] The presence of devoiced vowels does not disrupt this pattern (21). In cases of vowel deletion, the final consonant must still count as a syllable.

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[8]Labrune (2012) attempted to reanalyze this pattern without recourse to syllables; Kawahara (2016) argues that this reanalysis misses an important generalization, and reference to syllables is crucial.

[9]Not all loanwords follow Latin Stress Rule; for example, some four-mora words can be unaccented (Ito & Mester 2016b; Kubozono 1996; 2006). What is important in the current discussion is that these forms which follow Latin Stress Rule do not systematically show accent shift one syllable to the left.

(19)   Accent on penultimate syllable if heavy

    a.   [ɸu.re'n.do] 'friend'
    b.   [pu.ra'a.to] 'Praat'
    c.   [pu.ra'i.zu] 'prize'
    d.   [pu.ro'o.zu] 'prose'
    e.   [ɸu.ro'o.zuɴ] 'frozen'
    f.   [maa.ma.re'e.do] 'marmalade'

(20)   Otherwise accent on antepenultimate syllable

    a.   [re'.ba.noɴ] 'Lebanon'
    b.   [se'.ku.taa] 'sector'
    c.   [do'.ku.taa] 'doctor'
    d.   [pa'.ku.tɕii] 'coriander'
    e.   [ɕi'.na.moɴ] 'cinnamon'
    f.   [ɡa'.va.doɴ] (proper name)

(21)   Devoicing does not affect LSR

    a.   [pu.ro'.se.su̥] 'process' (cf. [ɸi.ro'.so.ɸii] 'philosophy')
    b.   [su.to'.re.su̥] 'stress' (cf. [ma.ho'.ɡo.nii] 'mahogany')
    c.   [su.te'.ru.su̥] 'stealth' (cf. [po.ri'.ɸo.nii] 'polyphony')
    d.   [su.ka'.ru.pu̥] 'scalp'
    e.   [ri.ri'.ʑa.su̥] 'religious'
    f.   [po.ri'i.pu̥] 'polyp' (cf. [bi.ri'i.bu] 'believe')
    g.   [ri.me'e.ku̥] 'remake' (cf. [be.ru'u.ɡa] 'beluga')
    h.   [bi.ba'a.ku̥] 'bivouac'
    i.   [ri.te'e.ku̥] 'retake'
    j.   [bi.za'n.tsu̥] 'Byzantine'

       Moreover, there is evidence from compound accentuation patterns and statistical distributions in native words that Japanese strongly disfavors accent on final syllables (Kubozono 1995; 2011). Given this dispreference, take words like [pu.ri'n.su̥] 'Prince' and [pu.ra'i.su̥] 'price'. If the final syllables are lost due to high vowel deletion, it would be natural to expect that accent shifts away to the word-initial syllables, which does not occur. This lack of accentual shift also supports the view that the syllables of deleted high vowels remain phonologically.

       In addition, devoiced syllables can bear pitch accents in modern Japanese (Kawahara 2015b; Vance 1987). For example, Japanese accented verbs predictably bear accent on the penultimate syllable; when the penultimate syllables in verbs are devoiced, accent remains on that syllable (e.g. [kaku̥'su̥] 'to hide'; [tsu̥'ku̥] 'to arrive'), especially in the speech of contemporary young speakers. Since the accent bearing unit in Japanese is the syllable (Kawahara 2016; Kubozono 2003; McCawley 1968), this observation too shows that syllables are maintained even in the presence of devoiced vowels. If, besides being devoiced, the vowel is also deleted in some of these cases, it must be that the remaining consonant supports the presence of the syllable.

       All of these observations converge on one conclusion: morphophonological processes that make reference to prosodic structure in Japanese do not treat devoiced vowels and voiced vowels differently. To the extent that devoiced vowels are deleted (Beckman 1982; 1996; Beckman & Shoji 1984; Matsui 2017; Shaw & Kawahara 2018c), then the general conclusion should be that moras and syllables remain after the deletion of these vowels, which is consistent with H2 in Figure 1.

       In the next section, we further corroborate this conclusion from the perspective of articulatory coordination. In particular, we build on previous research findings that different syllable structures show different

articulatory stability patterns (Browman & Goldstein 1988; Byrd 1995; Goldstein, Chitoran & Selkirk 2007; Hermes et al. 2013; 2017; Marin 2013; Marin & Pouplier 2010; Shaw & Gafos 2015; Shaw et al. 2009).

4 Temporal stability analysis

4.1 Approach

The following analysis is based on ElectroMagnetic Articulograph (EMA) data obtained for the study reported in Shaw & Kawahara (2018c). The general idea of the analysis is, as illustrated in Figure 4, to evaluate patterns of temporal stability in syllable-referential intervals across CV and CCV sequences. Previous studies, beginning with pioneering work by Browman & Goldstein (1988), have shown that languages that parse word-initial consonants tautosyllabically, i.e., as complex syllable onsets, tend to exhibit a specific pattern of temporal stability across CV and (C)CCV sequences. This general observation includes results for English (Browman & Goldstein 1988; Honorof & Browman 1995; Marin & Pouplier 2010), Romanian (Marin 2013), and rising sonority clusters in Italian (Hermes et al. 2013). Specifically, as illustrated schematically in the right side of Figure 4, in these languages the center-to-anchor (CC_A) interval is more stable across CV and CCV sequences than the left edge-to-anchor (LE_A) interval or the right edge-to-anchor (RE_A) interval (a.k.a. "c-center effect") . In contrast, languages that enforce a heterosyllabic parse of initial CCV sequences, e.g., Moroccan Arabic and Tashlhiyt Berber (Dell & Elmedlaoui 2002), tend to exhibit a different stability pattern. As illustrated schematically in the left side of Figure 4, these languages tend to show right edge-to-anchor stability (for Berber, see Hermes et al. 2017; for Arabic, see Shaw et al. 2009).
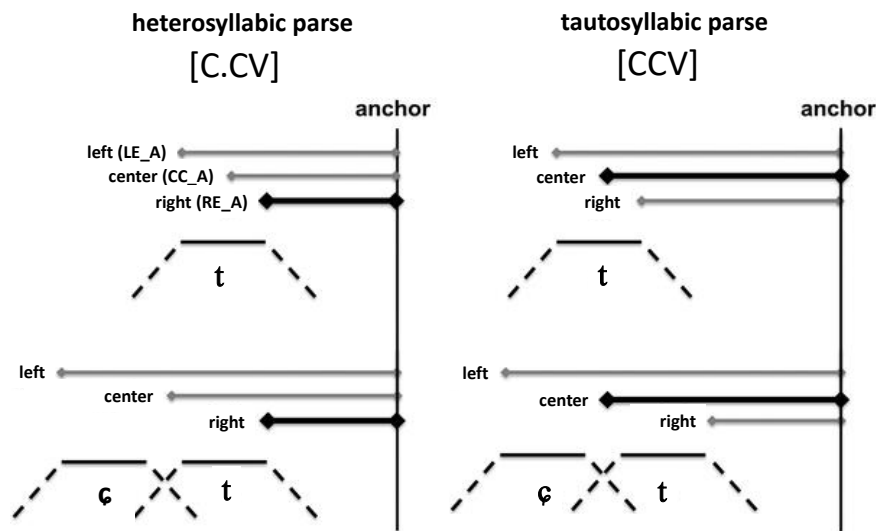
Figure 4: Illustration of temporal intervals over which stability indices are calculated—heterosyllabic parse vs. tautosyllabic parse.

The different patterns of temporal alignment illustrated in Figure 4 can be derived from distinct coordination topologies organizing the relative timing of consonant and vowel gestures (Gafos, Charlow, Shaw & Hoole 2014; Shaw & Gafos 2015). The key assumption linking syllable structure to patterns of temporal stability is an isomorphism between the arrangements of segments into syllables and the network of coordination relations that makes up the coordination topology. Specifically, onset consonants are assumed to enter into a relation of temporal coordination with the syllable nucleus, an assumption adopted from Browman & Goldstein (2000). Relevant coordination topologies are illustrated in Figure 5. Gestures are represented as vertices, and coordination relations between them are represented as edges, a schema which follows the representational formalism developed in Gafos (2002). Different types of coordination relations are color-coded. The relation between adjacent consonants, i.e., C-C coordination, is shown in blue; the relation between an onset consonant and a vowel, i.e., C-V coordination, is shown in red. For completeness, a yellow edge is also included, which indicates a relation between a vowel and possible post-vocalic segment, i.e., V-C coordination, although it does not play a role in the current analysis.
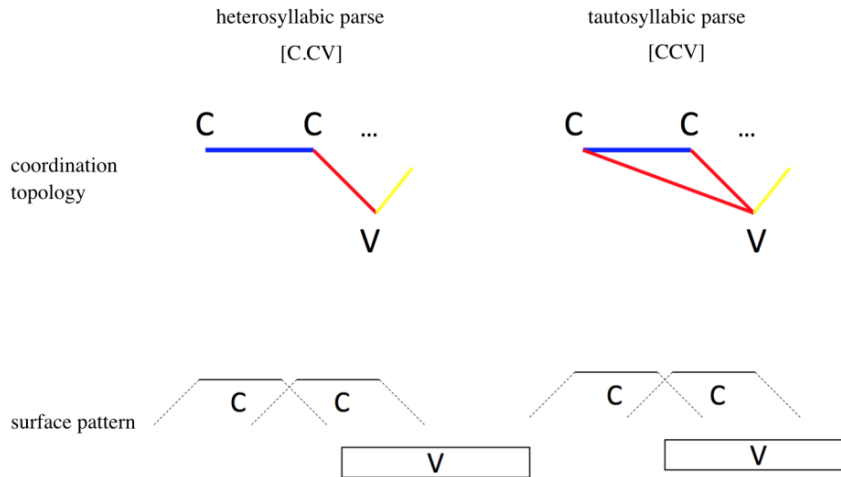
Figure 5: Relation between syllable parse, coordination topology and surface timing pattern for heterosyllabic (left) and tautosyllabic (right) parses of consonant clusters.

Under a heterosyllabic parse of initial consonants (Figure 5, left), the initial consonant is not contained in the same syllable as the following vowel—it is not a syllable onset—and, therefore, it is timed only to the following consonant (and not to the following vowel). In contrast, under a tautosyllabic parse (Figure 5, right) both pre-vocalic consonants are syllable onsets and, therefore, both enter into a coordination relation with the following vowel. Under the assumptions adopted here, complex onsets result in a coordination topology that, unlike the heterosyllable parse, places competing constraints on the temporal organization of gestures. That is, to satisfy the pattern of relative timing imposed by C-V coordination, the onset consonants would have to be temporally overlapped in time, a violation of C-C coordination. Satisfying C-C coordination, on the other hand, would entail a violation of C-V coordination. Although proposals differ in the technical details of how such competition is resolved (Browman & Goldstein 2000; Gafos 2002; Goldstein, Nam, E.L. & Chitoran 2009), the surface timing patterns shown at the bottom of Figure 5 derive from the coordination topologies shown in the top panels of the Figure. It is therefore possible to recover a syllabic parse from the pattern of relative timing in articulatory movements. We make use of this mapping to bring in phonetic data bearing on the syllabification of consonant clusters in Japanese. Specifically, we

pursue a stability analysis, evaluating the stability of intervals across CV and CCV sequences (Figure 4) to assess whether consonant clusters in Japanese resulting from targetless vowels syllabify like sequences in Arabic (i.e., $C_1.C_2V$, according to H2) or sequences in English (i.e., C_1C_2V, according to H1).

4.2 Method

The stimuli are listed in Table 1. They contained five dyads, the members of which differ in whether they contain a devoicable high vowel (first column) or not (second column); in addition, the stimuli included singleton controls (third column).

Table 1: The list of the stimuli.

Voiced vowel	Deleted (devoiced) vowel	Singleton control
[masuda] (personal name)	[mastaa] 'master'	[bataa] 'butter'
[jakuzai] 'medication'	[haksai] 'white cabbage'	[dasai] 'uncool'
[ɕudaika] 'theme song'	[ɕtaisee] 'subjectivity'	[taisee] 'system'
[ɸuzoku] 'attachment'	[ɸsoku] 'shortage'	[kasoku] 'acceleration'
[katsudoo] 'activity'	[katstoki] 'when winning'	[mirutoki] 'when looking'

Six native speakers of Tokyo Japanese (3 male) read items in the carrier phrase [okee _ to itte] 'ok, say _', where the underlined blank indicated the position of the target word. Items were randomized within a block, and 10-15 blocks were recorded per participant. For additional methodological details, such as EMA sensor attachments and post-processing routines, see Shaw & Kawahara (2018c). The second author and one research assistant inspected the acoustics of the produced tokens and found that all devoicable vowels were actually devoiced.

In order to assess whether the devoiced vowels were deleted or not, Shaw & Kawahara (2018c) analyzed tongue dorsum trajectories from the vowel preceding [u], e.g., [a] in [katsudoo] or [e] from the carrier phrase in [e#ɕudaika], to the following vowel, e.g., [o] in in [katsudoo] or [a] in [ɕudaika]. A sample illustration is given in Figure 6, which plots tongue dorsum height trajectories from the preceding vowel [e] in the frame sentence [ookee] through [u] and onto the following vowel [a]. The blue lines represent tongue dorsum movement across the underlined portion of [e#ɕudaika], whereas the red lines represent tongue dorsum movement across the underlined portion of [e#ɕutaisee]. A rise in tongue dorsum height between [e] and [a], corresponding to the intervening [u], is expected if there is an articulatory target for [u]. We observe from Figure 6 that when the [u]s are devoiced (red lines), the tongue dorsum does not substantially rise between [e] and [a], at least not in some tokens, indicating a lack of [u] target. To assess this quantitatively, Shaw & Kawahara (2018c) apply a novel analytical technique. They train a classifier on competing phonological hypotheses: (i) a vowel present scenario, for which the voiced vowels (Table 1: column one) provided the training data and (ii) a vowel absent scenario, which was simulated as a smooth interpolation between flanking vowels. The simulations were guided by the assumption of phonetic interpolation (Cohn 1993; Keating 1988; Pierrehumbert & Beckman 1988), i.e., if there is no [u] target, then the tongue dorsum will move from [e] to [a]. The technique for simulating trajectories based on phonetic interpolation of flanking targets (including the hypothesized vowel absent scenario) is described and justified in further detail in Shaw & Kawahara (2018a). The outcome of the classification yields a posterior probability that the trajectories contain a vowel target. Shaw & Kawahara (2018c) found that the posterior probability of a vowel target was very high for some tokens and very low for others, but there were few intermediate values. They conclude that the data support an optional process of phonological (i.e.

categorical) deletion; some tokens are produced like full, voiced vowels, whereas some tokens entirely lack an articulatory target.
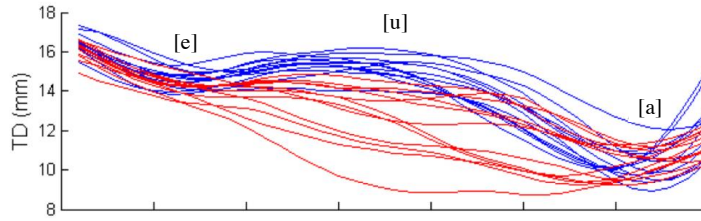
Figure 6: Sample tongue dorsum trajectories of [e#ɕudaika] (blue lines) and [e#ɕ(u)taisee] (red lines).

The current analysis builds on the results of Shaw & Kawahara (2018c). We applied the stability analysis to the subset of tokens that had a high (> 0.5) posterior probability of linear interpolation. These tokens were taken to lack a tongue dorsum target for [u], thereby forming a consonant cluster. This resulted in different numbers of tokens from different dyads. Only [ɕtaisee], [ɸsoku] and [katstoki] exhibited sufficient numbers of such tokens. For [ɕtaisee], there were 138 tokens (from five speakers) classified as deletion (lacking an [u] target); for [ɸsoku], there were 129 tokens (from four speakers); and, for [ɸsoku], there were 88 tokens (from two speakers). The following analysis is based on tokens from these three words, classified as lacking an [u] target, and an equal number of singleton controls. Since each item in Table 1 was produced in a block, we used in the analysis the singleton control from each block that also contained a case of vowel deletion. Consequently, the stability analysis below is based on 276 tokens for the [ɕtaisee] vs. [taisee] dyad, 258 tokens for [katstoki] vs. [mirutoki], and 176 tokens for [ɸsoku] vs. [kasoku].

The three intervals schematized in Figure 4, left-edge-to-anchor (LE_A), center-to-anchor (CC_A), and right-edge-to-anchor (RE_A) were calculated for each token containing a consonant cluster as well as for the singleton control (Table 1: third column). The stability of these intervals across CV (singleton control) and CCV provided our phonetic diagnostic of syllable affiliation. All three of the intervals were right-delimited by a common anchor, the point of maximum constriction of the post-vocalic consonant. The landmarks that left-delimit the three intervals were parsed in the following manner (Figure 7). The LE_A interval was left-delimited by the achievement of target of the first consonant in the sequence, e.g., [ɕ] in [ɕtaisee] (and [t] in the singleton control [taisee]). The RE_A interval was left-delimited by the release of the immediately pre-vocalic consonant, e.g., [t] in [ɕtaisee] (and also [t] in the singleton control [taisee]). The third interval, CC_A was left-delimited by the mean of the midpoints between the consonants in the cluster and by the midpoint of the single onset consonant in the singleton control. The midpoint was the timestamp halfway between the achievement of target and the release. The target and release landmarks were determined from the articulatory signal with reference to movement velocity, allowing us to apply a uniform criterion for all consonants, regardless of manner or place of articulation. Specifically, we used 20% of peak velocity in the movement towards/away from consonantal constrictions. Figure 7 illustrates the parse of relevant landmarks for C_1 and C_2 in a token of [ɕtaisee]. The achievement of target and release of C_1, which is [ɕ] in this case, is shown on the tongue blade (TB) trajectory (blue line). The parse of C_2, [t], is shown on the tongue tip (TT) trajectory.
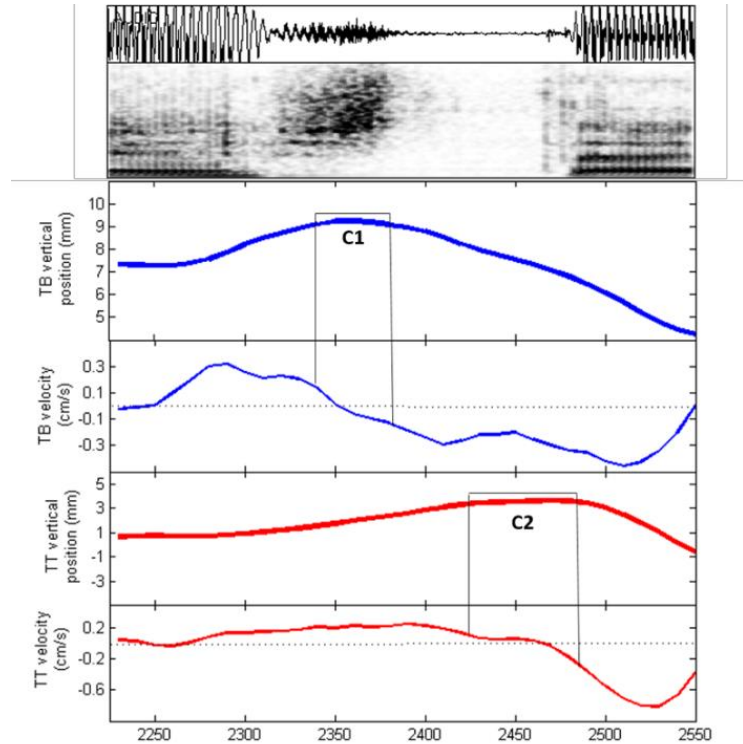
Figure 7: Illustration of how consonantal gestures were parsed based on a token of [ɕtaisee]. The portion of the signal shown begins with the [e] of the carrier phrase and ends with the [a]. The panels show, from top to bottom, the audio signal, spectrogram, tongue blade (TB) height trajectory, tongue blade (TB) velocity signal, tongue tip (TT) height trajectory, and tongue tip velocity signal. The thin black lines show the achievement of target and release of the consonants, C_1 and C_2, and the 20% threshold of the velocity peak that was used to parse them.

As an index of interval stability across CV and CCV sequences, we computed the relative standard deviation (RSD), also known as the coefficient of variance, by dividing the standard deviation of interval duration calculated across tokens of CV and CCV by the mean interval duration across these same tokens.

4.3 Results

Figure 8 shows boxplots of interval duration for LE_A, CC_A, and RE_A intervals as calculated across CV and CCV strings in three dyads (see Figure 4). Of course, it is always the case LE_A is the longest, followed by CC_A and then RE_A—what we are interested in is the degree of variability of these intervals, as, following the schema in Figure 4, this measure provides phonetic evidence for syllabic organization. We observe that for each of the dyads, RE_A shows the least variability (i.e. the boxplots have the smallest width). This result suggests that vowels are timed with respect to the right edge of the CC clusters, c.f., the center of CC clusters.
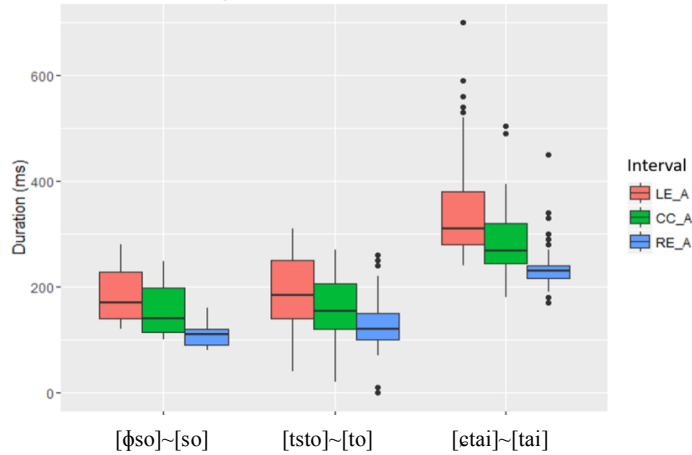
Figure 8: The durations between the three articulatory landmarks of the CCV and CV sequences.

All else equal, shorter intervals also tend to be less variable, a general property of timed events but also of other phonetic measurements (see, e.g., Nguyen & Shaw 2014 who show that variability in F1 and F2 for vowels is also correlated with the magnitude of the formant measurements). To correct for the effect that mean interval duration may have on the variability of the interval, we also computed the relative standard deviation.

The relative standard deviation (RSD) of the intervals in Figure 8 is shown in Table 2. Across dyads, the right-edge to anchor (RE_A) interval is the most stable (i.e. shows the lowest RSD). On the assumptions illustrated in Figure 5, this pattern points unequivocally to simplex onsets, i.e., a heterosyllabic parse of initial clusters. Although care must be taken when interpreting stability patterns in terms of syllable structure, a point we return to in the general discussion, the pattern of RE_A stability is one of the most straightforward to interpret. The timing between C and V remains stable across CV and CCV sequences, suggesting that the only the immediately prevocalic consonant is part of the syllable headed by the vowel. The results of the stability analysis, therefore, provides evidence for the same hypothesis as the phonological evidence discussed in section 3. Both point to H2, a heterosyllabic parse of consonant clusters arising from high vowel deletion.

Table 2: Relative standard deviation (RSD) of the three intervals shown in Figure 4.

	LE_A	CC_A	RE_A
[ɸso] vs. [so]	0.32	0.34	0.24
[tsto] vs. [to]	0.25	0.23	0.20
[ɕtai] vs. [tai]	0.23	0.28	0.11

5 General discussion

To summarize, the EMA study by Shaw & Kawahara (2018c) showed that Japanese [u] optionally but categorically deletes in devoicing environments, yielding consonant clusters. Both phonological and phonetic evidence reviewed here suggests that these consonant clusters are parsed heterosyllabically. The current results imply a rather surprising conclusion that Japanese allows consonantal syllables headed by a fricative

or an affricate, a conclusion that is especially surprising in light of the view that considers Japanese a "strict CV-language" (cf. Ito & Mester 2016a briefly discussed in the preamble).

The current results show that Japanese consonant clusters arising from high vowel deletion behave in terms of articulatory stability like word-initial consonant clusters in Moroccan Arabic. The similarity between Japanese and Moroccan Arabic is intriguing because word-initial clusters in Moroccan Arabic arose diachronically from the loss of short vowels (Benhallam 1980), and there have been similar debates about syllabification based on internal phonological evidence, see, e.g., Keegan (1986: 214) who argues for complex onsets (H1 in Figure 1) vs. Kiparsky (2003) who argues for moraic consonants (H2). Ultimately, the weight of the evidence, which includes now arguments from temporal stability in articulation (Shaw et al. 2009) and metrical patterns in verse (Elmedlaoui 2014) points to H2, the same conclusion that we have drawn for Japanese. In both cases, higher level syllabic structure is preserved despite the loss of a vowel.

More generally speaking, then, our data presents a case in which prosodic and temporal stability are maintained despite loss of a segment. Previously known cases of prosodic structure preservation include those discussed under the rubric of compensatory lengthening (Hayes 1989; Kavitskaya 2002; Wetzels & Sezer 1986). In this pattern, higher level structure preservation is more salient because it conditions segmental-level lengthening. In the Japanese case, loss of a vowel neither lengthens adjacent segments nor shortens the transitions between consonants (Shaw & Kawahara 2018c). The existence of patterns that delete segments while preserving prosodic structure supports independent representations of timing (prosodic structure) and articulation (segmental content), a dissociation with a known neural basis (Long et al. 2016). Generative phonology standardly assumes that prosodic structures are built off of segments, but it may instead be that prosody provides a temporal frame into which segments are "filled in" (cf. Fujimura 2000; Roelofs 1997; Sevald, Dell & Cole 1995).

We also find the convergence between the phonological evidence (section 3) and the phonetic evidence (section 4) to be generally encouraging, as it speaks to the potential to reach common conclusions from diverse data sources (see Broselow, Chen & Huffman 1997 and Maddieson 1993 for a similar argument). One can address phonological questions by examining phonetic data, and phonological questions can guide us as to where to look in phonetic research (Beckman & Kingston 1990).

We close here by pointing out some of the key assumptions that have been adopted to support this convergence. For starters, we assumed at times that the vowel deletion observed in Shaw & Kawahara (2018c) is present in other environments in which devoicing is observed, particularly in the word final environment. This may not be necessarily the case. Kilbourn-Ceron & Sonderegger (2018) have recently argued in fact that the devoicing processes word-finally and between voiceless consonants come from different sources/mechanisms. The EMA data supporting vowel deletion in Shaw & Kawahara (2018c) includes only vowels occurring between voiceless consonants. However, our phonological arguments assume that deletion of devoiced vowels also occurs at least some of the time in devoicing contexts word-finally. If devoiced vowels word-finally are never deleted, then the phonological arguments we presented in section 3 are less compelling. A related alternative, which we cannot rule out, is that the vowel gesture is preserved in just those cases in which it is required to fulfill a morphophonological bimoraic/bisyllabic requirement. Testing this hypothesis would require new EMA data. As it currently stands, the full force of our argument for converging phonological and phonetic evidence rests on the assumption that the optional deletion we have observed between voiceless consonants generalizes to other devoicing environments.

A second underlying assumption in our argumentation is that surface phonological forms dictate speech production patterns—therefore, on this assumption, the absence of a phonetic vowel implies the absence of a surface phonological vowel. On the other hand, we could salvage the "Japanese-as-a-strict-CV-language view" by postulating that high vowel deletion occurs solely at the phonetic implementation level. However, granting phonetics the power to delete a segment—or allowing a surface phonological segment to have no impacts on speech production —makes for a less restrictive theory of the phonetics-phonology interface. For example, we could imagine a system in which phonology inserts an epenthetic vowel, which

phonetics deletes, an instance of the "Duke-of-York" derivation (Pullum 1976). Efforts have been made to eliminate such derivations from the theory altogether (McCarthy 2003; Wilson 2000; though see Rubach 2003). More generally, we believe that there are compelling reasons to maintain transparency between surface phonological representations and phonetic production patterns (Broselow et al. 1997; Maddieson 1993; Shaw, Gafos, Hoole & Zeroual 2011).

A third assumption, on the side of the temporal stability analysis, is that RE_A stability reflects a heterosyllabic parse of consonants. There are by now numerous studies that have applied this phonetic heuristic, which follows from the theoretical framework summarized in Figure 5. Through computational simulation using stochastic models, Shaw & Gafos (2015) probed the range of stability patterns (expressed in terms of RSD, as we do in this paper) that can arise from different parses of initial clusters. They found that it is not always the case that simplex onsets correspond to RE_A stability while complex onsets correspond to CC_A stability. In particular, they highlight specific conditions under which simplex onsets are predicted to condition CC_A stability. This happens when there is a high level of overall variability in the data. A realistic scenario of increasing variability presents itself in language acquisition. During the acquisition of the lexicon, increasing exposure to new words and new speakers increases the overall level of temporal variability in speech experience, which can drive a shift in the aggregate statistics from RE_A stability to CC_A stability (Gafos et al. 2014). In the case at hand, that of our Japanese data, the level of variability in the data is low enough that we can be reasonably sure that simplex onset topology (Figure 5: left) maps to RE_A stability. More importantly, the conditions under which a complex onset (Figure 5: right) parse could condition RE_A stability are exceedingly rare (given our working assumption that onset consonants are timed to the syllable nucleus). We are therefore reasonably confident of our conclusions for the Japanese data, but a more complete analysis of patterns of covariation between temporal intervals predicted by the competing hypothesis would be useful (see, e.g., Shaw & Davidson 2011 and Shaw et al. 2011). To the extent that the above assumptions are valid, the results provide support for H2, the hypothesis that Japanese consonant clusters resulting from vowel deletion are parsed heterosyllabically. This conclusion follows from converging evidence from the analysis of phonological patterns sensitive to syllable structure and an analysis of temporal stability in articulation.

Finally, returning to the general issue that we reviewed at the beginning of the paper, Japanese instantiates a case of *persistence of prosody* (Garcia et al. 2016; Kager 1997), in that the rhythmic pattern is maintained after deletion of segments. Although we do not pretend as if we were the first one to find this pattern (see section 1.1), we believe that the current case study offers stronger evidence for *persistence of prosody* than previous research did. First, our analysis is based on an EMA study (Shaw & Kawahara 2018c), which directly showed that vocalic gestures are indeed deleted, eliminating the possibility that segment deletion may instead be segment reduction (see also Matsui 2017 for converging evidence from an EPG experiment). Second, we established the lack of resyllabification, again using articulatory data. The lack of resyllabification was further corroborated by examination of morphophonological patterns. With these, we conclude that Japanese does have syllables headed by a fricative or by an affricate.

We have limited our claims about syllabic consonants in Japanese in this paper to fricatives/affricates as it is for these manner classes that the currently available phonetic data happens to provide the strongest support, although we cannot rule out that other consonants can also head syllables. The phonological facts reviewed here are consistent with other voiceless consonants, including /k/, the only voiceless plosive that occurs before /u/ in native words, constituting syllable heads if, in fact, the devoiced vowel is deleted following /k/. In Shaw & Kawahara (2018c), we reported some data on this environment, i.e., the devoiced /u/ following /k/ in [haku̥sai]. Our method of detecting vowel deletion found very low rates in this environment. This is possibly due to the shared articulator between /k/ and /u/, which poses methodological challenges for our approach, as discussed Shaw & Kawahara (2018c); however, there are plausible phonological reasons as well why we might not expect to observe deletion in [haku̥sai]; i.e. why [ha.k.sai] is disfavorred. One is that [k], an oral stop, does not form a very good syllable nucleus (Dell & Elmedlaoui 1985; Prince & Smolensky

1993/2004), maybe because a moraic stop is marked relative to moraic versions of more sonorous consonants (Zec 1995). It may be the case that Japanese tolerates consonantal syllables only if the consonants are either [+continuant] or [+sonorant]. So far, the only conditioning environments for vowel deletion in Japanese that we know of require that the preceding consonant be voiceless, which (accidentally) precludes the possibility of syllabic consonants that are more sonorous than voiceless fricatives. Another possible phonological explanation for the lack of deletion following /k/ is syllable contact (Gouskova 2004; Murray & Vennemann 1983; Vennemann 1988): a [k.s] sequence across a syllable boundary involves a rise in sonority, which is dispreferred to a fall in sonority. A follow-up EMA experiment which was designed to test this hypothesis has been conducted, and the analysis is on its way (Shaw & Kawahara 2018d). If either of these hypotheses are correct, then it implies that even though Japanese allows consonantal syllables, they nevertheless follow markedness restrictions—restrictions on syllable nuclei or syllable contact—that are known cross-linguistically: i.e., we may be observing the emergence of the unmarked (McCarthy & Prince 1994) in the high vowel deletion pattern in Japanese.

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THE PERFECT PROSODIC WORD IN ITALIAN
OR FRUIT SALAD MATTERS[*]

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In this paper I investigate the concept of a Perfect Word by looking at truncated nouns in Italian. The perfect word in Italian is a bi- or trisyllabic trimoraic layered trochee, which is shown to determine the size of truncated forms and sometimes the size of the part that is deleted. The paper shows the usefulness of the notion of the perfect word for the analysis of truncations and provides further arguments for layered feet.

Keywords: Italian phonology, portmanteau, Prosodic Morphology, Optimality Theory

1 The struggle for perfection

Incomplete realizations of words or morphemes, i.e., truncations, have been a focal point in the development of Prosodic Morphology and Optimality Theory in the form of the discussion of the shapes of reduplicants in grammatical reduplication phenomena (e.g., McCarthy & Prince 1994, 1995, Gafos 1998, Hendricks 2001, Nelson 2003, Downing 2006), truncations with grammatical function or hypocoristics in nickname formation (Itô 1990, Mester 1990, Benua 1995, 1998, Itô et al. 1996, Itô & Mester 1997, 2003, more recently Alber 2010 on nicknames in Italian, Sanz-Álvarez 2015 and Martínez-Paricio & Torres-Tamarit 2018, on Spanish hypocoristics, Alber & Arndt-Lappe 2012). Clippings and similar abbreviatory processes that don't serve a grammatical function or nickname formation have received comparably less attention in the theoretical literature (see e.g., Wiese 2001, Piñeros 2002, 2004, Alber & Arndt-Lappe 2012, Trommer & Zimmermann 2012).

Many languages are subject to minimal word size requirements (McCarthy & Prince 1990, Golston 1991, see as well the discussion in Itô & Mester 2015; usually a heavy syllable, in some cases two light syllables, that is, usually two moras) or even maximality restrictions (e.g., Mandarin Chinese). Size limitations are usually considered an effect of prosodic well-formedness, just as the templates for reduplication or truncating morphology are determined by prosodic unmarkedness. When reduplicants don't copy the whole base, segments are left unrealized to achieve a binary foot or an unmarked syllable, i.e., without complex constituents or codas.

While such effects are usually derived as an interaction of markedness constraints aligning foot edges with word edges, determining foot size and banning unfooted material, Itô & Mester (2015), discussing the phonological condition for the realization of Danish stød, argue for a PERFECT WORD constraint, which, they speculate on in the end, might be of the MATCH type (Selkirk 2011).

(1)   MATCH-ω-to-f (=PERFECT WORD) (Itô & Mester 2015:30):
        The left and right edges of a constituent of type ω (prosodic word) must correspond to the left and
        right edges of a constituent of type f (foot).

Thus, a perfect Prosodic Word coincides with one foot and should be identical to the preferred foot type and structure of a language, that is, an iamb or a trochee. The above definition is intended to rule out such

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words as in (2c) with several feet as well as (2a) with its degenerate foot, while the two choices in (2b) are potentially perfect, depending on which kind of foot a language prefers, binary at the moraic or syllabic level.

(2)   a. Subminimal word   b. Minimal/Perfect Words   c. Too big a word

$$\omega \qquad\qquad \omega \qquad\quad \omega \qquad\qquad\qquad \omega$$
$$| \qquad\qquad | \qquad\quad | \qquad\qquad\qquad\quad f \quad f$$
$$f \qquad\qquad f \qquad\quad f$$
$$| \qquad\qquad \wedge \qquad \wedge \qquad\qquad\qquad \wedge \quad\; \wedge$$
$$\mu \qquad\qquad \mu\;\mu \qquad \sigma\;\sigma \qquad\qquad\quad \mu\;\mu \quad \mu\;\mu$$
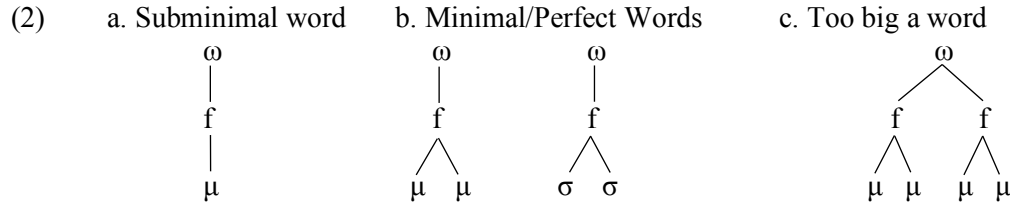
Even though they are not frequent, Italian doesn't seem to have any qualms with subminimal words, such as e.g., *gru* 'crane' or *tè* 'tea', which have a short vowel and are thus only monomoraic and can neither be a perfect iamb nor a perfect trochee, or with long words, as, e.g., *precipitevolissimevolmente* 'head over heals' (though nobody uses this one, Emanuela Canclini p.c.).

Italian shows otherwise clear evidence that every word contains at least one bimoraic trochaic foot (see Krämer 2009 and references there). Subminimal words such as *gru* thus need an explanation. To turn a form like *gru* into a prosodic word of minimal size it suffices to lengthen the vowel or epenthesize a consonant, which then can be associated with a mora, a consonant that is relatively unmarked in an Italian syllable coda, e.g., a placeless sonorant, like /ŋ/, though even that is unlikely given the coda filter in the native Italian lexicon (Itô 1986).

While we encounter vowel lengthening under stress in penultimate open syllables in Italian, words never end in a long vowel, even if they display final stress, such as *virtù* 'virtue'. Krämer (2009) considers penultimate lengthening as phonological, adding a mora to provide weight to the stressed syllable. (For more discussion of length see section 3.) Lengthening of the vowel of *gru* to achieve minimal word size is not an option due to the high ranking markedness constraint $*V^{\mu\mu})_{PWd}$, neither is any other kind of augmentation.

Italian does, however, display a wide array of truncated forms, nicknames, as *Fra* from *Francesca*, or *Manu* from *Manuela*, and abbreviated forms of common nouns, e.g., *frigo* 'fridge' from *frigorifero*, portmanteaus in the form of compounds with prefixoidal truncations, as *apericena* (from *aperitivo* 'aperitif' + *cena* 'dinner') or blends, such as *tigone* ('tigon', from *tigre* 'tiger' + *leone* 'lion'), or acronymic clippings, as e.g., *CONAD COnsortio NAzionale Dettaglianti* ('national consortium of retailers' - a supermarket chain). The size and shape of these truncated forms as well as the choice of realized segments should reveal the perfect word in Italian, i.e., whether the grammar is striving for perfect alignment of foot and word edges and whether there is a MATCH-like faithfulness relation between a truncated form and its base or rather whether a formalization with a range of edge-parameterized ANCHORING constraints (McCarthy & Prince 1995) is to be preferred. The idea that Italian truncations follow the template of the unmarked prosodic word in Italian was already put forward by Thornton (1996), who also observes that a bisyllabic trochee is the most frequent word type in the Italian lexicon. Montermini (2002) echoes this position, talking at one point about the "prototypical Italian word" ("parola italiana prototipica", p. 313) as the result of truncation processes. In addition, Thornton admits a trisyllabic ternary branching trochee. In this paper we will develop her notion of the Italian foot and word structure further by showing that the Italian perfect word consists of a trimoraic layered trochee. Layered trochees have been proposed by Martínez-Paricio (2013; see as well Jensen 2000, Davis & cho 2003, Yu 2004, Bennett 2013, Martínez-Paricio & Kager 2015) and Martínez-Paricio & Torres-Tamarit (2018) propose trisyllabic layered trochees as a template for Spanish trisyllabic hypocoristics.

In the next section, I will give an overview of truncation patterns, starting with nicknames, briefly touching on acronyms and dedicating most space in the section to the various truncated forms of common nouns in hybrid acronyms, blends, clippings and *parole macedonia* ('fruit salad words'). Section 3 will discuss the prosodic properties of truncated forms and argue that the perfect word in Italian is actually a trimoraic layered trochee. In 3.1 I argue for the layered trochee in Italian and its central role in truncations.

3.2 shows that when the output of truncation is not a perfect word then the unrealized part is. In section 3.3 I give a formal analysis in Optimality Theory. Section 4 concludes.

2 The typology of truncations in Italian

An excellent overview of the different forms of truncating word formation strategies is given in Thornton (1996, 2004). She distinguishes acronyms, abbreviations, fruit salad words (parole macedonia – a truncated word compounded with a more or less intact second word) among nouns, and i-formations ("I tipi Roby, Lori") and hypocoristics among proper names. In most of these categories she makes subdistinctions, some of which we will also discuss below, and she also discusses compound names, fruit salad compound names and diminutives and other suffixed names, such as the i-formations.

   Italian nicknames are discussed in a very enlightening way by Alber (2010), on whose formal analysis the analysis in this paper will be based. The overview given in this section is based mostly on these two sources, with a few examples added from Gaeta (2011), internet sources and my informants.

2.1 Nicknames and vocatives

Alber (2010) divides Italian truncated nicknames into two types, those anchored to the left edge of the word and those anchored to the stressed syllable. In the former, the nickname consists of segmental material starting with the beginning of the base name. In the latter the nickname is built around the stressed syllable of the base name, usually the stressed and the following syllable. Southern Italian vocatives consist of material from the beginning of the base name up to the stressed syllable, thus combining both strategies.

   Apart from the vocatives, which have as many syllables as it takes to get from the left edge of the word to the stress, the nicknames are either mono- or bisyllabic. Thornton (1996) also mentions (stress-anchored) trisyllabic nicknames based on names with antepenultimate stress. The mono-syllabic ones are usually left edge anchored, unless only the stressed syllable is realized, which is usually reduplicated, which makes the nickname bisyllabic.

   These reduplicated forms have another peculiarity which they share with the vocatives, final stress. One could speculate that this emerges because reduplicants are usually prefixal and Italian prefixes never carry primary word stress.

   These forms are also subject to segmental simplification which led a range of scholars to the conclusion that they are actually frozen child language forms (see the discussion in Thornton 1996).

   Left-edge anchored nicknames can also be adorned with the suffix *-i*, in which case all material up to the second vowel is realized, which is replaced by *i*, orthographically also represented as *-y* or *-ie*, which indicates the pattern's potential Anglo-Saxon origin (Thornton 1996).

   The different patterns are exemplified in (3) in Italian orthography. The accent on one vowel in each word is added here and further on in the paper to show the position of stress.

(3) Italian nickname truncation patterns
   a. Francésca   Fránce, Césca, Francé, Fra, Fráncy
   b. Salvatóre   Salvató
   c. Ippólito   Pólito
   d. António   Totó

2.2 Acronyms

These constructions can be divided into three types. The first type trivially just consists of the initial letter of each word in a long name of an institution, organization, concept or the like. These letters of each word

are sounded out individually, e.g., *CTN* (*Centro Tematico Nazionale* 'National Thematic Center'), is [tʃitiˈɛnne]. The stress and intonation pattern suggest that they are considered phrases. For example, the Democratic Party, PD, is [piˈdi], rather than *[ˈpidi].

Slightly more interesting phonologically is the next type, initial letters that are arranged in a way that makes speakers pronounce them as they would if this had been an ordinary word, such as *ARPA* (*Agenzia Regionale per la Protezione Ambientale* 'regional agency for the protection of the environment'). As in English, the initials of function words are usually ignored in the formation of acronyms. There are several collections of acronyms on the internet, such as nomix.it[1] or the wiktionary pages on Italian acronyms[2]. From the former I extracted all acronyms I suspected to be of this type and presented them to a native speaker who confirmed their pronunciation as, e.g., [ˈarpa] etc. The list is provided in the appendix.

As noted by Krämer (2009), in such acronyms word-final codas are allowed, but they are apparently not moraic, since even forms such as *AGIP* (*Azienda Generale Italiana Petroli* 'Company General Italian Petrols - General Italian Petroleum Company'), i.e., a light followed by a heavy syllable (LH), are stressed on the penultima.

Most of these forms are mono-syllabic, such as *DOC* (*di origine controllata* 'of controlled origin – a wine quality label'), or bisyllabic, as *AIPIN* (*Associazione Italiana per l'Ingegneria Naturalistica* 'Italian association of naturalistic engineering') or *ARCI* (*Associazione Ricreativa Culturale Italiana* 'Italian organization for cultural recreation'). Trisyllabic forms, such as *AGESCI* (*Associazione Guide E Scouts Cattolici Italiani* 'Association of Italian catholic guides and scouts'), are extremely rare and probably the upper limit.

In a third type of acronym, bigger units of some of the involved words are used, as illustrated in (4).

(4)   Type 3: Hybrids of acronym and truncation
        CONAD   COnsortio NAzionale Detaglianti   'National Consortium of Retailers'
        CONSOB   COmmissione Nazionale per le SOcietà e la Borsa
        ENEL   Ente Nazionale per l'Energia ELettrica
        GREST   GRuppo ESTivo
        INVALSI   Istituto Nazionale per la VALutazione del Sistema dell'Istruzione
        MAV   Mediante AVviso - Sistema di pagamento con bollettino
        RAV   Ruolo Mediante AVviso - Sistema di pagamento con bollettino
        SISMI   Servizio per l'Informazione e la Sicurezza Militare
        TARES   TAriffa comunale Rifiuti E Servizi
        TASI   TAssa sui Servizi Indivisibili
        TARI   TAssa RIfiuti
        Sepral   SEzione PRovinciale dell'ALimentazione

The maximum chunk that can survive from a single participating base word in these forms seems to be a light syllable, with the exception of *GREST*. Again, we find mostly mono- and bisyllabic forms. Trisyllabic forms, such as INVALSI are extremely infrequent, but attested.

The stress pattern on type 2 acronyms and type 3 hybrids is different from type 1 acronyms. The bisyllabic forms all have a trochaic stress pattern, regardless of the weight of the syllables, e.g., *ATAC* [ˈaːtak] *Agenzia del trasporto autoferrotranviario del Commune di Roma*, 'Roman Public Transport Services', *CONAD* [ˈkɔːnad]. They are thus all parsed as one prosodic word, while a proper acronym is a phonological phrase, cf. *tivù* [tivˈvu] 'tv' with final stress.

The few trisyllabic forms I found of type 2 and type 3 were all realized with penultimate stress, regardless of the weight of the initial syllable. The only exception is *COMECON* (*Consiglio di Mutua*

Assistenza Economica 'Council for Mutual Economic Assistance'), which receives initial stress. This, however, is a borrowed acronym and might as well have been imported with the antepenultimate stress. Type 3 acronyms can also be considered as a type of *parole macedonia*, since they share with them the truncation that leaves more base material than just an initial letter.

2.3 Parole macedonia

The term *parola macedonia* was coined by Migliorini (1949). The major characteristics of parole macedonia is that they blend at least two words, and in this process at least one of the two is truncated. While Thornton also divides the different types by semantic criteria, they can also be classified by the morphophonological mechanics of the manipulations, which is more useful for our purposes. From this angle we can identify three types, prefixoidal compounds, as *cantautore* 'singer songwriter' (5) of various levels of complexity (6), fusions, as *tigone* (*tigre* + *leone* 'tiger' + 'lion') (7) and acronymic salads, such as *PolFer* (*polizia ferroviaria* 'police + railroad-adj.,') (8).

(5)   Prefixoidal compounds

agriturismo	agricolo + turismo	'agrotourism'
amerasiatico	americano + asiatico	'American-Asian'
apericena	aperitivo + cena	'aperitif-turned-dinner'
cantautore	cantante + autore	'singer-songwriter'
cantadottore	cantante + dottore	'singer-doctor'
cantapoeta	cantante + poeta	'singer-poet'
cantaurocker	cantante + autore + rocker	'singer-author-rocker'
cartolibreria	cartoleria + libreria	'stationery and book shop'
cattocommunista	cattolico + communista	'catholic communist'
cinecittà	cinema(tografo) + città	'film studios in Rome'
cioccoblocco	cioccolato + blocco	'chocolate block'
discobar	discoteca + bar	'club and bar'
fantascienza	fantasia + scienza	'science fiction'
furgonoleggio	furgone + noleggio	'van rental'
giornattore	giornalista + attore	'journalist-actor'
palaghiaccio	palazzo + ghiaccio	'ice rink'
ristobar	ristorante + bar	'restaurant and bar'
scopamico	scopare + amico	'friend with benefits'

(6)   More complex compounds

autoferrotranviario	autobus-ferrovia-tranvia-ario
	'bus-railways-tramway-ADJ.'
postelegrafonico	postale + telegrafonico (Thornton 1996)
	postale + telegrafico + telefonico (Treccani on *telegrafonico*)
	(post~~ale~~ + (telegra~~fico~~ + ~~tele~~fonico)) (my suggestion)
	'postal + telegraphic + telephonic'

In type 1 blends, the truncated first member is usually bisyllabic or bimoraic and the second member is realized unscathed. Trisyllabic truncated forms of individual base words, such as the *aperi-* of *apericena*, are extremely rare. Bisyllabicity or trimoraicity is not a restriction on the initial part of the compound but rather on the individual truncated base word, as there can be concatenations of truncated words that each conform to this restriction, but together can be much bigger, as shown in (6).

       As illustrated in (7a), it is not always clear whether something is of the first or second type, as *mandarancio* might be analyzed as *manda-rancio* or *mand-arancio*. The examples in (7b) show nicely

blends in which both parts are truncated, the left member preserves the left edge of the base and the right member is stress anchored, i.e., it preserves the base material from the stressed syllable or rather the stressed rhyme, to the end of the word. For example, *leopardo* is stressed on the penult and so is *leone* (*leopárdo*, *leóne*) and the portmanteau is stressed in the same position as *leone*, i.e., *leopóne* and compounded of the initial part of *leopardo* and the stress foot rhyme of *leone*. The examples *kiwana* and *zebrallo* show that what is preserved on the right side is really the foot rhyme, that is, the foot minus its onset, since **kinana* and **zevallo* are unattested. However, this onset might as well have yielded to the last consonant(s) of the initial member for phonotactic reasons.

(7)   Portmanteaux
    a.   mandarancio   mandarino + arancio   'clementine ← mandarin + orange'

    b.   kiwana   kiwi + banana   'kiwi-banana'
          tigone   tigre + leone   'tigon ← tiger + lion'
          leopone   leopardo + leone   'lepon ← leopard + lion'
          zebrallo   zebra + cavallo   'zorse ← zebra + horse'

While in the acronymic forms in (8a) all members of the compound are truncated, (8b) exemplifies a mix of two monosyllabic truncations and a complete word.

(8)   Acronymic portmanteaux
    a.   Confapi   confederazione nazionale della piccola industria
                          'national confederation of small industries'
        Polfer   Polizia ferroviaria 'railway police'
        Federpro   federazione professsionale 'professional federation'
    b.   Cogepesca   Confederazione Generale della Pesca
                          'General confederation of fishing'

2.4 Autonomous truncated forms

There are several forms of truncations that are not compounding in nature. We can distinguish two types, those that just truncate everything on the right side of the word until only two or three syllables are left, as in (9a) and those that respect morphological boundaries, as in (10) and (11). In some cases, this leaves only a morpheme, even if that was a mono-syllabic prefix in the base forms, as in (10). And sometimes it looks as if the process deletes an affix, as in (11).

(9)   Truncations disrespecting morphological boundaries
    COOP Coop~~erativa di Consumo~~   'Consume Cooperative'
    frigo~~rifero~~   'fridge'
    bici~~cletta~~   'bike'
    cine~~matografo~~   'movie theatre'
    cinema~~tografo~~

(10)   Truncations to monomorphemes
    sub   subacqueo, sommozzatore 'scuba diver'
    ex   'ex'
    tele~~visione~~   'telly'
    foto~~grafia~~   'photo'

(11)   Suffix truncations
a.   qualifica   qualificazione   'qualification'
         classifica   classificazione   'classification'
         approva   approvazione   'approval'
         condanna   condannazione   'condemnation'
         confisca   confiscazione   'confiscation'
         perquisa   perquisizione   'search'

b.   concia   conciatura   'tanning'
         crepa   crepatura   'crack'
         imbraca   imbracatura   'harness'

This classification might be based on coincidental surface effects, since in most cases the deleted part starts with the stressed syllable, as in *qualifica-zióne* or *cinema-tó-grafo*. We might thus be dealing with one type of truncation in which the surviving structure has to conform to a bisyllabic template and one in which the prosodic structure of the material to be deleted determines the cut-off point for the truncation, i.e. everything to the right of the strongest word-internal prosodic boundary is discarded. The latter condition is thus the mirror image of what we saw in nicknames, such as *Stofero* from *Cristófero*. There don't seem to be any stress anchored truncations of common nouns apart from those in which the deleted material is anchored to and contains the stressed syllable.

2.5 Summary

The following table sums up the different shortening patterns discussed in this section.

Category	Example (base)
i. Nick names	
Left-anchored trochaic	Fránce (Francesca)
Left-anchored + i	Fráncy (Francesca)
Left-anchored monosyllabic	Frá (Francesca)
Left-anchored to stress	Francé (Francesca)
Stress-anchored	Césca (Francesca), Pólitio (Ippolito)
Reduplicated	Totó (António)
ii. Acronyms	
Type 1 – Letters (phrase)	tv [tivˈvu] (televisione) 'tv'
Type 2 – Letters (1pword)	ATAC [ˈaːtak] (Agenzia del trasporto autoferrotranviario del Commune di Roma) 'Roman Public Transport Services'
Type 3 – Hybrids (Trunc+letters)	CONAD (COnsortio NAzionale Detaglianti) 'National Consortium of Retailers'
iii. Portmanteaux/parole macedonia	
Prefixoidal compounds	agriturismo (agricolo + turismo) 'agrotourism'
Blends	kiwana (kiwi + banana) 'kiwi-banana'
Acronymic blends	Cogepesca (Confederazione Generale della Pesca) 'General confederation of fishing'
iv. Autonomous clippings	
Truncation to perfect word	bici~~cletta~~ 'bike'
Truncation to prefix	tele~~visione~~ 'telly'
Truncation of suffix/prfct wrd	qualifica~~zione~~ 'qualification' cinema~~tografo~~ 'movie theatre'

3 Prosodic delimitations of truncations

In this section we will first investigate the nature of the prosodic word in Italian and then pick up the thread from the end of the previous section, considering whether truncation patterns can be more insightfully analyzed by looking at the prosodic structure of the base material that is left unrealized in the truncated forms. The third part of this section brings together the factors that shape truncated forms in Italian in a sketch of an OT analysis.

3.1 Is the Italian perfect word a perfect trochaic foot?

Thornton (1996) observes that truncated forms that would be just a light syllable seem to be impossible, unless they are hypocoristics or part of a longer construction, as in *CoGePesca* or *CoNAD*. Furthermore, she argues that certain characteristics of stress-anchored hypocoristics are to be considered evidence for a dactylic foot in Italian.

The absence of nicknames for proper names with antepenultimate stress that consist of the last two syllables, e.g., *Cándido - *Dido*, is considered by Thornton to be the evidence that stress-anchored nickname formation is circumscription of the main stress foot. Second, the existence of nicknames with three syllables, e.g., *Ippólito – Pólito*, is seen by her as evidence for the ternary foot ((12)a).

Ternary feet are not particularly desirable in prosodic phonology, since prosodic constituents from the phrase to the syllable and its subconstituents show a tendency for binary branching. Alber (2010) provides examples of nicknames of names with antepenultimate stress in which only the stressed syllable and the following penult, but not the final syllable is retained, e.g., *Méni* from *Doménico*, *Stófo* from *Christóforo*, *Níba* from *Anníbale* (footnote 2). This suggests that the assumption of a ternary foot is oversimplifying. Moreover, Krämer (2009) has shown that the final syllable in words with non-final stress is not part of the main stress foot and analyzes it as extra-metrical.

His argument is based on the vowel lengthening facts: stressed vowels in the penult lengthen properly, with a length difference to unstressed vowels that equals that between short and long consonants, while stressed vowels in the antepenult are just slightly longer than unstressed vowels in the same position. Rather than restricting a Stress-to-Weight effect to the penult, it is more economic to assume that the Italian stress foot consists of two moras followed by an extra-metrical syllable/mora. Extrametricality, however, is a representational stipulation that can be avoided since the phenomena intended to be explained by extrametricality can be reanalyzed with layered feet, which have been proposed on independent grounds (most recently by Martínez-Paricio 2013).

The Italian pattern can be analyzed straightforwardly with such a layered foot. The three analytical options are directly comparable in (12).

(12)   Italian foot parsing options
     a. Ternary foot   b. Final extrametricality   c. Recursive trochee
        (Thornton 1996)   (Krämer 2009)
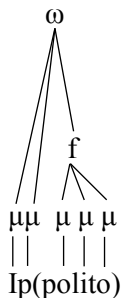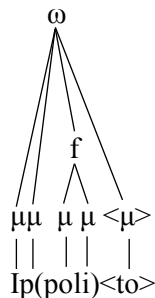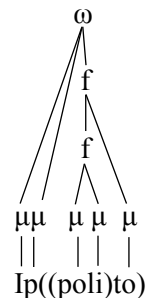
In this analysis, the most well-formed prosodic word in Italian can be trisyllabic and still have an edge of the same foot at either word edge. The pattern provided by Alber falls out naturally as the realization of the inner foot only. We thus wouldn't be surprised to run into an Italian *Ippolito* called *Poli* by his friends.

This bears the question why not all truncated forms are trisyllabic. Why is trisyllabicity, as in *a.pe.ri-cena*, the exception and bisyllabicity, as in *agriturismo* or *frigo*, the norm? A first partial answer to this is that the recursive foot can be built on three as well as two syllables, as long as there are three moras.

(13)   The perfect word in Italian
        a. Trisyllable   b. Bisyllable

              ω   ω
              | |
              f   f
             ╱ ╲   ╱ ╲
            f   ╲   f   ╲
           ╱╲   ╲   ╱╲   ╲
          μ μ   μ   μμ   μ
          | | | ╲╱ |
    (('ka· vo) lo) 'cabbage'   (('kaː) vo)   'cord, wire'
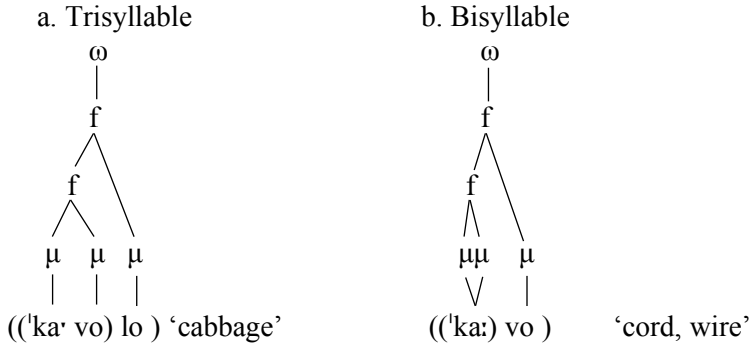
The bisyllabic form has several advantages over the trisyllabic one. It satisfies STRESS-TO-WEIGHT ('stressed syllables should be heavy' Myers 1987, Riad 1992), since the stressed syllable is bimoraic. If one tries to increase the weight of the stressed syllable in *cavolo*, one has to pay a price, either the perfect binary internal trochee becomes a trimoraic HL foot or the perfect foot parsing of all material in the word goes out the window, i.e., we would get *$((ka^{\mu\mu}vo^{\mu})lo^{\mu})$* or *$((ka^{\mu\mu})vo^{\mu})lo^{\mu}$*, respectively.

Furthermore, stress is right-edge oriented in Italian. There is a three-syllable stress window at the right edge of the word in Italian nouns in which any syllable can be stressed (see Krämer 2009 for a more detailed discussion). In the bisyllabic form stress is closer to the right edge than in the trisyllabic form, scoring better on EDGEMOST-Right (an alignment constraint responsible for dragging stress to the right edge of the word). And finally, since *cavo* has only two syllables rather than three, one can expect it to avoid some violations of markedness constraints that are incurred by any syllable (additional structure must come at some cost, at least in OT).

With this Italian perfect prosodic word established, we expect to see truncated forms and blends of either two or three syllables length with a preference for bisyllabic ones. Monosyllabic words, such as *gru* 'crane' or *Fra* (hypocoristic of *Francesca*) are clearly subminimal and can't be augmented, while the many acronyms with CVC structure, such as DOC, or TAV, are quite close to perfection, since the coda consonant can be considered moraic, which results in a bimoraic trochee and a perfect alignment of foot and word edges.

(14)   Italian monosyllables
        a. Subminimal   b. Minimal

              ω   ω
              | |
              f   f
              | ╱ ╲
              μ   μ   μ
              | | |
        Fra 'Fra~~ncesca~~'   D O C   'Di Origine Controllata'
        gru 'crane'   cl u b 'club'
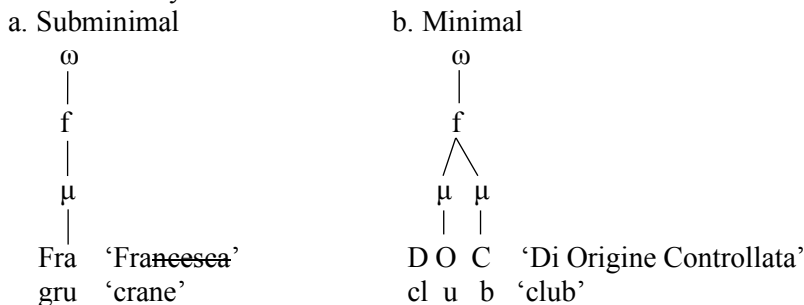
This then also tells us something about the prosodic flexibility of coda consonants in Italian: Word-internal codas in the regular lexicon and phonology are moraic since lengthening of stressed vowels is suspended in stressed syllables closed by a consonant (['peːzo] 'weight' vs. ['pesto] 'pesto'). In bisyllabic acronyms, such as ENEL, they are most probably not moraic, since this would result in a quadrimoraic foot, i.e., ((eᵘᵘ.)neᵘlᵘ), while they do have an associated mora in monosyllabic acronyms, such as TAV, to achieve minimal prosodic word size.

3.2 Perfect truncata?

Many truncated forms underparse exactly the main stress foot and all the material preceding the foot survives, as illustrated in (15).

(15)   Deleting the perfect word
        aperi((ti)vo)cena   'aperitif-dinner'
        cinema((tógra)fo)   'movie theatre'
        bici((elét)ta)   'bike (bicycle)'
        frigo((rife)ro)   'fridge'
        classifica((zió)ne)   'classification'
        imbraca((tú)ra) '(climbing) harness'

(16)   The perfect truncatum in Italian

bitʃi ((ˈkle t) ta) 'bike'   cinema ((ˈto gra) fo)   'movie theatre'
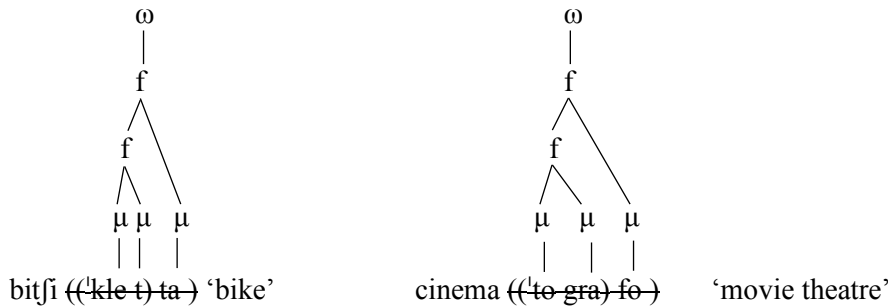
This is, however, obfuscated by a strong tendency of cut-off points to coincide with morphological boundaries, as in the following examples, repeated from above. A similar effect is observed by Itô & Mester (1996) in Japanese compounds in which syllabification can't cross a Sino-Japanese morpheme boundary in compound-internal contractions.

(17)   Morphological boundaries
        classifica-zióne   'classification'
        imbraca-túra   '(climbing) harness'
        tele-visióne   'telly'
        oto-rino-laringo-iatría 'otorhinolaryngology'

As noted already at the end of section 2, if we consider the stress pattern of the bases that undergo truncation respecting morphological boundaries we see that the truncated part is usually the stressed syllable and everything that follows, except for *tele-visione*. Montermini (2002) gives an oversized example, *otorino* from *otorinolaringoiatria* 'otorhinolaryngology', in which the surviving initial part has four syllables and the deleted part consists of six syllables. Only a tiny fraction of the deleted material here is parsed in the layered main stress foot. The rest is simply unfooted or only variably so, i.e., *otorinolaringoia((triː)a)*. I suspect that the morphosyntactic structure of this oversized word results in a prosodic word boundary at the major morphological boundary, which is between *otorino* and *laringoiatria*. What is deleted here is then a

very imperfect prosodic word, one with two to four unfooted syllables, but still a prosodic word. Leftover *otorino* is still enough material for two prosodic words and looks like an ordinary Italian diminutive, e.g., *motorino* 'moped', with stress on the penult.

If the deleted part in some patterns is defined as a (perfect) word, i.e., a layered foot, this would explain why we sometimes find deviations from the bisyllabic pattern, as in *apericena* or *cinema*, and why truncation often easily cuts right through a morpheme. The examples *bi-cicl-ett-a* and *frigorifer-o* can be perfectly divided by slicing off the recursive foot at the end without regard to morphological boundaries, leaving a bisyllabic trunk that only needs vowel lengthening for perfect prosodification into a layered trochee, i.e., ['biːt͡ʃi].

The stress pattern in forms like *classífica* (from *classificazióne*) and *appróva* (from *approvazióne*), which also seem to delete a potential perfect word, i.e., *-zione ((tsjóː)ne)* is interesting too. The former has stress on the antepenultima while the latter places it on the penult for no apparent reason (e.g., syllable weight). Since Italian does not build iambs from the left edge, but rather trochees from the right edge, this is unexpected. However, after truncation of the stressed material, it is not default stress placement that applies here. These forms revert to the stress pattern they display as verbs. Both truncated nominals are identical with the third person singular present tense verb form, which can be used to reveal lexically prespecified stress, because the inflectional affix does not have a lexically specified stress mark. Compare the infinitive and the third person forms.

(18)   Reverting to lexical stress of the stem
         classificáre – classífica (3.sg.), classíficano (3.pl.)
         approváre – appróva (3.sg.), appróvano (3.pl.)

Moreover, forms like *perquisa* from *perquisizione* 'search' attest to the suspicion that we are actually not dealing with truncations but with zero nominalizations of verb stems. In such an analysis, the final *-a* of these forms is an affix that marks feminine gender, which is the gender of all these short deverbal nouns. If this were simple truncation, *perquisizione* should be shortened to *perquisi, with a final *i*, not *perquisa*, with a final *a*. The same analysis then has to be extended to all other forms in this pattern.

Perfect Word truncation is also obviously not the driving force in formations like *furgonoleggio* (*furg̶o̶n̶e̶* + *noleggio* 'van + rental'), just as *palaghiaccio* 'indoors ice rink' truncates *zzo* from *palazzo* 'big building'. Here it is again the surviving material in the truncated member of the compound that conforms to the perfect word, consisting of two syllables or three moras, marked in italics in (19). Deleting the perfect word part of the base would result in a subminimal form, i.e., *<u>*fur*</u>-*noleggio* and *<u>*pa*</u>-*ghiaccio*.

(19)   Survival of the potentially perfect
         fur((ˈgoː)ne) + no((ˈled͡ʒ)d͡ʒo) → ((*fuᵘrᵘ*)*goᵘ*) no((ˈled͡ʒ)d͡ʒo)
         pa((ˈlats)tso) + ((ˈgjat͡ʃ)t͡ʃo) → ((*paˑᵗᵘ*)*laᵘ*) ((ˈgjat͡ʃ)t͡ʃo)

Whether such truncated forms actually have foot structure, as indicated here for the truncated form, still has to be confirmed by phonetic studies. The evidence for secondary stress, even in compounds, is very weak in Italian. One could speculate that deletion of the main foot in compounding truncations is a preferred strategy because the weak or non-final member(s) of a compound are destressed anyway (or receive only weak stress). Thus the whole foot structure would have to be dismantled and the unfooted syllables preceding the main word stress are more suitable for the weak position in a compound. However, as we see in (19), the metrical structure of the truncated form has to be reorganized completely and that of the base is ignored.

While stress anchoring is common in hypocoristics, in common nouns it is not an option. All truncated common nouns are anchored to the left word edge. The left edge of the truncated form always matches the left edge of the base. This is not the case at the right edge. At the right edge we either find some segment from somewhere inside the truncated form, as in *confisca̶z̶i̶o̶n̶e̶* 'confiscation' or *frigo̶r̶i̶f̶e̶r̶o̶* 'fridge'

or the right edge of an untruncated form to which a truncate is prefixed (*agriturismo*). In blends we find the right edge of a form that is missing its left edge, e.g., the underlined part in *zeb<u>rallo</u> 'zorse'*. Only in hybrid acronyms one finds the leftmost syllable of a truncated word on the right side, e.g., *CaRiPLo* from *Cassa di Risparmio delle Provincie Lombarde* 'Savings chest of the Provinces of Lombardy - a former regional Italian bank'. Especially the right-left mapping in blends respects the left and right edges. Blends such as *bra-vallo* or *bra-cava* from *zebra* and *cavallo* are unattested, not only because they would be hard to recognize, but presumably also because they don't map the respective base edges to the respective edges of the portmanteau word.

3.3 A cocktail with the PERFECTWORD as its central ingredient

While blends and *parole macedonia* can be bigger than three syllables, we have seen that for clippings, and the truncated part of *parole macedonia*, the perfect prosodic word of Italian is the size limit. Furthermore, they are always anchored to the left edge of the base, unless a truncated form is on the right side in a blend, in which case it is anchored to the right edge of the base. Unless it isn't, in which case we consider it a hybrid acronym. In this latter case, however, the maximum size of each truncate seems to be one syllable and the overall size of the construction limited to maximally three syllables.

There are clear parallels between truncated common nouns and hypocoristics. We can thus draw on some of the constraints proposed by Alber (2010) in the analysis. In particular she proposes a constraint that aligns the left edge of the truncated form with the left edge of the base as well as a size restricting constraint that demands that the truncated form and the first syllable of each involved morpheme coincide. The latter constraint can be considered the driving force behind the hybrid acronyms that consist of the initial syllable of each involved word. We would thus want to reformulate this constraint as referring to all base words involved rather than morphemes.

(20)　ANCHOR-Left (Alber 2010)
　　　Align the left edge of the *correspondent of TRUNC in the base* with the left edge of the base.

(21)　COINCIDE-$\sigma1$ (adapted from Alber 2010):
　　　Every segment of the output is in the first syllable of some base word.

Clearly the COINCIDE constraint is only relevant for a very restricted subset of truncations here, what is relevant for all truncations is a general ranking of faithfulness constraints mediating between the truncated form and its base, BT-Faithfulness, as well as general Input-Output faithfulness constraints with respect to the size restricting constraints (Alber & Arndt-Lappe 2012).

We have seen above that ordinary words in Italian can be smaller or significantly bigger than the perfect word. IO-Faithfulness thus has to outrank the PERFECTWORD constraint while the latter has to dominate BT-Faithfulness, since the truncated forms never exceed the size of a perfect word, unless they are a concatenation of truncated morphemes.

The following tableau illustrates the situation with words that are not clipped. Shrinking or augmenting them to perfect word size would violate some faithfulness constraint, mostly IO-MAX and IO-DEP. A word, such as *frigorifero* 'fridge' has a layered foot at its right edge and either two unfooted syllables at its left edge or a secondary stress foot (not considered here). These unfooted syllables violate the PERFECTWORD constraint. For the sake of simplicity I considered the violation of FOOT-BINARITY incurred by words such as *gru* 'crane' as a violation of PERFECTWORD here.

(22) Italian humdrum imperfection

i.	/frigorifero/	IO-MAX,	IO-DEP	PERFECTWORD
a.	{((rífe)ro)}	5!		
b. ☞	{frigo((rífe)ro)}			1
ii.	/gru/			
a.	{((grú:)te)}		2!	
b. ☞	{(grú)}			1

It is crucial for the analysis that a truncated form has no direct IO correspondents, but rather only BT correspondence relations, parallel to reduplicants in McCarthy & Prince's (1995) proposal.

(23) Base-Truncate correspondence

/input/

IO-Correspondence   ↕

[base] ←——— [[trunc]]
BT-Correspondence
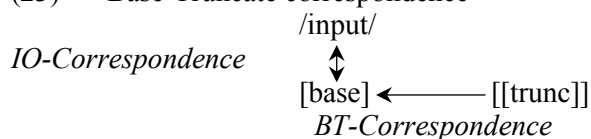
Thus, while IO-Faithfulness is ranked above PERFECTWORD, BT-Faithfulness is ranked below this constraint for most truncation patterns in Italian.

(24) Core ranking for truncations

IO-MAX, IO-DEP ≫ PERFECTWORD, ANCHOR-L ≫ BT-MAX, BT-DEP

The following tableau illustrates the effect of this ranking on truncations. The candidates are explained in turn.

(25) Left-edge oriented truncation to perfect size

	/frigorifero/	IO-MAX	IO-DEP	PERFECT WORD	ANCHOR-L	BT-MAX	BT-DEP
a.	{frigo((rífe)ro)}			1!			
b.	{fri(go(rí))}			1!		4	
c.	{((rífe)ro)}				1!	5	
d.	{((fé)ro)}				1!	7	
e.	{((góri)fe)}				1!	5	
f. ☞	{((frí)go)}					6	
	base: {frigo((rífe)ro)}						

Candidate (a) realizes the base form without any omissions. In this case this results in a structure that exceeds the perfect word by two syllables that are not in the maximal foot and thus violates the constraint PERFECTWORD. Candidate (b) is in spirit a southern Italian vocative and retains all material up to and including the stressed syllable. This violates PERFECTWORD since there is an unfooted syllable and since the foot structure is iambic rather than the usual trochee. Candidates (c) and (d) are right edge oriented, truncating material at the beginning, which violates ANCHOR-L. This constraint is also violated by (e), which is center aligned and has discarded one syllable at each word edge. This leaves candidate (f), a bisyllabic form corresponding to the left edge of the base as the winner.

A candidate not considered in (25) is the trisyllabic *frigori* (with stress either on the penult or the antepenult). As discussed above, stress on an open penult results in vowel lengthening, but this does not happen on stressed open antepenults. Vowel lengthening satisfies STRESS-TO-WEIGHT. This constraint plays a role in Italian phonology in general and together with PERFECTWORD it is responsible for limiting the clipped forms to two syllables.

(26)   Perfect size

	/frigorifero/	PERFECTWORD	STRESS-TO-WEIGHT
a.	{fri((gó:)ri)}	1!	
b.	{(((frí:)gori)}	1!	
c.	{(((frígo)ri)}		1!
d.	{(((frí)go)}		1!
e. ☞	{(((frí:)go)}		
	base: {frigo((rífe)ro)}		

Candidate (a) violates PERFECTWORD with the initial syllable which is not parsed within the only foot. Candidate (b) violates PERFECTWORD for the size of the foot. The stressed vowel is lengthened and thus bimoraic and the weak part of the foot contains two light syllables, i.e., another two moras. A layered foot contains three moras, two in the internal foot and another one as the weak part of the superordinate foot. Candidate (c) is thus a perfect foot in a perfect word. Had it not been for STRESS-TO-WEIGHT, which militates against stressed light syllables. The constraint is also violated by the bisyllabic candidate (d), which does not have a lengthened vowel in the stressed syllable, unlike candidate (e), which satisfies both constraints and thus wins.

One core property that Thornton mentions is that truncated forms usually end in a vowel. Of course, that does not hold for any kind of acronymic formation. Especially in types 2 and 3 word-final codas seem to be quite frequent. However, coda avoidance is a typical TETU effect (the emergence of the unmarked – McCarthy & Prince 1994, Becker & Potts 2011). Italian doesn't allow word-final codas in the core lexicon, only in loanwords. This state of affairs can be analyzed with a stratified lexicon with loanword-specific indexed faithfulness constraints (Itô & Mester 1999). Since clippings are not loanwords the highly ranked faithfulness for loans such as *club* 'club' doesn't apply to them and *CODA can have its way. In both the native lexicon and in clippings a constraint against disruption of input strings, CONTIGUITY (McCarthy & Prince 1995), warrants survival of string-internal codas, as discussed further in the next paragraph. Alternatively, the *CODA effect in clippings and the core lexicon could be a side effect of the PERFECTWORD. The perfect word is an HL layered trochee and in Italian, coda consonants potentially make syllables heavy, resulting in HH structures if a word is cut down to two maximal syllables, e.g., *?frigor*.

Truncates are always contiguous strings of base material. One might think that a efficient way of forming a shorter version of an Italian word that would otherwise be quite long, such as *partecipazione* 'participation', could be realizing just the initial syllable and the end of the word, i.e., **parne* or **parzione*. These just aren't attested and sound odd, while *partecipa* is ok. Words like *frigorifero* are truncated to *frigo*, never to phonotactically well-formed **frifero* or **friro*, recombining the left and right edge of the base. Though occasional syncope is observed, as in *benza* from *benzina* 'gas' (Montermini 2002:314). Accordingly, a constraint against the discontiguous realization of base material, BT-CONTIGUITY, has to be undominated (see McCarthy & Prince 1995 for the original definition of CONTIGUITY constraints, Piñeros 2002 in the context of Spanish truncations).

(27)   Contiguity

	/frigorifero/	BT-CONTIGUITY	PERFECT WORD	ANCHOR-L	BT-MAX	BT-DEP
a.	{(((frí)ro)}	1!			6	
b. ☞	{(((frí)go)}				6	
	base: {frigo((rífe)ro)}					

Apericena shows yet another factor that plays a role. The resultant prefixoidal clipping *aperi-* (from *aperitivo* 'aperitif') is bigger than the perfect word. As discussed in the previous subsection, it is the

potential perfect word at the end of the base form that has to be left unrealized. The base *aperitivo* has stress on the penult and the truncated part, *-((tí:)vo)*, thus corresponds to a perfect word.

While above I showed how restrictions on truncations emerge as effects of generally assumed constraints, it seems to be problematic to cast any restriction that defines the part to be deleted into constraints. Anti-faithfulness constraints (Horwood 2000, Alderete 2001) to material in prominent prosodic positions could account for such patterns, such as BT-UNMAX-MAINSTRESSFOOT 'do not realize any segment that is in the main stress foot in the base'.

Piñeros (2004) proposes special faithfulness to the weak, i.e., the segmental material that is not in the head foot of the base for a similar pattern in Spanish, which is adopted by Trommer & Zimmermann (2012) who analyze the same Spanish data with Coloured Containment. Both versions of the solution, Piñeros as well as Trommer & Zimmermann's, crucially have to refer to "every segment in the non-head". This non-head can only be understood as a negatively defined set, i.e., everything that is outside the main stress foot. Positional constraints usually refer to actual constituents or classes, such as McCarthy & Prince's (1995) FAITH-STEM and FAITH-AFFIX or Lombardi's (1999) IDENTONSET.

Last but not least one could resort to Direct OT (Golston 1997). In a Direct OT account, the truncation morpheme for this kind of clipping is represented in the lexicon as a violation of BT-MAX-MAINSTRESSFOOT.

Postponing this choice to future research, I include the size requirement on the deleted section of the base in the following tableau as a short-hand constraint demanding the truncated part to be a perfect word in the base.

(28)   TRNCPRFCTWRD: 'Truncate the perfect word: Assign a violation mark for every segment of the main stress foot in the base that is realized in the truncated form and for every unrealized segment that is not in the main stress foot in the base.'

The analysis is illustrated in (29). In candidate (a) the first two syllables of the truncated base member are mapped to the surface, which would result in a nice layered trochee. Candidate (b) incurs a violation of PERFECTWORD for its problem with weight of the stressed syllable. As discussed earlier, it either doesn't conform to Stress-to-Weight or it has too many moras for a perfect word and is thus inferior to a bisyllabic shortened word. However, candidate (a) has deleted a portion of the base that is outside the main stress foot of the base which violates TRNCPRFCTWRD.

(29)   Optimal omission

	/aperitivo + cena/	TRNCPRFCTWRD	PERFECT WORD	ANCHOR-L	BT-MAX
a.	{aperi((tí:)vo)} cena	2!			6
b. ☞	{aperi((tí:)vo)} cena		2		4
	base: {aperi((tí:)vo)}				

Here we see another reason why *frigori* is not an acceptable form for 'fridge'. As noted above, the truncated part of *frigo* also corresponds to a perfect word in the base form: *(((rife)ro)*. The truncated part of **frigori*, i.e., *fe)ro)*, doesn't. The same holds as for the formation of trisyllabic *aperi-* in *apericena* from *aperitivo* 'aperitif'+ *cena* 'dinner'.

While prefixoid, acronymic and autonomous truncated forms are never stress-anchored, and stress-anchoring only occurs as negative circumscription, as just discussed, positive stress-anchoring does occur in blends. The surviving part of the second base in blends such as *kiwana* (from *kiwi + banana*) coincides with the main stress foot, or more precisely the rhyme of the stressed syllable and all material from there to the end of the word. In Italian, as we have seen, this is a layered trochee which is the perfect word. Once this potential perfect word is united with the remaining material from the first base perfection is spoiled. However, it is only minimally spoiled. The part of the first base that is realized consists of the first syllable

plus the first syllable constituent that follows. Note that in *zebrallo* the complex onset of the second syllable, *br,* survives, while in *leopone* the nucleus of the second (onsetless) syllable of *leopardo, o,* survives.[3]

This contraction of compounds affects both members to some degree. For the analysis I propose now, the observation is crucial that even in compounds, there doesn't seem to be any reliable secondary stress. Unstressed syllables are the main source of imperfection for prosodic words. If there are too many of them this violates PARSE-σ ('syllables should be footed'). We can also measure violation of PERFECTWORD by counting the number of syllables between the foot and the word edge. In this type of truncation it is the whole construction that is assessed against PERFECTWORD, while in the prefixoidal construction it was only the shortened prefixed word that was under scrutiny. In ordinary words excess syllables are not a problem, since MAX-IO is ranked high. In blends they are and it is resolved by deletion. A further ingredient is the anchoring of the two compound members with their respective word edge in the blend. The left edge of the blend has to correspond with the left edge of the left compound member and the right edge of the blend with everything from the stressed vowel to the right edge of the right compound member. This is taken care of by Alber's Anchoring constraints for hypocoristics.

(30)   Blending of *zebrallo* 'zorse'

/dzebra + kavállo/		ANCHOR-L	PERFECT WORD	BT-MAX
a.	{dzebraka((vál)lo)}		3!	
b.	{dzebra((vál)lo)}		2!	2
c. ☞	{dze((brál)lo)}		1	4
d.	{dze((vál)lo)}		1	5!
e.	{bra((vál)lo)}	1!	1	4
f.	{((vál)lo)}	1!		7
base: {dzebraka((vál)lo)}				

Candidate (a) has three unfooted syllables in the prosodic word, yielding a violation of PERFECTWORD for each. Candidate (b) has only one unfooted syllable less than (a) and still one more than the winning candidate (c). Candidates (e) and (f) have not preserved the left edge of the leftmost base word and are thus suboptimal for their violation of ANCHORL. The difference between candidate (c) and (d) lies in the preservation of the onset of the stressed syllable in the rightmost base word in (d) versus its replacement by the second onset of the first base word. This is decided here by BT-MAX, since the complex onset "rescues" one more consonant from the bases. I regard this as coincidental and further research is needed to figure out why such constructions systematically replace the onset of the stressed syllable with material from the other base word.

These blends are the closest match to the constructions Trommer & Zimmermann analyse with Coloured Containment. A core ingredient of their analysis is the assumption that the initial syllable(s) of the first member substitute the initial syllables of the second. Thus when *ladrón* 'thief' and *makdónals* 'McDonald's' are fused to *ladrónals* 'McDonald's as a rip-off', *la* replaces *mak* and *drón* replaces *dón*. The Italian pattern is not amenable to this analysis since the number of syllables preceding the stress does not necessarily stay stable. In *le.o.pó.ne* from *le.o.pár.do* and *le.ó.ne* we see the mismatch. In *leone* the stressed syllable is preceded by one unstressed syllable, while in the blend there are two unstressed syllables from the base of *leopardo* preceding the stressed syllable.

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[3] The alert reader might have noticed that in *tigone* 'tiger-lion' the *r* of *tigre* is missing. My hunch is that resultant *tigrone* with realization of the complete complex onset of the second syllable of *tigre* is lexically blocked by the homophonous augmentative form with the suffix *-one*. Similarly, truncation of *leopardo* to *le-* rather than attested *leop-* in *leopone* would result in *le-one*, which is homophonous with *leone* 'lion', second member of the construction and would render the blend unrecognizable. *Lepone* would be an alternate, but is excluded. by its violation of CONTIGUITY.

In certain mixed forms of acronym and blend, exactly the first syllable of each member survives, as in *Polfer* from *Polizia ferroviaria* 'railway police'. In this case we also see a violation of the ban against form-final codas. Here Alber's (2010) COINCIDE-σ1 plays a pivotal role. This constraint outranks *CODA.

(31)   The importance of initial position

	/polizia ferroviaria/	COINCIDE-σ1	PERFECT WORD	*CODA	BT-MAX
a.	{poli((zári)a)}	7!	1		7
b. ☞	{((pól)fer)}			2	11
c.	{((pól)fe)}	1!		1	12
	base: {poli((zí)a)} {ferrovi((ári)a)}				

In (29), candidate (a) blends the first two syllables of the first base word with the main stress foot of the second and violates COINCIDE-σ1 with all segments that are not in the initial syllable (or its maximal extension) in one of the two base words. The orthographic double *r* in *ferrovia* is a geminate, which is in the coda of the first syllable of the base word and the onset of the second. Since this coda is missing in candidate (c), it violates COINCIDE-σ1 too.

Note that the first part, *pol*, does not exactly coincide with the first syllable in the base, but with the first maximally possible syllable. Realization of the consonant is an effect of quantity-sensitivity. As mentioned earlier, stressed syllables, at least in penultimate and final position, have to be heavy. Alternative lengthening of the vowel in *po* to provide weight to the stressed syllable would have resulted in unnecessary unfaithfulness. With the coda consonant of the first syllable providing weight and the coda consonant of the second as not adding weight, as discussed above we encounter a perfect word again: {((pó$^{\mu}$l$^{\mu}$)fe$^{\mu}$r)}.

The exclusive survival of material in the first syllable is characteristic for acronymic blends. As we have seen, in others it is defining that the surviving part has the size of a perfect word, in others it is more important to delete the main stress foot aka a perfect word, while in blends it is important to reproduce the rightmost perfect word. We are dealing with a range of patterns here which cannot be accommodated with one ranking. One way of dealing with this is constraint indexation (Itô & Mester 1999, Pater 2006). I spare the reader the details of this since the purpose of this section was to show the centrality of the perfect word and the constraints that promote perfection in the formal analysis of Italian truncated words.

4 Conclusions

Thornton (1996) proposed that there is a minimal word requirement of a bisyllabic or trisyllabic trochee that shapes the size of truncated common nouns in Italian. In this paper the notion of minimal word was replaced with Itô & Mester's (2015) concept of the perfect word, which is more adequate since it doesn't only pose a lower size limit but also an upper limit on truncated forms. The perfect word simply is perfect alignment of the edges of a prosodic word with the edges of the optimal foot. Languages display different preferences when it comes to foot type, and we have seen here that the Italian perfect word, containing one right-branching layered moraic trochee of three moras preferably distributed over two syllables, is very similar to the Danish perfect word, which is a trimoraic HL trochee.

As the observant reader might have noticed by looking at the English glosses while reading the paper, English clippings look markedly different from their Italian counterparts, consider e.g., *bike*, *fridge*, *zorse* or *shrink* (see Alber & Arndt-Lappe for more examples and discussion). While Italian truncations tend to result in bisyllabic forms, English truncated forms tend to be one heavy syllable. This might be partially attributed to the marked status of codas in Italian and their high popularity in the English lexicon. However, if truncation in English also results in perfect words, it also shows that the perfect word of English is different from that of Italian. English might only resort to recursion when absolutely necessary (also, the

English recursive trochee is left-branching in the upper layer, i.e., *(po(tato))*, rather than right-branching, see Martínez-Paricio 2013).

The fact that perfection is measured by different standards in different languages doesn't mean that the constraint PERFECTWORD, which matches prosodic structures of two different layers, is subject to language-specific parameterization, since the foot type and structure emerge through the interaction of other independently motivated markedness constraints.

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Appendix

Type 2: combinations of letters that can be read as if they were words:
(most data from http://www.nomix.it/acronimi.php)

ACI	Automobil Club d'Italia
AGIP	Azienda Generale Italiana Petroli
AIDO	Associazione Italiana Donatori di Organi
AIPIN	Associazione Italiana per l'Ingegneria Naturalistica
ANAS	Azienda Nazionale Autonoma delle Strade
ANSA	Agenzia Nazionale Stampa Associata
ARCI	Associazione Ricreativa Culturale Italiana
ARPA	Agenzia Regionale per la Protezione Ambientale
AVIS	Associazione Volontari Italiani del Sangue
BES	Bisogni Educativi Speciali
CAP	Codice di Avviamento Postale
CED	Centro Elaborazione Dati
CONI	Comitato Olimpico Nazionale Italiano
CUD	Certificazione Unica dei redditi di lavoro Dipendente
CRO	Codice Riferimento Operazione
DAG	Disturbo d'Ansia Generalizzato
DAT	Disposizioni Anticipate di Trattamento
DIA	Direzione Investigativa Antimafia
DOC	Denominazione di Origine Controllata
ENAC	Ente Nazionale per l'Aviazione Civile
ENPA	Ente Nazionale per la Protezione Animali
EVO	Extra Vergine di Oliva
FIAT	Fabbrica Italiana Automobili Torino
FILA	Fabbrica Italiana Lapis ed Affini
INAIL	Istituto Nazionale per l'Assicurazione contro gli Infortuni sul Lavoro
IRAP	Imposta Regionale sulle Attività Produttive
IRPEF	Imposta sul Reddito delle Persone Fisiche
ISA	Indici Sintetici di Affidabilità
ISEF	Istituto Superiore di Educazione Fisica
ISTAT	Istituto nazionale di Statistica
LAV	Lega Anti Vivisezione
LEA	Livelli Essenziali di Assistenza
LILT	Lega Italiana per la Lotta contro i Tumori
MES	Meccanismo Europeo di Stabilità

NAS	Nucleo Antisofisticazioni (organo dell'Arma dei Carabinieri)
ONU	Organizzazione delle Nazioni Unite
OPA	Offerta Pubblica di Acquisto
PIL	Prodotto Interno Lordo
PRA	Pubblico Registro Automobilistico
RAI	Radio Audizione Italiana
RAL	Retribuzione Annuale Lorda
RID	Rapporto Interbancario Diretto
RIS	Raggruppamento Investigazioni Scientifiche
SAS	Società in Accomandita Semplice
SCIA	Segnalazione Certificata di Inizio Attività
SIAE	Società Italiana Autori ed Editori
SNAI	Sindacato Nazionale Agenzie Ippiche
SNAM	Società Nazionale Metanodotti
SPA	Società Per Azioni
TAC	Tomografia Assiale Computerizzata
TAEG	Tasso Annuo Effettivo Globale
TAV	Treno ad Alta Velocità

MORA SENSITIVITY IN KAGOSHIMA JAPANESE: EVIDENCE FROM *NO* CONTRACTION[*]

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Japanese has a productive process of *no* contraction by which *no* is contracted to the coda nasal *-n* in several contexts in colloquial speech: e.g. *bakemono → bakemon* 'monster'. This paper discusses how this morphological process is constrained by phonological structure in Kagoshima Japanese, a southern variety of Japanese whose prosodic structure is supposed to be based entirely on the syllable, not the mora. It is concerned specifically with the contraction of the genitive particle *no* in such words as *haruo-no ie* (→ *haruo-n ie*) 'Haruo's house'. Looking at how three native speakers of Kagoshima Japanese produce the genitive particle in various phrases, the paper shows that the morphological process is blocked if it would yield a superheavy syllable in the output. It also demonstrates that the process often triggers shortening of the preceding long vowel. Furthermore, the same process triggers resyllabification of three-mora strings that would otherwise constitute trimoraic syllables. All these phenomena can be accounted for by the putatively universal constraint banning superheavy syllables. This generalization not only reinforces the view that superheavy syllables are avoided in Japanese, but also demonstrates that the notion of the mora is indispensable for the description of Kagoshima Japanese, which was previously thought to be a quantity-insensitive language. **Keywords:** mora, *no* contraction, Kagoshima Japanese, superheavy syllable, quantity sensitivity

1 *No* contraction in Japanese

The contraction of *no* to the coda nasal *-n* is a productive morphological process that characterizes casual, colloquial speech as opposed to careful, formal speech in Japanese. In Tokyo Japanese, for example, it occurs in various contexts including (a) the final position within nouns, (b) the genitive (GEN) particle *no*, and (c) the conjunctive particle *node*. These are exemplified in (1).

(1) *No* contraction in Tokyo Japanese
　　a. bakemono → bakemon 'monster'
　　b. boku-no uti → bokunti 'I-GEN-house; my house'
　　c. iku-node → ikunde 'go-because; because (I) go'

This contraction process occurs in a particularly productive fashion in Kagoshima Japanese (henceforth 'KJ'), a dialect spoken in the south of Japan. Thus, it occurs rather freely at the end of some specific morphemes such as *sono* 'garden' used in proper nouns and *mono* 'thing' in compound nouns. It also occurs very productively in the genitive particle *no*. These are illustrated in as in (2a) and (2b), respectively.[1] The last example in (2a) also involves a change of *ri* to *i*, which is another productive process characteristic of casual speech in the dialect: other examples include *tonari → tonai* 'next-door neighbor' and *kemuri → kemui* 'smoke' discussed in (4) and (5) below.

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[1] The coda nasal also results when a word-final vowel is deleted in other phonological contexts in colloquial speech: e.g. *inu → in* 'dog', *kodomo → kodon* 'child', *yasumi → yasun* 'a day off, holiday'.

(2) *No* contraction in casual speech in KJ
- a. kubo-zono → kubozon 'Kubozono (family name)'
  mae-zono → maezon 'Maezono (family name)'
  tabe-mono → tabemon 'food'
  tuke-mono → tukemon 'pickles'
  wasure-mono → wasuremon 'lost article'
  kazari-mono → kazaimon 'decoration'
- b. haruo-no kasa → haruo-n kasa 'Haruo's umbrella'
  asita-no sinbun → asita-n sinbun 'tomorrow's newspaper'
  tonari-no in → tonari-n in 'next-door neighbor's dog'
  neko-no esa → neko-n esa 'cats' food; food for cats'
  ie-no kagi → ie-n kagi 'house's key; key to the house'

While (2a) occurs in word-final position, (2b) occurs in phrase-final position before another phrase. This paper is concerned with *no* contraction in this latter context and examines the phonological contexts where the process is blocked.

Before we explore the phonological contexts, it is probably worth mentioning other genitive particles in KJ. Modern KJ has three genitive particles: *ga*, *no*, and *n*. *Ga* is the most traditional genitive particle in the dialect, reflecting the fact that it used to be the genitive particle in Japanese in general before it was replaced by the modern genitive form *no*.[2] This old feature survives in KJ, where male speakers still use it as a genitive marker very productively. However, the genitive *ga* can be used only as a possessive case marker: the noun to which *ga* is attached must possess the following noun. For this reason, it is impossible to say **asita-ga sinbun* 'tomorrow's newspaper', **neko-ga esa* 'cats' food; food for cats', and **ie-ga kagi* 'house's key; key to the house'. These ungrammatical phrases become grammatical if *ga* is replaced with *no* or its contracted form *n*, as shown in (2b) above.

No, on the other hand, is a marker used rather generally in KJ without being subject to the semantic constraint that governs *ga*: it can be used as a possessive case marker as well as a non-possessive case marker. It may be a form borrowed from Tokyo Japanese as many words have entered the dialect from the standard variety. This new particle is used rather freely in KJ by female speakers and in formal contexts in particular. In casual, colloquial speech, it is usually contracted to *n*, as is often the case in Japanese in general. In KJ, this contraction occurs characteristically in male speech as opposed to female speech since *n* forms imply being less polite than *no* forms.

Given this observation, it could be expected that *no* can turn into *n* in any phrase. This is not the case, however, as demonstrated by the following phrases. In the next section, we will consider why *no* contraction is allowed in (2b), but not in (3).

(3) a. atai-no kasa → *?atai-n kasa 'my (colloquial) umbrella'
   b. tonai-no in → *tonai-n in 'next-door neighbor's dog'
   c. oi-no kasa → *oi-n kasa 'my (colloquial) umbrella'
   d. kemui-no nioi → *kemui-n nioi 'smoke-GEN smell; smell of the smoke, smoky smell'

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[2] In Tokyo Japanese, the genitive *ga* survives in some archaic phrases such as *wa-ga ya* 'my home' and in place names like *oni-ga sima* 'devil's island' or *ziyuu-ga oka* 'liberty hill'.

2 Constraints on *No* Contraction in KJ

2.1 Blocking Effect

With a view to illuminating the constraints on *no* contraction, we looked at three native male speakers of KJ aged between sixty and eighty-two in 2016-2017; we did not examine female speakers or young male speakers since they do not use the morphological rule productively.

We presented a list of some 80 *no* phrases to the speakers, including those in (2b) and (3). They were asked to read each phrase and to judge whether *no* can change into *n*. This analysis has revealed that *no* contraction is disfavored or blocked if it would yield superheavy syllables, or syllables consisting of three moras. This can be seen most clearly in the pairs of phrases in (4)-(10): the phrases in (a) permit the contraction, while those in (b) do not.[3]

(4) a. tonari-no in → tonari-n in 'next-door neighbor's dog'
   b. tonai-no in → *tonai-n in 'next-door neighbor's dog (colloquial)'

(5) a. kemuri-no nioi → kemuri-n nioi 'smoke-GEN smell; smoky smell'
   b. kemui-no nioi → *kemui-n nioi 'smoke-GEN smell; smoky smell (colloquial)'

(6) a. dare-no kasa → dare-n kasa 'whose umbrella'
   b. dai-no kasa → *?dai-n kasa 'whose umbrella (colloquial)'

(7) a. watasi-no kasa → watasi-n kasa 'my umbrella'
   b. atai-no kasa → *?atai-n kasa 'my umbrella (colloquial)'

(8) a. boku-no kasa → boku-n kasa 'my umbrella'
   b. oi-no kasa → *oi-n kasa 'my umbrella (colloquial)'

(9) a. amerika-no miyage → amerika-n miyage 'America's souvenir; souvenir from America'
   b. hawai-no miyage → *hawai-n miyage 'Hawaii's souvenir; souvenir from Hawaii'

(10) a. tomodati-no kasa → tomodati-n kasa '(my) friend's umbrella'
    b. tomodat-no kasa → *tomodat-n kasa '(my) friend's umbrella (colloquial)'[4]

The two phrases in (a) and (b) in the above examples crucially differ from each other with respect to the structure of the final syllable in the pre-*no* noun. Namely, the relevant syllables in (a) are light (monomoraic), while those in (b) are heavy (bimoraic), involving either a diphthong or a coda consonant (see Kubozono 2004 and 2015a for evidence that KJ permits only three vowel sequences as diphthongs, i.e. /ai/, /oi/ and /ui/). More generally, *no* contraction is blocked when *no* is immediately preceded by a heavy syllable.[5] This is the descriptive generalization of the facts in (4)-(10), which raises a question of why the process is blocked in this particular context.

Moreover, apart from (9), the pre-*no* nouns in (b) are more casual forms than those in (a): *tonai*, *kemui*, *dai*, *atai*, *oi* and *tomodat* are casual forms as against *tonari*, *kemuri*, *dare*, *watasi*, *boku* and

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[3] KJ has a rather productive phonological rule turning *ri* into *i* in colloquial speech: e.g *tonari* → *tonai* 'next-door neighbor', *kemuri* → *kemui* 'smoke', *atari* → *atai* 'neighborhood', *tori* → *toi* 'bird, chicken'.
[4] The noun-final *-t* in *tomodat-no* in (10b) is realized as a coda obstruent, not as a coda nasal, in KJ.
[5] Not surprisingly, *no* contraction readily occurs if the preceding noun ends in a non-diphthongal vowel sequence: e.g. /ao/ *kao-no* → *kaon* 'face's', /ae/ *kigae-no* → *kigaen* 'spare clothes's', /oe/ *aloe-no* → *aloen* 'aloe's', /eo/ *bideo-no* → *bideon* 'video's'.

tomodati, respectively. Since *no* contraction has the effect of making the phrases sound more casual, this raises a second question of why the process is blocked in the phrases involving casual expressions.

These two questions can be answered in a principled way if one pays attention to the change that *no* contraction exerts on the syllable structure. Phonologically, *no* contraction is a process of depriving the particle of its syllabicity and attaching the resultant non-syllabic mora *n* to its preceding syllable; in other words, it is a coda-generating process. Because of this, the contraction process has the effect of creating a heavy syllable out of two light syllables as well as a superheavy syllable out of a heavy syllable plus a light one. These two cases are illustrated in (11a) and (11b), respectively.

(11) a. light → heavy
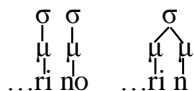
```
       σ σ           σ
       | |          /|
       μ μ         μ μ
       | |         | |
      …ri no      …ri n
```
   b. heavy → superheavy
```
       σ  σ           *σ
      /|  |          /|\
     μ μ  μ         μ μ μ
     | |  |         | | |
    …na i no       …na i n
```
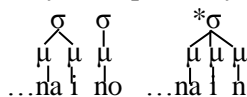
In sum, the blocking effect in (4b)-(10b) indicates that *no* contraction is blocked in contexts where it would yield a superheavy syllable such as /ain/, /oin/, /uin/, and /atn/.[6] This clearly shows that the putatively universal constraint banning superheavy syllables is at play in the prosodic system of KJ, too.[7]

2.2 Vowel Shortening in Pre-no Nouns

In addition to the blocking effect discussed above, our analysis has also shown that long vowels are often shortened as *no* is contracted to *n*. This is exemplified in (12).

(12) a. taroo-no kasa → taro-n kasa 'Taro's umbrella'
    b. kyoo-no tenki → kyo-n tenki 'today's weather'
    c. tookyoo-no miyage → tookyo-n miyage 'Tokyo's souvenir; souvenir from Tokyo'
    d. ataigee-no in → ataige-n in 'my house's dog; dog my house keeps'
    e. sensee-no kasa → sense-n kasa '(the) teacher's umbrella'

Many of these phrases permit a variant pronunciation with the original long vowel before the moraic nasal, e.g. /sensee-n kasa/ for (12e), as we will consider shortly. What is important here is the fact that the input forms with *no* do not permit variant patterns with a short vowel. This is shown in (13): /taro-no kasa/ and /kyo-no tenki/, for example, are not legal forms for (12a) and (12b), respectively.

(13) a. taroo-no kasa → *taro-no kasa 'Taro's umbrella'
    b. kyoo-no tenki → *kyo-no tenki 'today's weather'
    c. tookyoo-no miyage → *tookyo-no miyage 'Tokyo's souvenir; souvenir from Tokyo'
    d. ataigee-no in → *ataige-no in 'my house's dog; dog my house keeps'
    e. sensee-no kasa → *sense-no kasa '(the) teacher's umbrella'

---

[6] /atn/ in *tomodatn* may be ill-formed for a phonotactic reason, too, since it violates the sonority sequencing principle.
[7] See Kubozono (1995, 1999, 2015a, 2015b, 2015c) for evidence for this constraint in Japanese and Ito and Mester (2015) for the controversy over superheavy syllables in the language. It is known to that trimoraic syllables are disfavored in a wide range of languages including Latin (Martinet 1955), English and other Germanic languages (Árnason 1980), Hausa (Hayes 1986), Koya and Fula (Sherer 1994), and Pali (Zec 1995), to mention just a few (see Hayes 1995: 303 for more languages).

This means that vowel shortening illustrated in (12) is triggered by the morphological process of *no* contraction. In prosodic terms, the vowel shortening in question involves the change shown in (14), where the change in (12b) is used for illustration.

(14)　　　σ　σ　　→　　σ　　　σ

　　　　　μ μ μ　　　　μ μ μ　　μ μ μ

　　　　kyoo no　　　kyon　*kyoo n
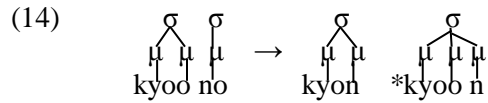
This process, too, can be attributed to the syllable weight of the output. Namely, *no* contraction would have yielded superheavy syllables consisting of a long vowel and a moraic nasal, which have been remedied into heavy syllables by the shortening of the long vowel.

2.3 Resyllabification

So far, we have seen two phenomena that can be attributed to a ban on superheavy syllables. On the one hand, *no* contraction is blocked after diphthongal vowel sequences as in (3), which would otherwise yield trimoraic syllables with a moraic nasal, i.e. */ViVjN/. On the other hand, *no* contraction takes place before a noun with a long vowel, but with the concomitant shortening of the long vowel, as in (12). These two phenomena can be attributed to a very general constraint banning trimoraic syllables.

Interestingly, KJ shows one more phenomenon that can be accounted for by the same constraint. This concerns resyllabification of trimoraic sequences. As suggested above, long vowels (and occasionally diphthongs) can sometimes surface after *no* contraction takes place. This pronunciation is only marginally acceptable to some native speakers. Some examples are given in (15).

(15) a. kyoo-no tenki → kyoo-n tenki 'today's weather'
　　b. tookyoo-no miyage → tookyoo-n miyage 'Tokyo's souvenir; souvenir from Tokyo'
　　c. ataigee-no in → ataigee-n in 'my house's dog; the dog my house keeps'
　　d. oigee-no in → oigee-n in 'my house's dog; the dog my house keeps (colloquial)'
　　e. waigee-no in → waigee-n in 'your house's dog; the dog your house keeps'
　　f. sensee-no kasa → sensee-n kasa '(the) teacher's umbrella'
　　g. atai-no kasa → atai-n kasa 'my umbrella'

This might be taken as suggesting that superheavy syllables are permitted in this context in KJ. A careful examination of word accent reveals, however, that what appears to form trimoraic syllables is actually made up of two syllables, i.e. a light syllable followed by a heavy syllable. To understand this, we need to know how word accent is calculated in KJ.

KJ has a two-pattern word accent system, a system that permits two accent patterns or types. All words thus belong to either of these accent types, which are conventionally called Type A and Type B (Hirayama 1951). KJ is also known as a 'syllable-counting, syllable dialect' (Kubozono 2004), which counts the number of syllables in accent assignment and assigns a high (H) tone on a certain *syllable*, not on a certain *mora*. Specifically, words in Type A exhibit an H tone on the penultimate syllable, while their Type B counterparts are H-toned on the final syllable. The only exception to this is monosyllabic Type A words, which involve a pitch fall within the sole syllable. These accent patterns are realized within the domain of *bunsetsu* (a minimal syntactic phrase consisting of a content word with one or more optional grammatical particles), rather than the word domain. This is illustrated in (16), where capital letters denote H-toned syllables and dots /./ syllable boundaries.[8]

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[8] KJ is subject to a left-dominant compound accent rule whereby it preserves the accent pattern (Type A or B) of the initial member in compounds (Hirayama 1951, Kubozono 2004, 2018).

(16) a. Type A

        na.tu.ya.SU.mi 'summer holiday'
        na.tu.ya.su.MI-no 'summer holiday-GEN'
        A.tai 'I'
        a.TAI-no 'I-GEN, my'
        a.TAI.gee 'my house'
        a.tai.GEE-no 'my house's'
        Oi 'I (colloquial)'
        OI.gee 'my house'
        oi.GEE-no 'my house's'

  b. Type B

        ha.ru.ya.su.MI 'spring holiday'
        ha.ru.ya.su.mi-NO 'spring holiday-GEN'
        sen.SEE 'teacher'
        too.KYOO 'Tokyo'
        too.kyoo-NO 'Tokyo's'
        KYOO 'today'
        WAI 'you (colloquial)'
        wai.GEE 'your house'

The penultimate syllables in (16a) and the final syllables in (16b) can be either bimoraic or monomoraic. This suggests that KJ has a quantity-insensitive pitch accent system, a system that is not sensitive to the weight distinctions of the syllable. Since KJ thus assigns H tones on a syllabic rather than moraic basis, it clearly shows how words are syllabified and, more specifically, where syllable boundaries are. This accent test reveals the following accent patterns and syllabifications for the three-mora sequences in the output forms in (15):[9] (17a) and (17b) show the patterns of Type A and Type B prenominal phrases, respectively.[10]

(17) a. Type A

       a.TA.in, *A.tain 'my'
       a.tai.GE.en, *a.TAI.geen 'my house's'
       oi.GE.en, *OI.geen 'my house's (colloquial)'

  b. Type B

       kyo.ON, *KYOON 'today's'
       too.kyo.ON, *too.KYOON 'Tokyo's'
       wai.ge.EN, *wai.GEEN 'your house's'
       sen.se.EN, *sen.SEEN '(the) teacher's'

As the examples above show, the trimoraic sequences split into two syllables in both accent types. For example, Type A phrases attract an H tone only on the antepenultimate mora of the trimoraic sequences: e.g. /ge/ in /ataigeen/. Type B phrases, in contrast, are H-toned on the final two moras in the trimoraic sequences: e.g. /on/ in /kyoon/. Both facts indicate that what appears to be a superheavy syllable actually consists of two syllables rather than one. This is illustrated in (18) with the last example in (17a).

(18)

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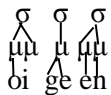
[9] These accent judgments are also collected from the three KJ consultants described above.

[10] /IN/ 'dog', /mi.ya.GE/ 'souvenir', and /ka.SA/ 'umbrella' are Type B words, while /TEN.ki/ 'weather' is a Type A word.

This phenomenon is interesting particularly because it involves a resyllabification of long vowels and diphthongs whereby they split into two syllables when they are followed by a coda nasal although they otherwise form one integral syllable as shown in (16). This is not an isolated phenomenon in the phonology of KJ, though, since the same reorganization of syllables is observed in loanwords (Kubozono 2015c). (19) gives some typical examples where what appears to form a superheavy syllable actually behaves as a sequence of two syllables, i.e. a light syllable followed by a heavy one.

(19) Resyllabification in loanwords
    a.   su.<u>PE.in</u> 'Spain'
    b.   de.<u>ZA.in</u> 'design'
    c.   ba.ren.<u>TA.in</u> 'Valentine'
    d.   ba.ren.<u>ta.IN</u>.dee 'St. Valentine's Day'
    e.   gen.<u>da.IK</u>.ko 'modern kid'
    f.   rin.<u>KA.an</u> 'Lincoln'

In sum, KJ relies on resyllabification as the last resort to avoid superheavy syllables. Trimoraic sequences that have escaped from the blocking of *no* contraction in section 2.1 and the application of vowel shortening in section 2.2 employ this third strategy to avoid being realized as superheavy syllables.

3 Comparison with Tokyo Japanese

In the preceding section, we have seen three phenomena pertaining to the contraction of genitive *no* in KJ: blocking of *no* contraction, vowel shortening accompanying *no* contraction, and resyllabification in contracted forms. At first glance, these phenomena might look independent of each other. Seen from the view point of syllable weight, however, it can be understood that they all conspire to avoid creating superheavy syllables. Blocking *no* contraction prevents superheavy syllables from being created; vowel shortening turns trimoraic sequences into bimoraic ones; and resyllabification reorganizes three-mora sequences at the surface into two syllables. Interestingly, these phenomena are not specific to KJ since previous studies show corresponding phenomena in the loanword phonology of Tokyo Japanese (Kubozono 1999, 2015b, 2015c).

      As is well known, Japanese often geminates stops and fricatives in the original coda position as it borrows words from foreign languages. This process of consonant gemination is blocked in certain phonological contexts, one of which concerns the length of the preceding vowel (see Kubozono et al. 2013 for other contexts and Ito et al. 2017 for an optimality-theoretic analysis of consonant gemination in Japanese loanwords). Thus, word-final coda stops in English readily geminate if they are preceded by a short (lax) vowel as in (20a), but not if they are preceded by a long (tense) vowel or diphthong, as in (20b).

(20) a. kap.pu 'cup'
        kat.to 'cut'
        buk.ku 'book'
   b. kaa.pu, *kaap.pu 'carp'
        kaa.to, *kaat.to 'cart'
        kai.to, *kait.to 'kite'
        bai.ku, *baik.ku '(motor) bike'

The blocking of gemination in (20b) can be accounted for as a result of avoiding superheavy syllables (Kubozono 1999, 2015b, 2015c). First of all, gemination adds one more mora to the preceding syllable, just like the *no* contraction process discussed in the preceding section. Given this, geminating a consonant after a short vowel means creating a heavy syllable consisting of a short vowel and the first half of a

geminate consonant. The same process, if applied after a long vowel or diphthong, yields trimoraic syllables consisting of a long vowel/diphthong followed by a coda consonant. The fact that gemination is blocked in this latter context indicates that consonant gemination in loanwords is subject to the trimoraic syllable ban: that is, gemination is blocked in the context where it would yield superheavy syllables. Thus, the blocking effect in (20b) is equivalent to the blocking of *no* contraction which we saw in (4)-(10) above.

Tokyo Japanese also shows a loanword phenomenon analogous to the vowel shortening we saw in KJ in (12) above. Loanwords often undergo vowel shortening before the moraic nasal. This change in vowel length, or 'pre-nasal vowel shortening' (Lovins 1975), occurs specifically in non-final position within the word, as illustrated in (21) (Kubozono 1995, 1999, 2015b).

(21) a. ein→ en
     tyenzi, *tyeinzi 'change', renzi, *reinzi 'range', sutendo gurasu, *suteindo gurasu 'stained glass'
     mentenansu, *meintenansu 'maintenance'
   b. aun → an
     fandeesyon, *faundeesyon 'foundation', merii-go-rando, *merii-goo-raundo 'merry-go-round'
   c. V:n → Vn
     konbiihu, *koonbiihu 'corned beef', gurin piisu, *guriin piisu 'green peas'

Analyzing this phenomenon in terms of syllable weight, Kubozono (1999) claimed that it is motivated by a pressure to avoid superheavy syllables: if vowel shortening had not occurred, the words in (21) would have yielded superheavy syllables consisting of a long vowel (or diphthong) and a moraic nasal. Pre-nasal vowel shortening in (21) is thus a phenomenon due to the restriction on syllable weight. In this sense, it is analogous to vowel shortening in KJ, which occurs concomitantly with *no* contraction to avoid creating a superheavy syllable.

Tokyo Japanese admits a certain number of apparent exceptions to (21), especially in word-final position and in sequences involving /ai/. This is exemplified in (22).

(22) a. ain
     rain 'line, Rhine', sain 'sign, signature', dezain 'design'
   b. ein
     pein 'pain', supein 'Spain', reinboo 'rainbow'
   c. oin
     koin 'coin', saaroin 'sirloin', pointo 'point'
   d. uin
     tuin 'twin', kuin 'queen', uindoo 'window'
   e. long vowel + n
     koon 'corn', roon 'loan', doroon 'drone', rinkaan 'Lincoln'

These words contain three-mora sequences most of which form superheavy syllables in the source language. This suggests that the same sequences might form superheavy syllables in the host language, too. However, this prediction is not borne out empirically (Kubozono 1999, 2015b, 2015c). There are several independent pieces of phonological evidence showing that the three-mora sequences in question actually function as a sequence of two syllables. Let us consider here the evidence from word accent.

Tokyo Japanese has a rule shifting an accent one mora to the left if the accent happens to fall on a non-head mora of a syllable although it is not always an obligatory rule. As this accent shift occurs within a syllable, it is blocked by a syllable boundary. This can be seen from the compound nouns in (23), where the relevant parts are underlined: those in (23a) permit accent shift, whereas those in (23b) block it

because of an intervening syllable boundary.[11] For the sake of simplicity, only the output forms are syllabified here.

(23) a. syoo<u>nai</u>'-gawa → syoo.<u>na'i</u>-ga.wa 'Shonai River'
         ama<u>zon</u>'-gawa → a.ma.<u>zo'n</u>-ga.wa 'Amazon River'
     b. si<u>nano</u>'-gawa → si.na.no'-ga.wa, *si.<u>na'.no</u>-ga.wa 'Shinano River'
         te<u>muzu</u>'-gawa → te.mu.zu'-ga.wa, *te.<u>mu'.zu</u>-ga.wa 'Thames River'

Using this compound accent test, we can examine whether the three-mora sequences in question in (22) form one integral syllable or not. This examination shows that accent shift readily occurs between the second and third moras in the relevant sequences, but not between the first and second moras. This suggests that the three-mora sequences in question function as a sequence of two syllables: one light syllable followed by a heavy syllable. Some examples are given in (24) (see Kubozono 1999, 2015c for more details).

(24) a. rain'-gawa → ra.i'n-ga.wa (~ra.in'-gawa), *ra'in-ga.wa 'Rhine River'
     b. supein'-kaze → su.pe.i'n-ka.ze (~su.pe.in'-ka.ze), *su.pe'in-ka.ze 'Spanish flu'
     c. koin'-syoo → ko.i'n-syoo (~ko.in'-syoo), *ko'in-syoo 'coin dealer'
     d. kuin'-bii → ku.i'n-bii (~ku.in'-bii), *ku'in-bii 'queen bee'
     e. rinkaan'-hai → rin.ka.a'n-hai (~rin.ka.an'-hai), *?rin.ka'an-hai 'Lincoln Cup'

The syllabification data in (24) are equivalent to those in (17) in KJ, where what appears to be a trimoraic syllable actually behaves like a sequence of two syllables.

In summary, loanwords in Tokyo Japanese exhibit three features which, as first glance, appear to be unrelated: blocking of consonant gemination (20b), pre-nasal vowel shortening (21), and resyllabification of three-mora sequences into two syllables (24). Seen from the perspective of syllable weight, all these can be generalized as phenomena conspiring to avoid creating superheavy syllables. They are completely analogous to the three phenomena we saw in KJ in the preceding section. This comparison is summarized in Table 1.

Table 1 Comparison of KJ with Tokyo Japanese

	KJ	Tokyo
Blocking of a mora-generating rule	Blocking of *no* contraction (4b-10b)	Blocking of consonant gemination (20b)
Vowel shortening	Pre-*n* vowel shortening (12)	'Pre-nasal vowel shortening' (21)
Resyllabification	Resyllabification of /VVN/ into /V.VN/ (17)	Resyllabification of /VVN/ into /V.VN/ (24)

4 Further Implications

In the foregoing sections we saw that *no* contraction in KJ exhibits three seemingly unrelated phenomena, all of which can be attributed to the constraint banning superheavy syllables. We also observed that Tokyo Japanese displays three analogous phenomena that can be accounted for in the same way. All these

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[11] Tokyo Japanese places a compound accent on the final syllable of the first member if the second member is one or two moras long (McCawley 1968, Kubozono 2008)

phenomena can best be understood as conspiring to avoid creating trimoraic syllables: they are standard cases of 'conspiracy' (Kisseberth 1970).

That the same constraint is at work in the prosodic systems of different dialects of the same language may not come as a surprise. Especially, the fact that Tokyo Japanese is subject to the constraint on superheavy syllables should not be very surprising since it is a quantity-sensitive system that is sensitive to the distinctions in syllable weight. In this system, it has been known that the weight distinctions play pivotal roles in many phonological and morphological processes. For example, word accent rules are sensitive to the number of moras, counting heavy syllables as equivalent to a sequence of two light syllables (Kubozono 2002, 2008). The weight distinctions play a role in the process of vowel coalescence, too, where, as shown in (25), the number of moras in the input tends to be preserved in the output by way of compensatory vowel lengthening.

(25) Vowel coalescence and compensatory lengthening in Tokyo Japanese
   a. tai.gai → tee.gee, *te.ge 'usually, approximately'
   b. su.goi → su.gee, *su.ge 'great, splendid'
   c. ka.e.ru → kee.ru, *ke.ru 'to go home'

On the other hand, accent rules of KJ are insensitive to the light/heavy distinction, as we saw in (16) above. Similarly, vowel coalescence is not usually accompanied by compensatory lengthening by which the weight of the syllables in the input is preserved in the output. What is invariant between the input and the output in KJ is the number of syllables, not the number of moras. This is shown in (26).

(26) Vowel coalescence in KJ
   a. tai.gai → te.ge, *tee.gee 'usually, approximately'
   b. sai.goo → se.go, *see.goo 'Saigo (family name)'
   c. hai → he, *hee 'ash'

In fact, one finds little or no evidence in the literature for the mora in the phonological system of KJ.[12] Seen in this context, it is quite interesting to find that the constraint on superheavy syllables is at play in KJ, too, which was previously thought to be a quantity-insensitive system: trimoraic syllables are disallowed in this system just as in the quantity-sensitive system of Tokyo Japanese. Since the notion of superheavy syllable hinges crucially on the notion of the mora, it follows that the notion of the mora as well as that of the syllable is indispensable for the description of KJ, which would otherwise look entirely quantity-insensitive. In sum, the phonological grammar of KJ must make reference to the mora despite what was previously thought: it is a quantity-sensitive language although its pitch accent system is essentially quantity-insensitive.[13]

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[12] The mora may play a role in the accentuation of some lexically idiosyncratic and archaic expressions such as /waz.zeE.ka/ 'outstanding, exceptional' (Type A) and /ta.no.kan.saA/ 'god in the rice field' (Type B) (Uwano 1992). The accentuation of these expressions can be accounted for historically since they are derived via phonological processes from /waz.za.E.ka/ and /ta.no.kan.sa.MA/, respectively, whose accentuation obeys the syllable-based rule of accent/tone assignment in the dialect.

[13] This generalization should be independent of the controversy over the syllable in Japanese (Kubozono 1999, Kawahara 2016 vs. Labrune 2012) so that it holds true even in a syllable-less analysis as proposed by Labrune (2012).

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Adjacent identical vowels: Vowel length or hiatus?*

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1 Introduction

Languages differ in their treatment of what we can informally call adjacent identical vowels. The term "adjacent identical vowels" is purposely vague, and meant to encompass both literal cases of this (arising through morpheme contact, for example), as well as long vowels where there may be only one bundle of features, linked to two moras. The surface form of two adjacent identical vowels across a morpheme boundary shows a language's resolution of what must be two originally separate, now adjacent, identical vowels. Such a sequence may result in a long vowel (e.g. Blackfoot; Elfner 2005), hiatus (e.g. Belep; McCracken 2012), or coalescence/deletion (e.g. Meithei; Chelliah 1997).

(1)   Examples of /V_i-V_i/ realizations[1]

Blackfoot	/ápɔkomi-iksi/	→	[á.pɔ.ko.miːk.si]	'horses with white neck markings'
Belep	/ju-u/	→	[ju.u]	'dig [detransitive]'
Meithei	/tʃá-hən-kʰi-í/	→	[tʃá.hən.kʰí]	'already caused to eat'

In some cases this resolution of vowels from different morphemes is the same as is found morpheme-internally. For example, Belep permits hiatus with all combinations of vowels, including identical vowels, and so the monomorphemic word [do.o] 'dirt' shows the same result as the resolution of two identical vowels across a morpheme boundary shown for the language in (1). On the other hand, while Blackfoot does have several processes to resolve hiatus, Taylor (1969) reports that in cases of intervocalic glide deletion, the resulting vowel sequence may either be said as a long vowel or may remain hetrosyllabic.

Morpheme-internally, it is more common for languages to realize adjacent identical vowels as long vowels, but we also find those in which the result is hetrosyllabic, resulting in hiatus. That is, a language can act like Quechua, which has contrastive vowel length and does not allow the configuration [$V_i.V_i$] (or indeed, hiatus more generally; Weber and Landerman 1985), or a language can act like Belep, which is argued not to have long vowels but permits the configuration [$V_i.V_i$] (and hiatus generally; McCracken 2012).

This paper looks at the case of two languages, Latin and Japanese, which allow both long vowels and hiatus with identical vowels, and proposes an analysis of the pattern in optimality theory (Prince and Smolensky 1993). Possible input and output structures are shown and discussed in §2. The contrastive syllabification of adjacent identical vowels in Latin and Japanese is shown and analyzed in §3, followed by the conclusion in §4.

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[1]Examples taken from sources cited in paragraph above. IPA transcriptions have been standardized.

2 Adjacent identical vowels

Presumably, a long vowel (e.g. [Vː]) or hiatus (e.g. [$V_i.V_i$]) can result from either a single set of vowel features linked to two moras (as is generally assumed in moraic theory; Hyman 1985, McCarthy & Prince 1986, Hayes 1989) or two separate sets of identical vowel features each linked to its own mora. These two possible sources are shown in (2).

(2) Possible underlying sources for [Vː] and [$V_i.V_i$]

     a. a single heavy vowel   b. two identical adjacent vowels

$$\begin{array}{ccc} \mu\mu & & \mu \quad\ \mu \\ \big\backslash\!\!\big/ & & \big| \quad\ \big| \\ \text{C} \quad \text{V} & & \text{C} \quad V_i \quad V_i \end{array}$$
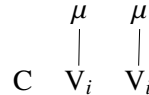
Either of the underlying representations in (2) can result in either a long vowel or hiatus. The two possible surface structures for (2a) are shown (3), where the one vowel's two moras may be linked the same syllable or to two different syllables. The two possible surface structures for (2b), assuming no deletion of segmental content, are shown in (4).

(3) Syllabifications of [Vː] and [$V_i.V_i$] assuming (2a)

     a. a long vowel   b. hiatus

$$\begin{array}{cc} \sigma & \sigma \qquad\ \sigma \\ \diagdown & \diagdown \qquad\ | \\ \mu\mu & \mu \quad\ \mu \\ \big\backslash\!\!\big/ & \diagdown \quad \diagup \\ \text{C} \quad \text{V} & \text{C} \qquad \text{V} \end{array}$$
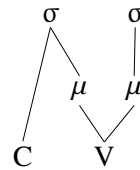
(4) Syllabifications of [Vː] and [$V_i.V_i$] assuming (2b)

     a. a long vowel   b. hiatus

$$\begin{array}{cc} \sigma & \sigma \qquad\ \sigma \\ \diagdown & \diagdown \qquad\ | \\ \mu \ \mu & \mu \quad\ \mu \\ | \ | & | \quad\ | \\ \text{C} \quad \text{VV} & \text{C} \quad V_i \quad V_i \end{array}$$
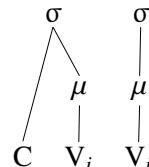
Both possible outcomes, regardless of the variation between (3) and (4), are marked, and so the syllable structure will depend on the relative ranking of the markedness constraints *LONGVOWEL ("no long vowels") and *HIATUS ("no adjacent hetrosyllabic vowels"). Or, of course, both types of markedness could be avoided by deleting a mora (violating MAX(μ), and presumably also MAXV in the case of (2b)).

While we would not typically expect two see variation within a language between the long vowel and hiatus realizations, languages can contrast the two when more than one morpheme is involved.[2] I now turn to two such cases.

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[2]In theory, a language could contrast vowel length and hiatus even monomorphemically, given the two possible underlying structures shown in (2), which is what Odden (1996) proposes occurs in Matumbi (also called Kimatuumbi) where the two forms are phonetically identical but the long vowel causes retraction of a following final high tone whereas the hiatus configuration does not.

3 Contrastive syllabic parsings

Both Latin and Japanese can contrast long vowels and identical-vowel hiatus. In the examples from Latin, the long vowel in (5a) is due to the genitive morpheme, and so the word is taken to be /me$_\mu$tu$_\mu$s - μ/ underlyingly. In the Japanese example, the long vowel in (6a) arises from a vowel that is heavy underlyingly (presumably /sa$_\mu$to$_{\mu\mu}$- ja$_\mu$/). The cases of hiatus with identical vowels in the (b) example of both languages, however, arise due to a morpheme boundary.

(5)   Latin[3]

     a.   me.tuːs   'fear (gen. sg.)'

     b.   mu.tu.us   'mutual'

(6)   Japanese[4]

     a.   sa.toː.ja   'sugar shop'

     b.   sa.to.o.ja   'foster parent'

       Because both languages have long vowels monomorphemically, we can deduce they prioritize the avoidance of hiatus, as shown in (7) for the example in (6a). (The input is shown with the assumption that long vowels have the form as in (2a), /V$_{\mu\mu}$/, as is the standard assumption under moraic theory, but the same result would obtain if the input had the form as in (2b), /sa$_\mu$to$_\mu$o$_\mu$- ja$_\mu$/.)

(7)   Japanese (and Latin) preference for long vowels over hiatus

	/sa$_\mu$to$_{\mu\mu}$- ja$_\mu$/	*HIATUS	*LONGVOWEL
☞ a.	sa.toː.ja		*
b.	sa.to.o.ja	*!	

       The long vowel example in Latin given above is the result of the genitive singular morpheme adding a mora. The ranking *HIATUS ≫ *LONGVOWEL will also result in /me$_\mu$tu$_\mu$s + μ/ being realized with a long vowel, as shown in (11). The syllabic structure of the long vowel candidate (a) and the hiatus candidate (b) are shown in (8) and (9).
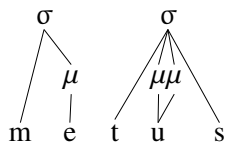
(8)   Candidate (a) in (11)   (9)   Candidate (b) in (11)
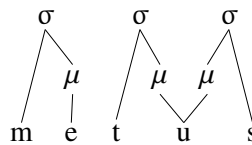
       Two additional candidates are shown which either do not realize the genitive morpheme (candidate (c)) or link the mora of the genitive morpheme to the wrong vowel (candidate (d)). These candidates are ruled out by REALIZEMORPHEME (Kurisu 2001) and alignment of the genitive to the right (in the schema of Generalized Alignment; McCarthy and Prince 1993). (Right-alignment of the morpheme is taken to be satisfied in the optimal form here.)

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[3] Thanks to Nick Kalivoda for the word in (a). The word in (b) is taken from Ito (2000:21).

[4] Examples from Vance (1987:14). Vance reports that there is disagreement whether the hiatus form in (b) is pronounced with an epenthetic glottal stop. Thank you to Jen Smith for drawing this pair to my attention.

(10) a. REALIZEMORPHEME: A morpheme in the input must be phonologically recoverable in the output

  b. ALIGN (GENITIVE, RT; PRWD, RT): The right edge of the genitive must be aligned to the right edge of prosodic word

(11) Latin preference for a long vowel realization of a morphemic /μ/

	/me$_\mu$tu$_\mu$s + μ/	RM	ALIGN-GEN-R	*HIATUS	*LONGVOWEL
☞ a.	me$_\mu$.tu$_{\mu\mu}$s				*
b.	me$_\mu$.tu$_\mu$.u$_\mu$s			*!	
c.	me$_\mu$.tu$_\mu$s	*!			
d.	me$_{\mu\mu}$.tu$_\mu$s		*!		*

Turning to the forms in which we find hiatus of adjacent identical vowels in Latin and Japanese, we see that they result from a second vowel being introduced by a segmental morpheme. In these cases, there are two separate sets of vowel features. The optimal candidate will have the structure with hiatus in (12).

(12) Hiatus: optimal candidate (a) in (16)
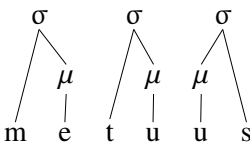
Both Latin and Japanese use this hiatus structure in despite both languages' preference for long vowels over hiatus. There are two possible long vowel candidates, one with deletion of one of the two vowels, and one in which both are parsed into the same syllable. These two alternative structures are shown in (13) and (14) for the word in (12).

(13) Long vowel: candidate (b) in (16)   (14) Long vowel: candidate (c) in (16)
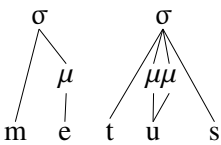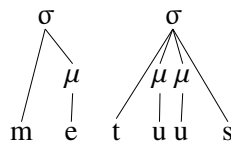
While the structure in (13) would come at the cost of deleting a vowel, violating MAX ("no deletion"), there is no cost in faithfulness to the parse of both vowels into the same syllable, as in (14). This latter parse, however, can be seen to fail to align the edges of the morphemes to the edge of a syllable. We can see the difference between the preferred long vowel parse in Latin and Japanese and the actual surface form involving hiatus as a high-ranking preference for the edges of morphemes to be aligned to the edges of syllables. The alignment constraint in (15) is formulated to force alignment of the left edge of every morpheme to the left edge of a syllable. Ito and Mester (2015) observe a stronger requirement for Sino Japanese compounds, where both the left and right edges of the roots in such cases must align to syllable edges.

(15) ALIGN (MORPHEME, LT; σ, LT): The left edge of every morpheme must align to the left edge of a syllable

Taking this alignment constraint to be higher ranked than *HIATUS, we can rule out both long vowel candidates in (16). The alignment constraint would also rule out a coalescence candidate, *[me.tuː$_{i,j}$s].

(16)   Latin (and Japanese) preference for morpheme-to-syllable alignment over avoidance of hiatus

		/me$_\mu$tu$_\mu$ + u$_\mu$s/	ALIGN-LEFT (MORPH, σ)	*HIATUS	*LONGVOWEL
☞	a.	me$_\mu$.tu$_\mu$.u$_\mu$s		*	
	b.	me$_\mu$.tu$_{\mu\mu}$s	*!		*
	c.	me$_\mu$.tu$_\mu$u$_\mu$s	*!		*

Thus we can understand the different parses of adjacent identical vowels in Latin and Japanese as arising from a preference for long vowels that is superseded by the preference for the alignment of morphemes to syllable edges.

4 Conclusion

Latin and Japanese present interesting cases of contrast in the syllabification of adjacent identical vowels. While the analysis presented here takes the underlying long vowel in the case of Japanese to orientate as a single vowel (bundle of features) with two moras, the ranking ALIGN-LEFT (MORPH, σ) ≫ *HIATUS ≫ *LONGVOWEL results in a long vowel in any case where there is not a morpheme to align to a syllable edge. This means that an input structure with two adjacent identical vowels, each with a single mora (corresponding to the structure of (2b)) would also map to a long vowel on the surface (either with both feature bundles in the nucleus or with them coalesced or one deleted).

It is not a coincidence that both Latin and Japanese prefer long vowels but chose the hiatus configuration in order to achieve morpheme-to-syllable alignment. A language that preferred hiatus (to long vowels) is predicted not to show a different pattern when morpheme edges are involved, as there is no possible push toward a long vowel specifically in this case. Thus we expect that languages will either act as Belep is described as doing, with hiatus of adjacent identical vowels both morpheme-internally and at morpheme edges, or as Latin and Japanese do, with long vowels morpheme-internally and hiatus at morpheme boundaries.

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The Perception of a Secondary Palatalization Contrast:
A Preliminary Comparison of Russian and Irish[*]

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The typology of secondary palatalization contrasts reveals certain asymmetries (Kochetov 2002; Takatori 1997), e.g. a contrast in coda position implies one in onset position, and a contrast in labials implies one in coronals. This paper presents results from a perceptual study of Irish and Russian that addresses the positional asymmetry in relation to labial stops and fricatives and provides further support for the hypothesis that a palatalization contrast in coda or word-final position is disfavored for perceptual reasons. The study, which tests both Russian and Irish listeners on both Russian and Irish productions using the same methodology, allows a direct comparison of the results for the two languages.
Keywords: palatalization, perception, Irish, Russian

1. Introduction

The typology of secondary palatalization contrasts reveals certain asymmetries (Kochetov 2002; Takatori 1997). For example, a contrast in coda position implies one in onset position, and a contrast in labials implies one in coronals. It is reasonable to think that these asymmetries may have a basis in the production and/or perception of a secondary palatalization contrast. However, there have been very few studies designed to address this hypothesis, and their results are not always consistent with each other. This paper reports on a perceptual study, employing an AX discrimination task, addressing the question with respect to onset vs. coda position. It represents a significant contribution in several respects. First, the study is conducted using listeners of both (Connemara) Irish and (Contemporary Standard) Russian, listening to the same set of controlled stimuli produced by both Russian and Irish speakers. This novel design allows us to directly compare results across the two languages. Second, it employs three speakers of each language to provide the stimuli for the discrimination task, allowing for more confidence in the results and generalizability. Finally, it compares the palatalization contrast in stops to that in fricatives (in addition to that in onset vs. coda), a comparison that has not been made before.

Russian and Irish differ in an important way. Unlike Russian, Irish is a minority and, arguably, an endangered language. Recent literature discussed below suggests that even in areas where Irish is spoken as a community language, young speakers are becoming more English-dominant. The Irish secondary palatalization contrast, a fundamental feature of Irish phonology, has generally seemed stable in the sense that speakers produce the contrast. However, our study provides some reason for possible concern. We find that our Russian listeners perceived a palatalization contrast more accurately than our Irish listeners, and that this was true whether the contrast was produced by Russian speakers or Irish speakers. In addition, our Russian stimuli were more accurately perceived whether the listeners were Russian or Irish. Though we must be

cautious when inferring anything about the state of the Irish language from a limited set of speakers, one possible conclusion is that the Irish palatalization contrast is showing subphonemic signs of instability. Another reason for caution in interpreting the results reported on here is that they involve the palatalization contrast only for the labial consonants [p] and [f].

2. Background

Unlike Russian, a dominant language having many millions of speakers, Irish is a minority language that could be regarded as endangered and that is spoken as a community language or on a daily basis by only tens of thousands of people according to the 2016 census (Central Statistics Office 2017). A recent study of children ages 7-11 who live in parts of Connemara where Irish is a community language, found that even there many children were English dominant in various measures, including (in a limited domain) phonetic accuracy (Péterváry et al. 2015). Loss of phonemic contrast, such as the palatalization contrast fundamental to the language, would be of more serious concern than phonetic accuracy, and such loss is not generally observed. However, phonetic accuracy potentially bears on contrast, and impressionistic reports of contrast may actually tell us little about the stability of the phonetic system. This is a point we return to in the conclusion.

(1) shows the phoneme inventory of Irish as spoken in Connemara, a dialect of Connacht Irish spoken largely west of Galway, while 0 shows that of Contemporary Standard Russian. As can be seen, the languages have in common a secondary palatalization contrast that pervades the phonemic inventory. The contrast exists in both onset and coda position in both Irish and Russian. In addition, various grammatical distinctions, often in coda position, rely solely on this contrast, e.g. Irish /bɔ:d/ 'boat' vs. /bɔ:dʲ/ 'boat (pl.)', and Russian /govorit/ 'speak (3rd sg.)' vs. /govoritʲ/ 'speak (inf.)'. (For more on Irish phonology and palatalization, see Ní Chasaide 1990; Ní Chasaide 1995.)

(1)   Irish phoneme inventory

	Labial	Coronal	Dorsal	Glottal
Stop	p pʲ	t tʲ	k kʲ	
	b bʲ	d dʲ	g gʲ	
Fricative	f fʲ	s sʲ	x xʲ	h (hʲ)
	v vʲ		(ɣ) (ɣʲ)	
Nasal	m mʲ	n nʲ	ŋ ŋʲ	
Liquid		l lʲ		
		r rʲ		

Russian phoneme inventory

	Labial	Coronal		Dorsal
Stop	p pʲ	t tʲ		k kʲ
	b bʲ	d dʲ		g gʲ
Fricative	f fʲ	s sʲ	ş ʃ:	x xʲ
	v vʲ		z̢	
Affricate		ts tʃʲ		
Nasal	m mʲ	n nʲ		
Liquid		l lʲ		
		r rʲ		

These properties make both Irish and Russian ideal for testing for a relationship between the implicational generalization onset > coda for a palatalization contrast and phonetic factors like the discriminability of the contrast in onset vs. coda position. For example, if speakers of Russian or Irish discriminate the contrast more poorly in coda position compared to onset, even though the contrast is robust in both positions, this would support a hypothesized perceptual basis for this typological asymmetry. If a contrast is more poorly discriminated in coda position, this might lead to the erosion of the contrast in that position over historical time, explaining why some languages, including Slavic languages related to Russian, lost the contrast in coda position where it had previously existed.

Kochetov (2004; 2006) examined the relative perceptibility of the Russian palatalization contrast in [p] vs. [t], in onset vs. coda position (using nonsense forms like [ta] and [apʲ]), employing an identification task. He found that listeners identified forms more accurately in onset compared to coda position, and for coronals compared to labials, a result that mirrors the typology. Using a discrimination task, Ní Chiosáin and Padgett (2012) found that Irish listeners likewise performed more accurately on the contrast in onset position compared to coda position. However, they also found that listeners more accurately discriminated the contrast in labials compared to coronals, contrary to the prediction that discriminability will mirror the typology.

Both of the above studies are limited in the sense that they made use of stimuli produced by only one speaker, a fact that severely limits our ability to generalize the results to the language at large. In addition, their methods differed in several ways. For example, Kochetov's study involved an identification task while that of Ní Chiosáin and Padgett employed a discrimination task; the consonants in Russian were voiceless unaspirated while those of Irish were voiceless aspirated and voiced unaspirated. Given these limitations and differences, what do we make of contradictory results like those seen above for labials vs. coronals in Russian vs. Irish? Do these reflect a real difference between the languages or are they artifacts of different experimental methods, or even of the use of a single speaker to produce experimental stimuli?

The study described here provides a comparison between Russian and Irish using the very same experimental methodology and the very same stimuli produced by both Russian and Irish speakers. It employs three speakers of each language to provide the stimuli. As a separate contribution, this study also compares the perception of the palatalization contrast in stops vs. fricatives, something that has not been done before. Does the onset vs. coda perceptual asymmetry seen in earlier experiments obtain for fricatives too? The typological generalization that a coda palatalization contrast implies an onset one applies to fricatives too, so the prediction

is that the fricatives should pattern like stops in this respect. Apart from this question, does the manner difference itself matter to the perception of palatalization?

The study described below manipulated position (onset vs. coda), place of articulation (labial vs. coronal), and manner (stop vs. fricative). However, the results presented in this paper focus only on the position and manner differences and are limited to the labial place of articulation.

3. Experimental methods
3.1 Participants

Three Irish speakers and three Russian speakers, all female, recorded the stimuli used for the perception experiment. The Russian speakers were students of Lomonosov Moscow State University, 18-19 years of age, who had lived their entire lives in Moscow or the Moscow area. The Irish speakers, aged 22, 30, 46, lived in the Connemara Gaeltacht up until their college years.[1] All three lived in the greater Dublin area since their early twenties and were all employed in the Irish medium education sector. All continue to use Irish on a daily basis. None of our speakers reported any difficulties with hearing or speaking. All volunteered for the experiment.

For the perception experiment itself there were 18 Russian participants and 15 Irish participants, who we will henceforth call 'listeners'. All Russian listeners were students of Lomonosov Moscow State University who volunteered for the experiment. All were between 17 and 23 years of age, except for three participants who were 29, 31, and 55 (average = 23). Most were the equivalent of undergraduate students in the U.S. system, but four were post-graduate students. All but three of the participants were female, reflecting a gender imbalance of the department from which they were recruited. Of the 18 participants, 10 had lived their entire lives in Moscow. The regions where the rest had lived are described in Figure 1. None reported any difficulties with hearing or speaking.

Subject	Regions - Ages
6	Tashkent, Uzbekistan, until 14, Tula, Russia, until 18, Moscow until 55
9	Denmark 23-25, otherwise Moscow until 29
10	Pskov, Russia, until 17, Moscow until 18
11	Tiraspol, Moldova, until 10, Moscow until 17
13	Tartarstan Region until 17, Moscow until 22
14	Volgograd Region until 9, Moscow until 19
15	Kovrov (Vladimir Region) until 17, Moscow until 19
17	Nizhny Novgorod, Russia, until 17, Moscow until 19

Figure 1: Areas lived in (and ages) of 8 of the Russian listeners.

The Irish participants, who volunteered for the experiment, were students pursuing their studies through the medium of Irish in Acadamh na hOllscolaíochta[2], National University of Ireland, Galway. Participants were aged between 19 and 47 (10 were between 19 and 29 (average=23), 5 were between 39 and 47). Ten were undergraduate students, and five were postgraduate students. All but three of the participants were female. Eight of the younger participants and one of the older participants lived all their lives in various townlands in the Connemara Gaeltacht, along with two of the older participants who spent one year and eight years, respectively, in English

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[1] One speaker lived with her family in London from age 4-9, returning to Connemara until she went to college at 20.
[2] 'academy of university education'

speaking countries in their 20s. A further two of the younger participants spent nine and ten years, respectively, in England, while a further older participant, whose parents were native Irish speakers from Connemara, spent the first 14 years of her life in England. The last participant lived in Connemara until her teenage years before going to an English medium boarding school. She moved back to Connemara shortly after finishing her degree and was settled there for over 20 years. Twelve of the participants spoke mostly Irish at home; a further two whose mothers were not native Irish speakers spoke Irish and English, and English, respectively, at home. The final speaker, who returned from the UK aged 9, spoke English at home. All participants regardless of language background were very competent, natural speakers.

3.2 Materials

Since it was impossible to construct the controlled materials we wanted out of familiar words occurring in both Irish and Russian, we opted to use nonce forms. Figure 2 shows the forms aimed for in both languages (for the full experiment, only some of which is analyzed here), rendered in broad IPA transcription. Target consonants (underlined) were voiceless obstruents. As can be seen, we varied palatalization (palatalized vs. velarized), place of articulation (labial vs. coronal), manner (stop vs. fricative), and position (syllable/word onset vs. coda). The non-target consonant (on the opposite side of the vowel) was always velar [k] (if onset) or [x] (if coda), thus differing in place of articulation from the target consonant. We used non-target [x] in coda position because words of the desired shape ending in [k] are rare in Irish and strike speakers as odd. For consistency we transcribe non-palatalized target consonants as velarized, though velarization is less evident than palatalization in the context of back vowels.[3]

	Onset				Coda			
	Labial		Coronal		Labial		Coronal	
Stop	pʲax peách пях	pˠax pách пах	tʲax teách тях	tˠax tách тах	kapʲ cáip капь	kapˠ cáp кап	katʲ cáit кать	katˠ cát кат
Fricative	fʲax feách фях	fˠax fách фах	sʲax seách сях	sˠax sách сах	kafʲ cáif кафь	kafˠ cáf каф	kasʲ cáis кась	kasˠ cás кас

Figure 2: Nonce forms used. In each cell, first row is broad IPA transcription, second and third rows are the Irish and Russian spelling used in production elicitation. Target consonant is underlined.

While the broad transcriptions in Figure 2 convey the Russian pronunciations well, the Irish forms depart from these transcriptions in three significant ways (see Ní Chiosáin & Padgett 2012 for relevant discussion of the Irish facts). First, the vowel was generally longer in the Irish stimuli. Irish distinguishes short and long vowels; we chose the long low vowel, because the quality of short vowels in Irish depends greatly on the palatalization of surrounding consonants, something that would have undermined the comparability of the Russian and Irish materials.[4] Second, the realization of the long low vowel in Irish is [ɔː], not [aː]. Third, palatalized /sʲ/ is realized as [ʃ] or [ɕ] in Irish.

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[3] We don't transcribe velarization in the non-target velars. The palatalization/velarization contrast in velars is marginal in Russian.

[4] The quality of non-low short vowels in Irish is *entirely* dependent on the neighboring consonants' palatalization, making collection of comparable materials with Russian impossible. Though they do not feature in this experiment, our recorded stimuli include the high vowels /i/ and /u/ as well.

Our materials are (mostly) nonce forms, for the purposes of control, but they are sequences of sounds that should cause little trouble for our speakers or listeners. In the case of Russian, two of the stimuli happen to be occurring words ([pax] 'groin' and [kap] 'wart, nodule'). Most of the rest occur not as words but as stressed syllables in longer words, e.g. [kat] in [ɐdvɐˈkat] 'lawyer', [tʲax] in [puˈtʲax] 'way (loc.pl.)'. Four stimuli are an exception to this: the subsequences [fʲax], [sʲax], [kapʲ], and [kafʲ] do not occur in the corpus described in Sharoff (2008) of word forms having a frequency of at least one occurrence per million. Regarding the first two, other stressed syllables of the form *Cʲax* are common (where *Cʲ* is any palatalized consonant), and stressed syllables of the form *fʲak* and *sʲak* occur in [tʲuˈfʲak] 'bed, mattress' and [tak i sʲak] 'this way or that'. Regarding the last two, stressed syllables of the form *kaC* are very common and a stressed syllable of the form *Cafʲ* occurs in [prʲɪtˈstafʲ] 'present (imper.)'. While syllables of the form *Capʲ* do not occur, other forms have palatalized labials following [a], e.g. [prʲɪtˈstafʲ] 'present (imper.)', or other vowels before [pʲ], e.g., [topʲ] 'swamp'. Our three Russian speakers appeared to have no unusual difficulty producing any of these forms.

In the case of Irish, five of the stimuli happen to be occurring words ([kɔːtʲ] 'Cáit (a name)', [sɔːx] 'well-fed, satisfied', [kɔːʃ] 'cheese', [kɔːs] 'case', and [fɔːx] 'in favour (of)'). All but the last are very familiar and would be frequent. In the case of [fɔːx], stressed syllables of the form *fɔːC* occur relatively frequently in other words, e.g., [fɔːs] 'growth'. As for the other nonce forms, where the target consonant is initial, the relevant *Cɔː* sequence occurs in another *CɔːC* word, e.g., [pʲɔːn] 'pen', [pɔːn] 'pawnshop, [tʲɔːn] 'tight', [tɔːl] 'yield', [fʲɔːl] 'deceit', [ʃɔːn] 'Seán (a name)'. The initial *Cɔː* in all cases also occurs in longer *CɔːCVX* forms. Where the target consonant is final, two possible forms arise: since the initial syllable is stressed in Irish[5], the target consonant is unquestionably syllabified with the preceding vowel only in monosyllabic forms, e.g. [stɔːt] 'state' and [rɔːp] 'confusion'. The remaining sequences occur in words where the consonant in question is intervocalic, in which case its syllable affiliation is less clear (Ní Chiosáin et al. 2012), e.g. [ˈkɔːpʲeːʃ] 'document', [ˈɔːfʲeːʃ] 'nonsense', [ˈɔːfɔx] 'however'. The three Irish speakers were not as comfortable with the nonce reading task as the Russian speakers were, and they had to repeat occasional forms, but no words seemed to cause special difficulty.

The words were produced in the carrier phrase [skɐˈʒʲvʲitʲɪ ___] 'Say ___' (Russian) or [ˈdʲeːrhə mɛ ___] 'say-FUT I ___' (Irish). Speakers were asked to speak naturally (as if to a friend), with no pause between the words, to place the stress on the target word, and to repeat any word if they felt they had made a mistake. Before recording they read out loud through the list of words, and we clarified the intended pronunciation if speakers produced the wrong phonemes (e.g., producing a velarized instead of palatalized sound). Words were presented in randomized order on a computer screen, along with the carrier phrase, and speakers read each phrase twice when it appeared. The presentation was blocked so that words with initial target consonants came first and words with final ones came second. This order of blocks was then repeated, so that there were four recorded tokens of each word in all. The recorded material included additional target words and sentence frame conditions not used for the experiment described here.

For all Russian speakers and one Irish speaker, recordings were made using a MicroTrack 24/96 recorder set to 41 KHz and 16-bit and a Shure WH20XLR headset dynamic cardioid microphone. A Marantz PMD670 recorder at 22 KHz and a Shure SM104 headset dynamic cardioid microphone were used for two of the Irish speakers. The Russian recordings were made

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[5] This is true of the dialects in question with the exception of a small number of words (e.g. inniu 'today'. inné 'yesterday, anseo 'here'). Stress shift to a heavy syllable applies only in the southern dialects.

in a quiet room at Lomonosov Moscow State University, and the Irish recordings were made in separate locations for each speaker: in a quiet room in a home, in a school, and in a recording studio.

Words were extracted from carrier phrases for use in the discrimination experiment. The words were extracted so as to omit the velar non-targets from the words, meaning that the extracted sequences were nonsense CV and VC syllables like *at, fʲa*, etc. This removed a potentially distracting irrelevant consonant, and it shortened the time that syllables must be held in short term memory for the purposes of discrimination. To remove initial non-target [k], words were extracted starting at the point where the second and higher formants of the vowel became high in energy; if there was still an impression of an initial [k], this boundary was moved to the right until no such impression was left. To remove final non-target [x], words were extracted up to the point where the vowel periodicity of the waveform ceased. As for the target consonants, we judged their beginning or end based on information in the waveform and spectrogram; for initial stops we did not include the voiceless portion prior to the audible release; for final stops the audible release was included.

As noted above, during each trial the speakers produced each phrase twice. As a rule we extracted the second repetition within each trial for the perception experiment. Since there were two trials per stimulus word, this resulted in two recordings of each word (for each speaker and language) for the perception experiment. For all speakers but Irish Speaker 2, we extracted the first repetition only when the second was anomalous (due to hesitation, microphone pops, or the like). For Irish Speaker 2 we generally extracted the first repetition within each trial, because her second repetition word-final velar fricatives were unusually elongated.

The stimuli from Russian Speakers 1-3 and Irish Speaker 1 were downsampled to 22050 Hz to match the sampling rate for Irish Speakers 2-3 (who were recorded using different equipment). All of the stimuli were roughly normalized in intensity using the 'scale peak' feature of Praat (set to 0.8).

3.3 Perception experiment procedures

The perception experiment was presented using Superlab version 4 on an Apple laptop computer. It was conducted in a quiet room at Acadamh na hOllscolaíochta, National University of Ireland, Galway, located in An Cheathrú Rua (Carraroe) in Conamara (Irish) or at Lomonosov Moscow State University (Russian). The listeners wore headphones and received instructions via Superlab slides; these are given in full in the Appendix. All participants were volunteers.

As seen above, three properties of the stimuli were manipulated for this experiment, schematized in Figure 3 below. In the full experiment conducted, every trial was drawn from one of the eight cells in Figure 3. Since the results presented here are only for the labial consonants (unshaded in Figure 3), we focus on those. For each cell there were four kinds of trial, depending on the order of the stimuli and on whether the target consonants were the same or different in palatalization. For example, there were four kinds of trial involving initial /p/: *pʲa-pʲa*, *pʲa-pˠa*, *pˠa-pˠa*, and *pˠa-pʲa*. The number of 'same' and 'different' trials was thus identical. For the 'same' trials, the paired forms were different recorded tokens.

	Onset		Coda	
	Labial	Coronal	Labial	Coronal
Stop	pax	tax	kap	kat
Fricative	fax	sax	kaf	kas

Figure 3: Three factors manipulated in the experiment: position, place of articulation, manner of articulation.

Given the four conditions examined in this paper, four trial types, and two repetitions (per speaker) of each stimulus in the experiment, there were 32 trials per speaker. Since there were three Russian and three Irish speakers, there were 192 trials all. The experiment was blocked by speaker, so that there were six blocks, presented in random order for each listener. Within each block the order of presentation of the 32 trial types was also random. Listeners were prompted with the option to take a break between blocks. The interstimulus interval was 100ms. For half of the listeners, the button for 'same' corresponded to the right hand; for the other half, this correspondence was reversed.

Both accuracy and reaction time were collected, though primarily accuracy is reported here. Reaction times were measured relative to the onset of the second of the paired stimuli. During the experiment, the listeners were prompted to respond more quickly every time their reaction time exceeded 600ms.

4. Results

Before analysis, all trials recording reaction times greater than 3000ms. were removed. This eliminated only 8 observations, about 0.3% of the data.

Figure 4 plots listener performance on stimuli produced by Irish speakers against that on stimuli produced by Russian speakers, for proportion correct (left) and reaction time (right). Points represent Irish and Russian listeners. We make several observations based on these plots. First, our listeners responded fundamentally similarly to the stimuli from both languages, whether native or not. We infer this from the correlations evident in the plots: better performance w.r.t. one language's stimuli tends to accompany better performance w.r.t. the other's stimuli. Taking proportion correct first, for both the Irish and Russian listeners the Pearson's correlation showed a large positive association between the two ($r(13)= 0.72$, $p<.01$, $r(16)=0.72$, $p<.001$ respectively).[6] In the case of reaction times, again there were strong positive correlations for both Irish and Russian listeners ($r(13)=0.77$, $p<.001$, $r(16)=0.73$, $p<.001$). If, for example, Irish listeners simply could not make sense of the Russian palatalization contrast because it is so different, we would not expect to see such correlations. This is important because the conclusions of this paper assume that listeners perceive and respond to a palatalization contrast even for stimuli that are not native to them.

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[6] The Pearson test assumes a normal distribution, but just in the case of Russian listeners hearing Russian speakers the distribution is significant on the Shapiro-Wilk normality test, which means this assumption is not safe. However, even using the Spearman correlation test for the Russian listeners there is a large positive correlation ($\rho(16)=0.62$, $p<.01$). For reaction times, in the case of Irish listeners hearing Russian speakers the normality assumption is not safe. The Spearman correlation again shows a strong positive correlation ($\rho(13)=0.59$, $p<.05$).

Proportion correct

Reaction Time
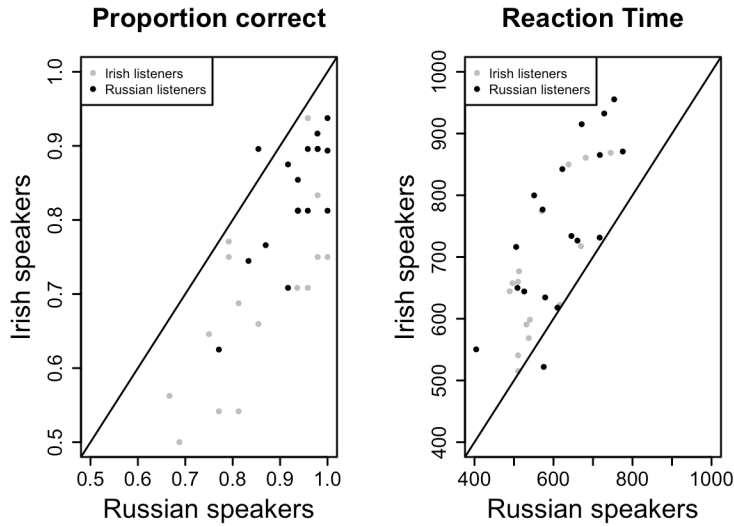
Figure 4: Performance of listeners hearing Irish stimuli plotted against that of listeners hearing Russian stimuli, for proportion correct (left) and RT (right).

The second observation we make based on these plots is that the Russian listeners were more accurate overall than the Irish listeners. This observation is based on the relative distribution of gray and black points in the left panel of Figure 4, with light gray points nearer to the lower left and black points nearer to the upper right of the figure. Finally and perhaps most surprisingly, all listeners – including Irish listeners – responded more accurately (left panel) and quickly (right panel) to stimuli produced by Russian speakers. If listeners had responded more successfully to stimuli from their own language, we would see the gray and black points separated by the line y=x.

These latter two observations can be seen more directly in Figure 5. The overall mean proportion correct was 0.88 for Russian listeners and 0.77 for Irish listeners (left panel). The overall proportion correct for listeners hearing Russian stimuli was 0.89 while that for those hearing Irish stimuli was 0.77. As the right panel shows, this advantage for Russian stimuli held across all speakers.

Proportion correct by listener language

Proportion correct by speaker
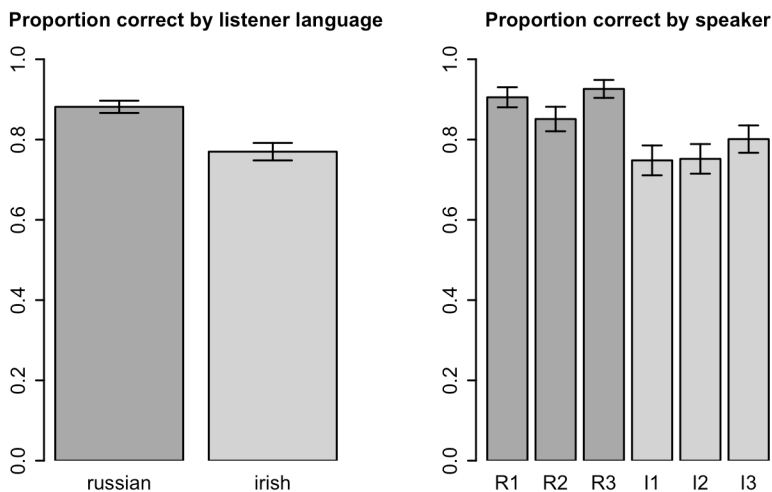
Figure 5: Overall proportion correct by listener language (left) and by speaker (right), for Russian (dark gray) and Irish (light gray) listeners and speakers.

Figure **6** shows overall proportion correct by syllable position (onset vs. coda) and manner of articulation (stop vs. fricative). Overall, accuracy appears to be greater for the palatalization contrast in onset position (mean=0.91) compared to coda (0.76). The contrast in stop consonants [p,t] had an overall advantage (mean=0.85) over that in fricatives [f,s] (0.81) as well, but this difference really only appears to hold in coda position.

Proportion correct by position and manner
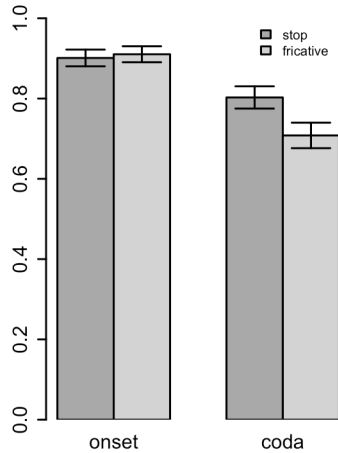
Figure 6: Proportion correct by syllable position and manner of articulation, for all listeners combined.

To better understand these effects it is helpful to break the data down further, where we can see important sub-patterns depending on the combination of listener language and speaker language. Figure 7 shows proportion correct by speaker language, for all combinations of position and manner. (For example, 'af' stands for the combination of coda and fricative conditions.) Dark gray bars represent Russian speakers and light gray bars Irish speakers. The left panel shows Russian listeners, the right panel Irish listeners. As can be seen, Russian listeners responded very accurately overall to Russian and Irish stimuli in onset position. However, in coda position Russian listeners responded less accurately to Irish stimuli, and this difference seems heightened in the case of fricatives. What is most remarkable is that Irish listeners (right panel) show a very similar pattern overall.
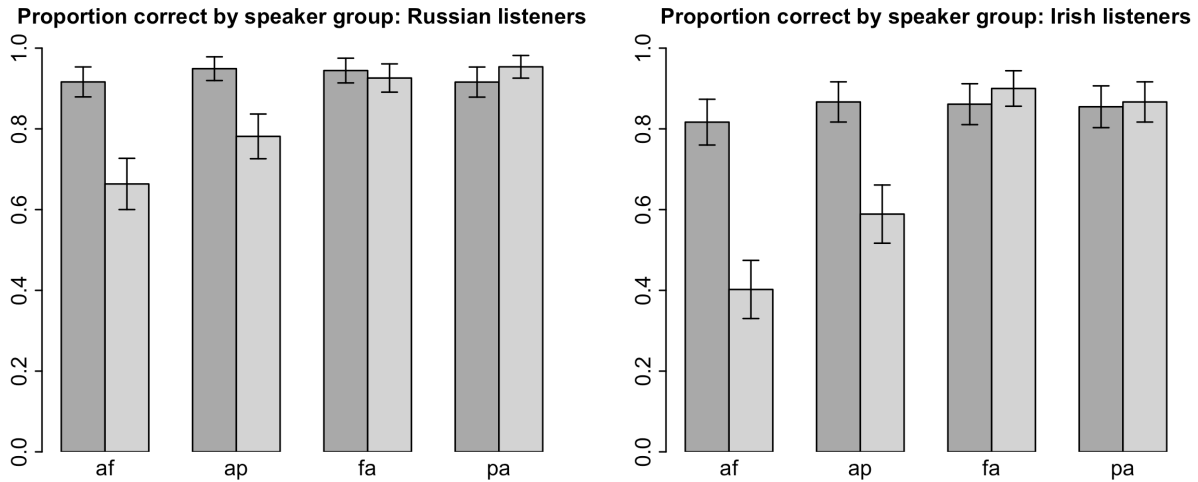
Figure 7: Proportion correct for all combinations of position and manner. On the left: Russian listeners hearing Russian speakers (dark gray) vs. Irish speakers (light gray). On the right: Irish listeners hearing Russian speakers (dark gray) vs. Irish speakers (light gray).

To test the observations above we ran a linear mixed effects logistic regression in R (R Core Team 2013) employing the *lme4* package (Baayen et al. 2008, Bates et al. 2012, Barr et al. 2013), with response (correct or incorrect) as the dependent variable and position (default=onset), manner (default=stop), speaker language (default=Russian), and listener language (default=Russian) as factors.[7] We included speaker and listener as random intercepts. (Models with random slopes did not converge.) Given the apparent interplay above between position and manner, we included this interaction in the model. The effect of position also seems to depend on the speaker group, so we also included this interaction. This last model was the best fit according to an ANOVA comparison (Baayen et al. 2008). No other interactions were pursued. The results of this analysis are shown in Table 1.

	b	*se*	*z*	*p*
Intercept	2.83	0.27	10.4	< 2e-16*
Position:coda	0.35	0.21	1.7	0.09
Manner:fricative	0.12	0.18	0.7	0.51
Listener_language:irish	-0.95	0.26	-3.7	0.0002*
Speaker_language:irish	0.19	0.27	0.7	0.48
Position x Manner	-0.77	0.22	-3.5	0.0005*
Position x Speaker_language	-2.04	0.23	-8.9	< 2e-16*

Table 1: Fixed effects in a logistic regression model of (in)correct responses

Focusing first on position and manner, this analysis reveals no significant main effects of these factors. Instead we see a significant position x manner interaction, reflecting poorer accuracy on the coda palatalization contrast particularly in the case of fricatives. In addition there is a significant position x speaker language interaction, driven by poorer accuracy w.r.t. coda contrasts when the stimuli are from Irish speakers. Finally, there is a significant main effect of listener language, reflecting poorer accuracy overall in the case of the Irish listeners.

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[7] We are grateful to Jenny Bellik for assistance with this analysis.

5. Discussion and conclusion

The results of this perception study provide further support for the hypothesis that a palatalization contrast in coda or word-final position is disfavored for perceptual reasons. First, our listeners were less accurate in discriminating the palatalization contrast in the case of codas when the stimuli were from Irish speakers. Second, they were less accurate particularly in the case of coda [f], whether the stimuli were Irish or Russian. This finding of a perceptual vulnerability for the contrast in coda position jibes with that of Kochetov (2002) and Ní Chiosáin and Padgett (2012), but it is based on a more robust dataset than was available to those previous analyses: three speakers of each language, 15 Irish listeners, and 18 Russian listeners.

Our results also suggest that the palatalization contrast in stops may have a perceptual advantage over that in fricatives, but we found this asymmetry only in coda position, as noted above. Such an asymmetry has not been observed before, and it will be interesting to explore in future research whether it generalizes to other stop-fricative pairs than [p-f], and whether this asymmetry is reflected in the typology of palatalization contrasts.

What is perhaps most interesting about this study is its unusual design: testing both Russian and Irish listeners on both Russian and Irish productions using the very same methodology. This design allows us to directly compare the results for the two languages. A striking finding is that both Russian and Irish listeners discriminate the palatalization contrast more accurately in the case of Russian stimuli, as seen in the position x speaker interaction in our results. To put it differently, this experiment provides direct evidence that our Irish speakers did not produce the coda palatalization contrast as successfully as did our Russian speakers, if 'success' is gauged by a listener's ability to discriminate the contrast. Nor did Irish *listeners* discriminate the contrast as successfully as did Russian listeners, even holding productions constant, as can be seen in the main effect of listener language we found. In this study, at least, those who spoke Russian were more proficient at both producing and perceiving the palatalization contrast.

What should we make of these findings? Obviously the Russian participants may have differed from the Irish participants in some way that can explain these differences without any bearing on the status of Irish generally. For example, though all of the participants were college students, the Russian participants were all students at Moscow State University, a very prestigious university. It is conceivable that they were more adept at the experimental tasks for reasons related to their level of education or socio-economic status. Though we cannot rule such an explanation out, our results may instead provide a new kind of experimental evidence that proficiency in Irish w.r.t. the palatalization contrast is vulnerable or unstable compared to that in Russian, an interpretation that is consistent with other research discussed in section 2. Though this may be a matter of 'phonetic accuracy' in the terminology of Péterváry et al. (2015), if it suggests a possible erosion of the Irish palatalization contrast that is in progress then it is obviously no mere matter of pronunciation. Rather, it bears on a fundamental structural property of Irish phonology. Of course, the results reported here are based only on the palatalization contrast borne by /f/ and /p/. It remains to be seen whether they generalize to other consonant types.[8]

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[8] Independent research on the production of palatalization contrasts by a different group of speakers of Connemara Irish shows that labials display secondary palatalization and velarization tongue body gestures as robust as those at other places of articulation (Bennett et al. 2018). Thus although the current experiment focused on labials, the place of the consonant was not likely a critical factor when considering the robustness of the contrast for this group of listeners.

Appendix

I. Perception experiment instructions. Below are the Irish and Russian instructions that were presented to the perception experiment participants, and a rough English translation. (Phrases in '[]' brackets were omitted in Irish.) Slide transitions are indicated by '||'.

Perception experiment

Thank you for your participation in this experiment. Its goal is to help us understand how people perceive speech sounds. || [In this experiment], pairs of small invented "words" are presented. (These words may or may not resemble words of the Irish (Russian) language.) [After listening to each pair], you should decide whether they are the same "words" or not. || If the words seem the same to you, press the BLUE button on the button box. If the words sound different to you, press the RED button. || In the course of the experiment, you will receive information about whether you answered quickly enough. Please try to answer as accurately *and* quickly as possible. || When you are ready, put on the headphones, place your left and right hands on the corresponding colored buttons, and press one or the other button to begin.

Triail éisteachta

Go raibh maith agat as ucht páirt a ghlacadh sa triail seo. 'Sé aidhm na trialach ná cabhrú linn tuiscint a fháil ar an gcaoi a gcloiseann daoine fuaimeanna sa gcaint. || Séinnfidh an ríomhaire péirí 'focal'. (D'fhéadfadh go bhfuaimneodh na focail cosúil le focail Ghaeilge ach ní gá gur mar sin a bheadh.) Éist leis na focail agus socraigh an mar a chéile atá siad nó éagsúil. || Má shíleann tú gur mar a chéile atá siad, brú an cnaipe GORM ar an mbosca cnaipí. Má shíleann tú gur éagsúil atá siad brú an cnaipe DEARG ar an mbosca cnaipí. || I rith na trialach inseofar duit an bhfuil tú ag freagairt sách scioptha. Déan iarracht freagairt chomh cruinn *agus* chomh scioptha agus is féidir. || Nuair atá tú réidh, cuir ort na cluaisíní, cuir do lámh dheis agus do lámh chlé ar na cnaipí cuí, agus brú ceann de na cnaipí.

Эксперимент на восприятие

Спасибо за Ваше участие в этом эксперименте. Его цель – помочь нам понять, как люди воспринимают звуки речи. || В этом эксперименте предъявляются пары маленьких, придуманных «слов». (Эти слова могут или не могут походить на слова русского языка.) При прослушивании каждой пары, Вы должны решить, это – те же самые «слова» или нет. || Если слова кажутся Вам теми же самыми, нажмите ГОЛУБУЮ кнопку на коробочке с кнопками. Если слова кажутся Вам различными, нажмите КРАСНУЮ кнопку. || Во время эксперимента, Вы будете получать информацию, о том, ответили ли Вы достаточно быстро. Пожалуйста, старайтесь отвечать как можно правильно *И* быстро. || Когда готовы, наденьте наушники, положите левую и правую руки на соответсвующие цветные кнопки, и нажмите ту или другую кнопку чтобы начать.

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COUNTING PARSES[*]

ALAN PRINCE
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Metrical theory allows for a rich if finite variety of ways that a string of syllables can be parsed by feet. We deploy a couple of different techniques to determine the number of parses admitted under various structural assumptions.

In so doing, we are led to effective procedures for constructing the entire set of parses. Since a claim of optimality refers to an entire candidate set, and not just to a handful of obvious competitors, these procedures provide a starting point for establishing the truth of any such claim in the realm of foot-level prosody.

1 At Issue

How many metrical parses are there for a string of *n* syllables?

1.1 Going Meta

Why would a linguist ask or seek to answer such a question, with no immediate empirical consequences in sight? No quick advantage to be claimed over a competitor? Curiosity is sufficient motive for some, as is an interest in exactitude. Both play a driving, behind-the-scenes role in investigations of all kinds: yesterday's math is tomorrow's physics, and vice versa; enough, even felt from a distance, to rattle the disciplinary cage. On the empirical side, the field's growth is a history of influx. The work of the dedicatees of this volume, central to modern prosodic theory, brings into play a diversity of illuminations coming from a vast, searching, and sometimes even playful exploration of phenomena and ideas that often lie well beyond the canonical foci and sources.

In the case at hand, we will find that asking a question about the theory, purely because of its formal interest, can lead us to useful insights or tools that can shape our understanding of the things we want to understand.[1] As an encouragement to the venture, very little specialized math is needed to reach the answer; all that's required is persistence with the familiar slightly beyond the bounds of familiarity.

1.2 Optimal

A candidate is optimal if there is nothing better in its candidate set.[2] *Nothing*. To establish optimality, then, requires that we control every candidate in the set.[3] Vast infinities of candidates may vanish at a glance, through harmonic bounding arguments. For example, Prince & Smolensky (1993/2004, ch. 6), in studying the Basic Syllable Theory system, quickly reduce all candidate sets to finitude by establishing the (few) conditions under which epenthetic material can appear in optimal forms.

But as Tesar has reminded us from time to time, and as this example shows, infinity is often the easy part.[4] The twists, imperspicuities, and surprisingly large numbers that arise from finite combinatorics

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[1] This line is promoted in "The Pursuit of Theory" (Prince 2007).
[2] See "What is OT?" (Prince 2016) for a recent treatment, and Prince & Smolensky 1993/2004, ch. 5 for the first.
[3] It's a fact that the literature is not replete with arguments to the effect that claimed optima are in fact optimal. But this does not lessen the need: live by the heuristic, die by incomprehension. Theories, if not theorists, are remarkably immune to assertions of personal belief. On showing optimality, see Prince & Smolensky (1993/2004, ch. 7).
[4] Qualitatively speaking, one might conjecture that this is so because reaching infinity typically requires a kind of uniformity of structural possibilities that leads to the availability of broad generalizations.

can be daunting.[5] In some cases, it may be necessary to contend directly with exhaustive lists of candidates; and, even when broad generalizations *exist*, it may well be useful to have exhaustive lists to ponder as a lead-in to finding those generalizations.

To answer the *how many parses* question, we will construct a way (indeed: ways) to produce the exhaustive list of parses. We examine these methods of construction to determine the number of forms they generate. But it is only a matter of a change in perspective to be able to use these methods to generate the forms and thereby provide the analyst with the desired fodder for analysis.

1.3 The Parses

We work with an unremarkable conception of prosodic structure.[6] Feet are bisyllabic or monosyllabic, and do not overlap.[7] A licit metrical parse, for our purposes, is a PrWd consisting of a sequence of feet and unfooted syllables.

Any number of syllables may be left unfooted, including all of them. Every foot has one head; and one and only one foot may be distinguished as the head or (in a stress system) the main-stress-bearing constituent of the PrWd. For simplicity, we will refer to the head of a foot as a 'stress' and the head of the head foot as the 'main stress', bypassing questions of realization. We will occasionally abbreviate 'syllable' by σ.

The term *unit* will be used here to refer to any child node of a PrWd: a foot or an unfooted syllable; and used only to refer to those entities.

Here's an example of our assumptions and usage:

(1) A 4σ parse
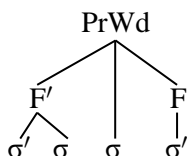
The English word 'perigrinate' provides an instance. This parse has three units: two feet (of which the first is bisyllabic, the second, monosyllabic) and one unfooted syllable. In this illustration, we portray headship by marking a head category C as C′: hence F′ (head of PrWd) and σ′ (head of foot). This parse is of *length* 4. We reserve the term *length* to measure the size in syllables of the string being parsed.

In building the argument, we will proceed analytically from the simpler to the more complex by introducing distinctions into previously analyzed classes that lack them.

We separate out the Quantity Insensitive (QI) systems, in which metrical terminals (syllables) are treated as being metrically equivalent. These contrast with Quantity Sensitive (QS) systems, in which a relevant binary distinction exists between syllable types.[8] This move is fully justified because the QS parse count can be derived from the more basic QI count.

We also recognize a class of systems *with **no main** stress* (NM) where all feet are prominentially nondistinct, with the head of the PrWd ignored. We distinguish these from systems where the head of the PrWd is attended to; these are *systems recognizing **main** stress* (M). This move is analytically justified because the count of M(ain) systems can be determined directly from the count of N(o)M(ain) systems.

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[5] In Harmonic Serialism, for example, candidate sets are strictly finite, but the plenitude and complexity of the derivations will (in certain perfectly ordinary cases) defeat some current software (Mullin et al., 2010, §1.2:7–11). The HS package in OTWorkplace (Prince et al 2007-2018) aims to adhere closely to the basic premises of the theory.
[6] Of course, it was remarkable at certain points in recent history and derives from inter alia Liberman 1975, Prince 1976, and more proximately Selkirk 1980 and Hayes 1981.
[7] Hyde 2002 et seq. finds a number of striking properties in an overlapping foot theory.
[8] For the terms abbreviated by QS and QI, and much else, see Hayes 1995.

The course of analysis will run from QI/NM, the simplest class, which honors the fewest structural distinctions, to QI/M, and thence to QS/NM and QS/M.

1.4 Strategies of Enumeration

We use two different strategies for enumerating parses, which we will name idiosyncratically: the *method of continuations*, and the *method of arrangements*. The first has a bottom-up flavor; the second, top-down.

- The method of continuations asks this question: given a (partially completed) structure, how many ways can we continue it one syllable further?[9]

- The method of arrangements asks: given that a parse has a certain number of units, how may we arrange them to form licit structures?

1.5 Preview of the Counting Results

Using the method of continuations, we will determine that $P_{NM}(n)$, the number of No Main QI parses of n syllables, $n > 0$, is as follows, where round(x) denotes 'the nearest integer to x':

(2) QI/NM
$$P_{NM}(n) = \text{round}\left(\frac{(1+\sqrt{3})^{n+1}}{2\sqrt{3}}\right)$$

Using the method of arrangements, we will find another expression for the same quantity, in which we write U for the number of units in the parse, B for the number of binary feet, and use the notation $[n/2]$ to mean 'the largest integer less than or equal to $n/2$'.

(3) QI/NM
$$P_{NM}(n) = \sum_{B=0}^{[n/2]} 2^U \binom{U}{B}$$

We'll see that $U = n - B$, and since we fix n, this relation will allow us to compute with equation (3).

Equation (3) uses the *binomial coefficient*, which has this interpretation:

(4) Binomial coefficient
$$\binom{U}{B} = \frac{U!}{B!(U-B)!}$$

This counts the number of ways of choosing B things out of a collection of size U, and hence would often be read 'U choose B'.[10]

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[9] See Riggle 2004 for major development of the finite state machine idea of which this is an instance.

[10] Qualitatively speaking, the factor $B!$ shows up in the denominator because we don't care about the order of choosing the B things. Similarly, we don't care about the order of the things we don't choose, hence the appearance of $(U-B)!$. This entity is called the 'binomial coefficient' because it appears when we expand the expression $(1+x)^n$ as a sum of terms involving some number of times x^k, $0 \leq k \leq n$: that number is n-choose-k. This is because each x^k term arises from the choice of an element, either 1 or x, from each of the n factors in the product $(1+x) \times \ldots \times (1+x)$. We have to choose k x's and $n-k$ 1's to get x^k. Each such choice gives us one term x^k. The number of ways to do this is the total number of x^k terms we get, and this is just the number of ways we can choose k things from n possibilities.

Using the method of arrangements, we determine that the number of QI parses containing a main stress, $P_M(n)$, is as follows:

(5) QI/M
$$P_M(n) = \frac{n}{2} P_{NM}(n)$$

Quantity sensitive totals are obtained by noting that each QI parse of a string of n syllables gives rise to 2^n QS parses, since each QI syllable independently yields two QS syllables (light/heavy).

(6) QS
$$P_{QS}(n) = 2^n P_{QI}(n)$$

We will encounter various other expressions of interest along the way. In the end, the methods of arriving at these formulas may be of more interest than the formulas themselves.

1.6 By the Numbers

We close the preliminaries with a glance at the resulting numerics.

(7) Quantities of Parses

Sylls	QI No Main	QI w/ Main	QS No Main	QS w/ Main
1	2	1	4	2
2	6	6	24	24
3	16	24	128	192
4	44	88	704	1,408
5	120	300	3,840	9,600
6	328	984	20,992	62,976
7	896	3,136	114,688	401,408
8	2,448	9,792	626,688	2,506,752
9	6,688	30,096	3,424,256	15,409,152
10	18,272	91,360	18,710,528	93,552,640
11	49,920	274,560	102,236,160	562,298,880
12	136,384	818,304	558,628,864	3,351,773,184
13	372,608	2,421,952	3,052,404,736	19,840,630,784
14	1,017,984	7,125,888	16,678,649,856	116,750,548,992
15	2,781,184	20,858,880	91,133,837,312	683,503,779,840

Two things to note:

1. The 'w/ Main' category reckons only those parses that *actually have* a main-stressed syllable; footless forms are not included in this count. We amplify below, in §5.

2. The QS counts aggregate over all possible QS inputs, thereby summing all possible faithfully-parsed output candidates from any QS input string whatever. Each QI length has, of course, only one input, whereas under QS, for a string of n syllables, we have 2^n distinct inputs, namely all length-n sequences over {light, heavy}. See §6 below.

The rate of growth in the QI sector settles down so that each successive length provides approximately 2.7 times the number of parses of its predecessor. The QS sector ultimately grows at about twice this rate.

Given any OT system, of course, the *total number* of violation-distinct optima in any candidate set—forms that can be optimal under some ranking—is limited by the interactions of the constraint system, regardless of the number of candidates. It will therefore be capped, and must stop growing, even though the total number of parses grows, nay *explodes*, with candidate length. For example, a QI/NM version of the system studied in Alber 2005, with seven constraints, has just 9 even-length possible optima and 14 of odd-length, for any length above three syllables (Alber & Prince 2008, in prep). Indexing these findings against the table, we note that whereas about 20% of the length-4 candidates are optimal in some system, a mere 0.0005% of length-15 forms are. This forcefully illustrates the fact that, even in systems like this, where each candidate set is finite, almost all forms are harmonically bounded. And it highlights, on the one hand, the tremendous power of a constraint system to exclude, and on the other, the remarkable effectiveness in parsing obtained by researchers like Tesar 1995 and Riggle 2004.

2 Counting NM Parses by Arrangements

Let's begin with the method of arrangements, which is conceptually akin to the hierarchical way of thinking about metrical constituency and which uses familiar techniques to do its counting. We'll then move to the method of continuations, which yields a very simple and practical generation scheme.

A syllable string is exhaustively parsed into units, each of which is a foot or unfooted syllable. Consider all metrical parses that contain U units: how many of these are there? To answer, we need to distinguish the number of binary units, B, from the number of monosyllabic units, M. The total number of units is merely their sum:

(8) $U = M + B$

What we want to know first is how many distinct ways a collocation of $U = M + B$ units may be linearly arranged. This is simply a matter of taking U sequential units and choosing B of them to binary: *U*-choose-*B*, the binomial coefficient (see fn. 10 for a brief characterization), whose definition we repeat here:

(9) Number of ways of choosing B things out of U things.
$$\binom{U}{B} = \frac{U!}{B!(U-B)!}$$

Next, we ask how many distinct full structures there are on U units, distinguishing x ('unstressed syllable') from X ('stressed syllable'). Observe that each binary unit comes in two varieties, which we notate -Xx- and -xX-; and each monosyllabic unit comes in two varieties, which we notate -x- and -X-. With two independent choices for *each* unit, whether binary or monosyllabic, there are 2^U full parses for each distinct collocation of U units. Putting these observations together:

(10) Number of parses with U units, B binary: $2^U \binom{U}{B}$

To make use of this, we need to be able to go through the parses of a length-*n* string, classified by the number of units each parse contains. That is: we need to relate U to B and n. Straight from the

definition of *M* and *B*, we have that the number of syllables must equal the number of monosyllabic units plus twice the number of bisyllabic units:

(11) $n = M + 2B$
$$= (M + B) + B = U + B$$
Rearranging, we have

(12) $U = n - B$

Observe that the number of binary feet in the parse of a length-*n* string runs from a minimum of zero, with all units monosyllabic, to [*n*/2], the greatest integer less than or equal to *n*/2, obtained when we deploy as many binary units as possible. (For example, a five-syllable string can host a maximum of two binary feet.) Putting this together with equations (10) and (12), we arrive at the desired expression for the total number of parses:

(13) QI/NM

$$\mathrm{P_{NM}}(n) = \sum_{B=0}^{[n/2]} 2^{U} \binom{U}{B}$$

$$= \sum_{B=0}^{[n/2]} 2^{n-B} \binom{n-B}{B}$$

Let's do an explicit calculation for length 5, noting that [5/2] = 2.

(14) QI/NM: length 5

$$\mathrm{P_{NM}}(5) = \sum_{B=0}^{[5/2]} 2^{5-B} \binom{5-B}{B}$$

$$= 2^5 \cdot \binom{5}{0} + 2^4 \cdot \binom{4}{1} + 2^3 \cdot \binom{3}{2}$$

$$= 32 \cdot 1 + 16 \cdot 4 + 8 \cdot 3$$

$$= 32 + 64 + 24$$

$$= 120$$

3 Counting NM Parses by Continuations

For purposes of analysis, we introduce a convenient notation that refers to the structure of constituency and headship. We choose '||' as the edge-marker over '-'and '.' for reasons of visibility.

Unstressed syllable	x
Stressed syllable	X
Main-stressed syllable	Y
Unit edge marker	||

Here are some examples of usage:

||Xx||Xx|| Two binary trochaic feet, No Main
||Xx||Yx|| Two binary trochaic feet, of which the second is the PrWd head
||x||x||X||X|| Two unfooted syllables followed by two monosyllabic feet, No Main
||x||x||Y||X|| Ditto footwise, except the penultimate foot is the head of the PrWd
||Yx||x||X|| Example (1) above

NB: We are treating the *unfooted syllable* as a demarcated unit which is notationally on a par with a monosyllabic foot: ||x|| *vs.* ||X||, ||Y||.

To enrich to QS, when the time comes, we can regard x, X, and Y as denoting *light* syllables, and use h, H, and K to denote their *heavy*-syllable cognates, as in OTWorkplace's built-in systems.

The vocabulary of characters used to encode QI/NM parses has three members: {X, x, ||}, of which the first two represent syllables. Generation starts from the symbol "||". Assume that we have built all strings of length $n - 1$ syllables ending in one of these three characters. Let's consider how any such string may be continued, advancing to strings of length n syllables. (We work arbitrarily left-to-right.)

(15) **Table of Continuations**

	IN: Ends in	OUT: May be continued as	Yields: A string ending in
[1a]	… x	X||	bisyllabic iamb
[1b]		||x	unstressed syllable
[1c]		||X	stressed syllable
[2a]	… X	x||	bisyllabic trochee
[2b]		||x	unstressed syllable
[2c]		||X	stressed syllable
[3a]	… ||	x	unstressed syllable
[3b]		X	stressed syllable

Examples:
- The 3σ parse ||Xx||x can continue one syllable further in three ways:
    - by [1a] to ||Xx||x**X||**
    - by [1b] to ||Xx||x**||x**
    - by [1c] to ||Xx||x**||X**
- The first 4σ parse ||Xx||x**X||** can continue in two ways:
    - by [3a] to ||Xx||xX||**x** or
    - by [3b] to ||Xx||xX||**X**, and in no other ways.
- And so on.

Representing the continuations in this way has four useful properties:
a) The output continuations end only in symbols mentioned in the inputs.
b) Continuation advances by exactly one syllable.

c) The footing status of x is left open at stage $n - 1$; it is determined at the next stage.
d) We may stop at any time and have a complete parse.[11]

Property (c) permits us to look at the *single* characters at the very end of the stage $n - 1$ input. We never need to examine the footing status of a final x, which would require us to know what characters precede and follow it.

In this scheme, for non-0 lengths, a *final* "‖" marks the end of a binary foot. Monosyllabic feet are demarcated at the next step, when there is a next step; or by quitting, leaving them final in the string.

The continuations therefore fall into two classes:
  • those ending in the unit-boundary marker "‖", indicating the end of a binary foot
  • those ending in a syllabic symbol, x or X
Let's write b(n) for the number of parses of length n ending in the boundary marker ('b-parses'), and s(n) for the number of parses ending in a syllable character x or X ('s-parses').

Writing $P_{NM}(n)$ for the number of parses on n syllables, our first observation is simply that this quantity is the sum of the number of s-parses and the number of b-parses.

(16) $P_{NM}(n) = s(n) + b(n)$

Less trivially, an examination of table (15) discloses that there is exactly one b-parse of length n syllables for each s-parse of length $n - 1$ syllables. These are shown in [1a] and [2a] of the table.

(17) $b(n) = s(n - 1)$

From this, it follows that solving for either s(n) or b(n) will solve the whole problem. Returning to the table, we observe that each s-parse on length $n - 1$ leads to *two* s-parses on length n, as shown in rows [1b,c] and [2b,c].

(18)   a. $s(n) = 2\,P_{NM}(n - 1)$
         b. $= 2\,s(n - 1) + 2\,b(n - 1)$ from equation (16)
         c. $= 2\,s(n - 1) + 2\,s(n - 2)$ from equation (17)

We have now obtained a linear recurrence relation that defines the value of s at length n in terms of its values at lengths $n - 1$ and $n - 2$. This kind of relation has a unique solution, once we fix its two initial conditions, the values of s(0) and s(1). The length 0 string has just one parse , namely "‖" in the notation, to start continuation off properly, which does not end in a syllable; therefore s(0) = 0. The length 1 string has two parses, namely as an unfooted syllable "‖x" and as a monosyllabic foot "‖X", by rules [3a] and [3b]. We have exactly the following problem to solve: find the function s meeting these conditions:

(19) $s(n) = 2\,s(n - 1) + 2\,s(n - 2)$
         $s(0) = 0$
         $s(1) = 2$

---

[11] If we stop by just ceasing to continue, a final unit may be explicitly demarcated by "‖" as in the example ‖Xx‖xX‖, or not, as in ‖Xx‖x. This orthographic inhomogeneity is irrelevant to the counting project. To fix it in implementation, we need merely add a stopping step which affixes the edge-marking character ‖ when necessary. This step does not affect the number of parses.

The usual methods[12] yield the following solution:

(20) QI/NM
$$s(n) = \frac{(1+\sqrt{3})^n - (1-\sqrt{3})^n}{\sqrt{3}}$$

From equations (16) and (17), we have the following:

(21) $P_{NM}(n)$ $=$ $s(n) + b(n)$
$=$ $s(n) + s(n-1)$

As Paul Smolensky notes, equation (18)c gives us, by dividing out the 2 on its right-hand side:

(22)
$$s(n) + s(n-1) = \tfrac{1}{2}\, s(n+1)$$

Thus from equations (21) and (22), we obtain

(23)
$$P_{NM}(n) = \tfrac{1}{2}\, s(n+1)$$

With equation (20) in hand, this yields a closed-form expression for the total number of QI parses with no main stress on a syllable string of length n:

(24) QI/NM
$$P_{NM}(n) = \frac{(1+\sqrt{3})^{n+1} - (1-\sqrt{3})^{n+1}}{2\sqrt{3}}$$

Observe that the subexpression

(25)
$$\frac{(1-\sqrt{3})^{n+1}}{2\sqrt{3}}$$

is small for $n = 1$, at approximately 0.155, and only gets smaller as n increases. For all values of $n > 0$, it cannot carry us far from the integer we are seeking. Therefore, we arrive at the following, using the function 'round(x)' to deliver 'the closest integer to x'.

(26) QI/NM
$$P_{NM}(n) = \text{round}\left(\frac{(1+\sqrt{3})^{n+1}}{2\sqrt{3}}\right) \qquad n > 0$$

Returning to the full unrounded result in equation (24), we note that expressions of the form

(27)
$$\frac{(1+x)^n - (1-x)^n}{x}$$

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[12] See, for example, "Recurrence Relation" in Wikipedia if you want to work by hand; or search on "recurrence relation" to find a solver and take your pick. Finding the solution requires no more than solving a quadratic equation and a pair of linear equations. Another linguistic application to a prosodic theory is found in Prince 1993. The commenter "d**a**/dt" worries whether expression (20) always provides integer values. Observe (or accept) that expression (20) does satisfy the recurrence relation for $s(n)$. It agrees with initial conditions $s(0) = 0$ and $s(1) = 2$, which completely determine all further values, which are thus integers. The same conclusion follows from a calculation like that outlined in exx. (27)-(28).

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are ripe for simplification via expansion of the numerator's terms by the binomial theorem. Clearly, the constant terms and all terms containing x^{2k} will drop out and all the surviving numerator terms will contain x^{2k+1}, both parenthesized numerator terms in the above contributing one such, which will simplify, when divided by x, to a term containing x^{2k}. This is convenient when $x = \sqrt{3} = 3^{\frac{1}{2}}$, and the final result looks like this:

(28) QI/NM
$$P_{NM}(n) = \sum_{k=0}^{\left[\frac{n+1}{2}\right]} 3^k \binom{n+1}{2k+1}$$

As above, we write $[q]$ for the greatest integer less than or equal to q, and we take the value of the binomial coefficient to be zero when the lower number exceeds the upper.

One might not imagine from looking that equation (28), with its powers of 3 from the method of continuations, and equation (13), with its powers of 2 from the method of arrangements, come to the same thing. But they both count identical sets, so we can be confident that they do.

To get a sense of the way this formula plays out, let's recalculate the length-5 example:

(29) QI/NM: length 5

$$
\begin{aligned}
P_{NM}(5) &= \sum_{k=0}^{\left[\frac{5+1}{2}\right]} 3^k \binom{6}{2k+1} = \sum_{k=0}^{3} 3^k \binom{6}{2k+1} \\
&= 3^0 \cdot \binom{6}{1} + 3^1 \cdot \binom{6}{3} + 3^2 \cdot \binom{6}{5} + 3^3 \cdot \binom{6}{7} \\
&= 1 \cdot 6 \quad + 3 \cdot 20 \ + 9 \cdot 6 \quad + 27 \cdot 0 \\
&= 6 + 60 + 54 + 0 \\
&= 120
\end{aligned}
$$

4 Main Stress

Now that we have expressions for the number of mainstressless QI parses on an arbitrary syllable string of length n, we inquire as to the status of the next level of complexity: metrical parses containing a single head foot (giving us the *main stress* when footheads are interpreted as stresses).

Here's the result:

(30) QI/M
$$P_M(n) = \frac{n}{2} P_{NM}(n)$$

To show that this is correct, let us associate each parse π with (what we will call) its X/x-dual, $\bar{\pi}$, which is obtained from π by switching every x for X and every X for x. The X/x-dual swaps iamb and trochee, monosyllabic foot and unfooted syllable, uniformly throughout the string. Consider the entire collection DP(n) of dual *pairs* of parses of length n syllables, writing $\Pi(n)$ for the set of individual QI parses on a length-n string.

(31) Dual pairs $\qquad$ DP$(n) = \{ \; \{ \pi , \bar{\pi} \} \mid \pi \in \Pi(n) \; \}$

We make four observations:

    I. $\bigcup$DP$(n) = \Pi(n)$.
    II.   For every $\pi \in \Pi(n)$, there is exactly one $\delta \in$ DP(n) such that $\pi \in \delta$.
    III. There are ½ P$_{\mathrm{NM}}(n)$ elements in DP(n).
    IV. Each element $\{ \pi , \bar{\pi} \} \in$ DP(n) contains a total of n X's.

To establish the last, consider any pair $\{ \pi , \bar{\pi} \}$ and say π contains k X's and $n-k$ x's, $k \geq 0$. Then $\bar{\pi}$ contains $n - k$ X's. Sum across the pair to obtain the total of $k + (n-k) = n$ X's.

To generate the totality of main stress possibilities, take each *pair* and produce from it all individual parses in which one of the X's in one of its members has been replaced by a Y. Each pair then produces exactly n parses with one syllable identified as the main stress. Take this with observation III, and we obtain the result claimed in equation (30).

(32) QI/M $\qquad$ $P_{\mathrm{M}}(n) = n\left|\text{DP}(n)\right| = \dfrac{n}{2} P_{\mathrm{NM}}(n)$

This method of counting reckons only with those parses that contain at least one stress. If we include parses without feet, we add for each input exactly one parse with no stresses at all. Call the number of these inclusive parses $P_{\mathrm{M}+\varnothing}(n)$. We have:

(33) *All* QI/M parses $\qquad$ $P_{\mathrm{M}+\varnothing}(n) = \dfrac{n}{2} P_{\mathrm{NM}}(n) + 1$

5 QS, All Types

Each QI parse, under either the NM or M regimes, blows up to a set of QS parses by taking each syllable independently to be either light or heavy. Since there are two independent choices for each of the n syllables in a length-n parse, we get the following counts:

(34) $P_{\mathrm{NM/QS}}(n) = 2^n \, P_{\mathrm{NM/QI}}(n)$

(35) $P_{\mathrm{M/QS}}(n) = 2^n \, P_{\mathrm{M/QI}}(n)$

(36) $P_{\mathrm{M}+\varnothing\mathrm{/QS}}(n) = 2^n \, P_{\mathrm{M}+\varnothing\mathrm{/QI}}(n)$

Observe that this covers all the possibilities of QS parses: no new groupings, or assignments of stressed/unstressed status, are made available when the quantity distinction is imposed. Recall that in the QS case we are lumping all parses together from every possible QS input.

6 Generative Schemes

The counting strategies can be turned into procedures that produce the parses.

6.1 QI Generation

The method of continuations can be put to use quite directly. Let K_1, K_2,… be sets of output parses, where K_n is based on input of length-n syllables. Let's set up K_1 by hand:

(37) $K_1 = \{ \|x, \|X \}$

We notate carefully, so as to feed properly in the continuation recipe.
Now we iterate through this set, examining the final symbol of each parse, storing for each of them *all* of its licit continuations, following the recipe of table (15) above.[13]

(38) 1σ parses to 2σ parses

$$-x \rightarrow \quad \|x\mathbf{X}\|$$
$$\|x\|\mathbf{x}$$
$$\|x\|\mathbf{X}$$

$$-X \rightarrow \quad \|X\mathbf{x}\|$$
$$\|X\|\mathbf{x}$$
$$\|X\|\mathbf{X}$$

This gives us the six possible parses on a length-2 input. Continue in this fashion, iterating through each of these six, producing the continuations, and we'll get the 16 length-3 parses; and so on.

Let's lay out the results for the first half of the length-3 set:

(39) 2σ parses to 3σ parses (half)

    a. $\|xX\| \quad \rightarrow \quad \|xX\|\mathbf{x}, \quad \|xX\|\mathbf{X}$

    b. $\|x\|x \quad \rightarrow \quad \|x\|\mathbf{xX}\|, \quad \|x\|x\|\mathbf{x}, \quad \|x\|x\|\mathbf{X}$

    c. $\|x\|X \quad \rightarrow \quad \|x\|X\mathbf{x}\|, \quad \|x\|X\|\mathbf{x}, \quad \|x\|X\|\mathbf{X}$

The remaining half, we see, consists of the X/x-duals of these forms.

6.2 QS Generation: Copy & Change

The basic problem here is to take a sequence of n identical characters and produce the full set of sequences in which each character freely takes on one of two distinct forms.

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[13] Akers 2008 is the first work to convert the counting scheme of table (15) into a candidate generator.

Here's one way to do it. For purposes of illustration, let's take T and F as our two basic characters. Suppose we have a list containing a sequence of 3 T's: ⟨TTT⟩. The following procedure will generate every sequence of length 3 over {T,F}.

1a. Copy the list and attach it to the original, producing:
> TTT
> *TTT*

1b. Turn all *first* characters *in the copy* to their opposite value:
> TTT
> ***F***TT

2a. Copy this whole list, and attach it to itself:
> TTT
> FTT
> *TTT*
> *FTT*

2b. Turn all *second* characters in the *copy* to their opposite value:
> TTT
> FTT
> T***F***T
> F***F***T

3a. Copy *this*, and attach:
> TTT
> FTT
> TFT
> FFT
> *TTT*
> *FTT*
> *TFT*
> *FFT*

3b. Now turn all third characters in the copy to their opposite value:
> TTT
> FTT
> TFT
> FFT
> TT***F***
> FT***F***
> TF***F***
> FF***F***

In this method, there are *n* steps for a length-*n* string. We start out at step 1 with a one-element list containing a single length-*n* string.

On the mth step, we copy the result L_{m-1} of the $(m-1)^{th}$ step and subjoin the copy to the original, creating a list of the form $L_{m-1} + L_{m-1}$. Then we change each character in the mth serial position in each string *of the copy* to its opposite (non-initial) value. That's it.

We will certainly want to obtain all faithful prosodic parses from a given input; in this case, the input must have the same quantitative profile as all of its output parses. To generate, we must therefore

change the *input* and everything in its output-set appropriately and simultaneously. So we apply the method to a list structure that joins the input with its QI parses.

To illustrate, let's construct the QS parses on all inputs of length 2. In the table below, the start row contains the input /xx/ and its parses. The final block (2b) lists all QS inputs of 2 syllables in length, from /xx/ to /hh/. Each is associated with a row that contains all its parses.

This requires two steps of copy & change. We write ch(k) for the procedure changing the kth character in the copy. We replace "‖" with ".".

Start: QI parses	L_0	xx	.x.x.	.x.X.	.X.x.	.xX.	.Xx.
1a. Copy L_0	$L_0 + L_0$	xx	.x.x.	.x.X.	.X.x.	.xX.	.Xx.
		xx	*.x.x.*	*.x.X.*	*.X.x.*	*.xX.*	*.Xx.*
1b. Change copy	L_1: ch(1)	xx	.x.x.	.x.X.	.X.x.	.xX.	.Xx.
		hx	.**h**.x.	.**h**.X.	.**H**.x.	.**h**X.	.**H**x.
2a. Copy L_1	$L_1 + L_1$	xx	.x.x.	.x.X.	.X.x.	.xX.	.Xx.
		hx	.h.x.	.h.X.	.H.x.	.hX.	.Hx.
		xx	*.x.x.*	*.x.X.*	*.X.x.*	*.xX.*	*.Xx.*
		hx	*.h.x.*	*.h.X.*	*.H.x.*	*.hX.*	*.Hx.*
2b. Change copy	L_2: ch(2)	xx	.x.x.	.x.X.	.X.x.	.xX.	.Xx.
		hx	.h.x.	.h.X.	.H.x.	.hX.	.Hx.
		x**h**	.x.**h.**	.x.**H.**	.X.**h.**	.x**H.**	.X**h.**
		h**h**	.h.**h.**	.h.**H.**	.H.**h.**	.h**H.**	.H**h.**

We are now fully equipped to go all the way from a starting point "‖", using the method of continuations to produce QI parses of whatever length we desire and then, by means of the copy & change procedure, to produce the full panoply of QS parses. Parses marked for main-stress can be produced by working through the NM parses, iteratively selecting every X or H for promotion.

6 Concluding Remarks

Deploying techniques to solve a natural formal question—*how many parses*?—has led us to simple, effective methods for *constructing* the parses in their entirety. These methods enable the analyst to conduct sound analysis. We gain knowledge not only of parsing numerics, but also of the entire range of structures implied by our structural assumptions.

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ANCIENT GREEK PITCH ACCENT:
EXTENDING TONAL ANTEPENULTIMACY TO ENCLITICS AND THE *ΣΩΤΗΡΑ* WORDS[*]

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This article extends Itô & Mester's (2016) tone-based analysis of the recessive pattern in Ancient Greek to enclitic constructions and the so-called *σωτῆρα* (sotera) words. The hub of Itô & Mester's proposal is that recessive accentuation results from a tonal constellation that includes the basic word melody, i.e. HL, and a word-final boundary tone $L_\%$ that is strictly confined to the last mora of the word, e.g. $o^H i^L ko^{L\%}s$ 'house'. This analysis, however, cannot straightforwardly account for the accentual behavior of enclitic structures, especially those in which the final syllable of the host – presumably reserved for the $L_\%$ – surfaces with a H tone, e.g. $o^H i^L ko^H s$ *tinos* 'someone's house'. Furthermore, it cannot explain the dubious accentual behavior of word-final consonant clusters, especially in relation to the retraction of H in *σωτῆρα*-type words like $ke^H \varepsilon ryks$ 'orator', instead of the expected $k\varepsilon\varepsilon^H ry^L k_\mu^{L\%}s$, without postulating an additional stratum. In this article, we claim that Itô & Mester's analysis can be easily sustained provided it is amended, first, with the notion of *phonological adjunction* (Itô & Mester 2007, 2009) that provides a more refined layering of phonological structure necessary for the prosodification of certain enclitic patterns and, second, the premise that phonological representations are built of symbols (e.g. segments, moras) that are numerically *gradient* (Smolensky & Goldrick 2016). Gradient representations allow us to distinguish between moras with different degrees of strength and hence make various tonal processes sensitive to such strength differences.
Keywords: activity level, Ancient Greek, enclitics, gradient symbolic representation, phonological adjunction, tonal antepenultimacy

1 Introduction

The status of pitch accent systems as a typologically independent category, next to stress and tone systems, has been called into question, most notably by Hyman (2009: 213–215) who argues against the existence of a pitch-accent prototype. In particular, he claims that the so-called pitch accent languages simply pick-and-choose properties from both tone and stress systems often giving rise to hybrid and analytically indeterminate systems that are tough to typologically categorize. A typical example is Tokyo Japanese, which has been analyzed both accentually and tonally (McCawley 1968, 1977, 1978, Haraguchi 1977, 1999, Poser 1984, Pierrehumbert & Beckman 1988, and so on) with no consensus whatsoever on the exact role, if any, of the foot structure in the tonal/accentual grammar (see Poppe 2015 for extensive argumentation based on cross-dialectal research). Ancient Greek[1] is another pitch accent system which has been analyzed – within the generative framework at least[2] – by means of both metrical structure and

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[*] I wish to thank two anonymous reviewers for their valuable comments and suggestions. All errors and infelicities remain my own.

[1] In this article Ancient Greek refers strictly to the Attic dialect (7th c. BC – 3rd c. BC), which has been described as a pitch accent language (see Probert 2006: 55, and references cited therein). Other dialects, such as Thessalian, for example, are believed to have replaced pitch accent with stress (Probert 2006: 73–74).

[2] Ancient Greek accentuation has been a favorite topic of investigation both in generative phonology (Kiparsky 1967, 1973, 2003, Kiparsky & Halle 1977, Sommerstein 1973, Steriade 1982, 1988, Sauzet 1989, Golston 1990, Noyer 1997, Halle 1997,

contrastive relative pitch. More specifically, both syllabic and moraic trochees have been proposed (e.g. Steriade 1988, Sauzet 1989, Golston 1990) to account for the positioning of the H tone either on the antepenultimate syllable, e.g. *pélekys* 'axe-NOM.SG'[3] or on the antepenultimate mora, e.g. *daímɔɔn* 'god-NOM.SG', commonly known as the *recessive* pattern. Under Sauzet's (1989) and Golston's (1990) analysis, for instance, moraic trochees are built from right to left, e.g. pe(leky)[s][4] 'axe-NOM.SG', (*dai*)(*mɔɔ*)[n] 'god-NOM.SG', whereas tones are aligned with specific positions within these feet. More specifically, the L component of Allen's (1973) HL 'contonation' is aligned with the head mora of the rightmost foot, whereas the H surfaces on the immediately preceding vocalic mora: $pe^H(le^Lky)[s]$, (*dai^H*)(*mɔ^Lɔ*)[n].

Itô & Mester (2016) argue that some features of particular pitch accent systems, such Ancient Greek, are basically tonal in nature and pursue a non-metrical approach in order to capture the antepenultimacy bias exhibited by the recessive pattern. More specifically, they argue that recessive accentuation results from a tonal constellation that includes the basic word melody, i.e. HL, and a boundary Low tone, symbolized as $L_\%$,[5] that indicates the end of the *phonological word* (ω, Selkirk 1981, Nespor & Vogel 1986), e.g. $pe^Hle^Lky^{L\%}[s]$, $dai^Hmɔ^Lɔ^{L\%}[n]$. An integral role in their analysis has a tonal anti-lapse constraint, which is at play in other pitch accent systems such as Japanese. This constraint militates against the presence of more than one low-toned vocalic mora at the right edge of the word and, therefore, ensures that the boundary tone (i.e. $L_\%$) and the tonal fall that yields will be confined to the very end of the word.

In this article, we will claim that Itô & Mester's proposal – as it stands – faces some empirical challenges and, therefore, needs to be modified. More specifically, we will show that their analysis encounters some serious problems in deriving the correct tonal patterns in certain host+clitic constructions and, in particular, those in which the last mora of the host is either extrametrical or linked with a lexically-specified tone. We propose, therefore, a revised analysis that incorporates two key elements: first, the notion of *gradience*, that is, the premise that phonological representations are built of symbols (i.e. segments, moras) that have a different degree of strength or presence in the structure (Smolensky & Goldrick 2016, see also Inkelas 2015); and, second, the concept of *phonological adjunction* (Itô & Mester 2007, 2009 et seq.), which provides the appropriate platform for deriving a more refined layering of prosodic structure, needed for the prosodification of certain enclitic patterns. Gradient representations will be shown to be pivotal in determining the moraicity of the last syllable and hence the ability of a boundary tone to associate to the target position (i.e. the final mora of the ω). The presence or not of $L_\%$ at the final mora will turn out to have important repercussions on the overall tonal pattern of the word in isolation and in enclitic contexts. On the other hand, adjunction enriches the set of structural relations within the ω, thus enabling us to treat enclitics in specific accentual contexts as occupying positions within extended ω's.

The remainder of this article is organized as follows: In Section 2 we present Itô & Mester's tonal antepenultimacy account of the recessive pattern in Ancient Greek and discuss some problems it encounters at the empirical level. The solution to these problems is offered in Section 3 where we develop an analysis that makes crucial use of gradient phonological representations and extended word structures. Section 4 offers a brief overview of alternative analyses that employ both metrical and tonal constraints and discusses their shortcomings compared to the analysis proposed here; it also concludes this article.

Blumenveld 2004, among others) as well as in the non-generative grammatical tradition (Lejeune 1945, Vendryes 1945, Allen 1966, 1973, 1987, Devine & Stephens 1985, 1994, Probert 2000, 2006, among others).

[3] The following abbreviations are used in this article: acc: accusative, dat: dative, gen: genitive, masc: masculine, nom: nominative, pl: plural, sg: singular, TBU: tone bearing unit, Ø: null suffix.

[4] Final consonants are extrametrical [C] and, consequently, do not contribute to the moraicity of the syllable.

[5] An anonymous reviewer points out that the % symbol is commonly used to indicate the boundary of an *Intonation Phrase* and proposes instead to codify the boundary tone with a diacritic that refers to its domain of association, namely L_ω (see Hayes & Lahiri 1991). However, we decided to remain faithful to Itô & Mester's original notation for reasons that will become clear in Sections 3.2-3.3, where enclitic constructions are discussed.

2 Antepenultimacy as the result of a L%, and some problems

In this section, we present Itô & Mester's proposal on how the recessive pattern is computed in Ancient Greek (Section 2.1) and then move on to discussing some challenging data (Section 2.2) from enclitic constructions which pose a threat to their account. The discussion also extends to a second group of problematic data that involve the traditional σωτῆρα (sotera) law (from *sɔɔtéɛra* 'savior-ACC.SG'). This law prohibits a H to fall on the second mora of the penultimate syllable, if the final contains a single *vocalic* mora: *VV́.V. Under Itô & Mester's account, such cases cannot be handled unless one posits a retraction rule that triggers leftward shift of the H at a later stage/different stratum of the phonological computation (see also Kiparsky 2003).

2.1 Itô & Mester's tonal antepenultimacy and the recessive pattern

In Ancient Greek recessive word accent may fall within one of the last three syllables but not further than the antepenultimate mora when the final is (at least) bimoraic ('Law of Limitation'). The weight of the final syllable is causally related to the surfacing of the antepenultimacy effect that typically characterizes recessive accentuation, and has been subject to many different interpretations, as will be discussed in Sections 3 and 4. More precisely, words ending in a light (i.e. CV, CVC) syllable have a H tone (known as *acute* 'V́') either on the antepenultimate syllable (1a–d) or on the antepenultimate mora (1e–g). Shorter words that end in a HEAVY-LIGHT sequence, like the ones in (1f-g), reveal the full HL tonal melody (traditionally called *circumflex* 'V́V̀'). If, on the other hand, the final syllable is heavy (i.e. CVV, CVCC), the H is restricted to the penult, as demonstrated by the examples in (2). Antepenult accent is therefore permitted in a word like *ánt^hrɔɔpos* (1c) with short /o/ in the last syllable, but not in *ant^hrɔɔpoo* (2a) (**ánt^hrɔɔpoo*) with long final /o/.

(1)   *Recessive accent in words ending in a light (CV, CVC) syllable*
        a.   pélekys   /peleky-s/   CV^H.CV^L.CVC   'axe-NOM.SG'
        b.   hélɛɛnos   /helɛɛn-os/   CV^H.CV^L V.CVC   'Hellene-GEN.SG'
        c.   ánt^hrɔɔpos   /ant^hrɔɔpo-s/ V^HC.CV^L V.CVC   'man-NOM.SG'
        d.   hɛérɔɔa   /hɛɛrɔɔ-a/   CVV^H.CV^L V.CV   'hero-ACC.SG'
        e.   sɔɔmata   /sɔɔmat-a/   CVV^H.CV^L.CV   'body-NOM.PL'
        f.   sɔɔ́ma   /sɔɔmat/   CV^H V^L.CV   'body-NOM.SG'
        g.   óìkos   /oiko-s/   V^H V^L.CVC   'house-NOM.SG'

(2)   *Recessive accent in words ending in a heavy (CVV, CVCC) syllable*
        a.   ant^hrɔɔ́poo   /ant^hrɔɔp-oo/ VC.CVV^H.CV^L V   'man-GEN.SG'
        b.   daímɔɔn   /daímɔɔn/   CVV^H.CV^L VC   'god-NOM.SG'
        c.   kapádoks   /kapadok-s/   CV.CV^H.CV^L CC   'Cappadocian-NOM.SG'
        d.   lipót^hriks   /lip-o-t^hrik^h-s/ CV.CV^H.CV^L CC   'hairless-NOM.SG'

The above examples illustrate that there are certain phonologically defined positions where the tonal melody may fall and others where it may not. Ancient Greek is a morphology-controlled system at heart in the sense that the position of accent/tone is not always predictable from the phonological shape of the word; rather, it is a lexical property of individual morphemes (e.g. Kiparsky 1973, Steriade 1988). That is to say, many (un)derived words have a lexically pre-linked accent/tone on positions other than those defined by recessive accentuation, as demonstrated by the examples in (3).[6]

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[6] Non-recessive accentuation is peripheral to Itô & Mester's analysis and, consequently, to the subject matter of the present section. It will be briefly addressed in Section 2.2 in relation to the accentual patterns of enclitic constructions.

(3)   *Lexically accented words*
    a.   iskʰyyrós   /iskʰyy-ro^{HL}-s/   'strong-MASC.NOM.SG'
    b.   psyykʰikoós   /psyykʰ-iko^{HL}-s/   'spiritual-MASC.NOM.SG'
    c.   patεέr   /patεε^{HL}r/   'father-NOM.SG'
    d.   psyykʰikɔ́ɔ̀n   /psyykʰ-iko-ɔ^{H}ɔ^{L}n/   'spiritual-MASC.GEN.PL'
    e.   patrída   /patr-i^{H}d-a^{L}/   'fatherland-ACC.SG'

Itô & Mester treat Ancient Greek as a pitch accent system, where recessive (i.e. non-lexical) word accent is interpreted as the combination of a tonal HL complex (see Allen 1966) followed by boundary tone L$_%$ that demarcates the end of the ω.[7] Their approach builds on Misteli's (1868) insight that the word-final mora is reserved for this L$_%$ boundary tone, whereas the preceding ones host the HL contonation. A significant component of their analysis is that it dispenses with a foot-controlled conditioning in the distribution of accent/tones. All that is needed is the constraint NOLAPSE-L$_%$/μ ('L$_%$ occupies no more than one mora', Itô & Mester 2016: 5), which essentially prohibits L$_%$ to span over more than one mora. Ranked high enough in the Ancient Greek tonal grammar, this constraint penalizes prospective outputs like *antʰrɔɔpo$^{L%}$o$^{L%}$*, for instance, in which the L$_%$ is associated to two consecutive moras. With L$_%$ occupying the final mora, the L element of the HL contonation will then associate to the immediately preceding mora(s) (depending on the length of the penultimate), whereas the H will dock on the mora of the preceding syllable:

(4)   *The tonal melody of recessive accentuation* (Itô & Mester 2016)

    H L   L$_%$
    | ＼ |
    μ. μ (μ.) μ.   pélekys (1a), hélεεnos (1b)
    μ μ. μ.   sɔ́ɔ̀ma (1f), óikos (1g)
    μμ. μ μ. μ.   ántʰrɔɔpos (1c), hεέrɔɔ (1d)
    μμ.μμ. μ μ.   antʰrɔɔ́poo (2a)

Furthermore, words ending in a consonant cluster like *li.pó.tʰrik$_μ$s* (2d) are taken to place the H tone of the contonation on the penultimate syllable because the pre-final coda consonant, being intrametrical, projects a mora,[8] as opposed to the final one (see fn 4). Evidently, this is the mora that hosts the L$_%$, as portrayed in (5a). Had the consonant at issue lacked a mora, the H tone would have been located on the antepenultimate syllable, which is not the case, as evinced by the ungrammaticality of (5b).

(5)   *Recessive accentuation in words ending in CC#*
    a.   H LL$_%$ b.   H L L$_%$
        | || | | |
        μ. μ. μμ.   μ. μ. μ.
        li.pó.tʰrik$_μ$s (2b)   *lí.po.tʰriks

According to Itô & Mester, the H tone is compelled to appear as close to the left edge of the word (ALIGNLEFT-H/ω$_i$) as permitted by the constraints that regulate the alignment of L and L$_%$. CONTIGUITY-T ensures that there will not be a gap, i.e. a tone-less mora, between adjacent tones, whereas CRISPEDGE-σ/T penalizes a tone that spreads over two syllables. Finally, ALIGNRIGHT-L$_%$/ω specifies the ω as the domain at the right of which L$_%$ occurs. These constraints are stated in (6):

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[7] From Hyman's (2009) perspective, Ancient Greek could be approached as a *restricted tone system* (see also Voorhoeve 1973), which is the view we adopt in our analysis (Sections 3 and 4).
[8] Steriade (1988: 273–275) discusses several compound words of this pattern, e.g. *polyántʰranks* 'with much coal' (**polýantʰranks*).

(6)   *Itô & Mester's constraints for recessive accent*
  a.   ALIGNRIGHT-L%/ω: L% is a word-final boundary tone.
  b.   CONTIGUITY-T: Tone domains are contiguous.
  c.   CRISPEDGE-σ/T: Multiple linking of tones between syllables is prohibited.
  d.   ALIGNLEFT-H/ωi:[9] H is leftmost in ω.

The ranking of the constraints presented in tableau (7) generates all permissible recessive patterns. Inputs with a final light syllable will yield a H tone on the antepenultimate syllable (7i–a) and not on the penultimate one (7i–b), because ALIGNLEFT-H/ωi keeps the H as far from the right edge as permitted by the higher ranked constraints. Notice also that this constraint, being strategically ranked above CONTIGUITY-T, rules out the form *an^H t^h rɔ^L ɔ^L po^L% s, where the H is located on the consonantal mora of the initial syllable in compliance with the demands of CONTIGUITY-T. That is, ALIGNLEFT-H/ωi, from the ranking it occupies, masks the moraicity of word-medial consonantal moras.

Moreover, words with a bimoraic final syllable will have their H tone placed on the second mora of the penult (7ii–a). This is ensured by the workings of the constraints that regulate the alignment of L%, which render ungrammatical candidate outputs such as (7ii–b, c) and (7ii–d). The alignment of the second leg of the HL contonation is determined by CONTIGUITY and CRISPEDGE; the former eliminates candidate (7ii–f), while the latter rules out candidate (7ii–e).

			AR-L%	CONTIGUITY-T	CRISPEDGE-σ/T	NOLAPSE-L%/μ	AL-H/ωi
(7) i. /anthrɔɔpo-s/i HLL%	☞	a. H L L% — ánthrɔɔpos					
		b. HL L% — anthrɔ́ɔpos					*!
ii. /anthrɔɔp-oo/i HLL%	☞	a. HLL% — anthrɔɔ́poo					**
		b. H L L% — ánthrɔɔpoo	*!				
		c. H L L% — anthrɔ́ɔpoo				*!	*
		d. H L L% — ánthrɔɔpoo				*!	
		e. HL L% — anthrɔ́ɔpoo			*!		*

---

[9] Itô & Mester index this constraint to apply to an *i* class of lexical words, that is, those that are lexically specified to be accented recessively. However, indexing can be dispensed with if word-final H(L) (see the examples in (3)) is treated as the result of lexical pre-specification (i.e. pre-association of HL to the final short or long TBU of a particular exponent).

f.   H   L   L%
     | \ |
  ántʰrɔɔpoo
		*!		

2.2 Empirical problems with the tonal antepenultimacy account

When a clitic is attached to the right edge of a word, the accentual pattern within the host+clitic construction alters dramatically.[10] Some representative examples are listed in (8). The host in (8a) has a recessively assigned H on the non-head mora of the penultimate syllable because the final long syllable can foster both the L of the HL contonation and the L% that demarcates the right edge of the ω. Disyllabic enclitics appear either with a H on their final syllable or with a HL when inflected with the inherently accented gen.pl suffix /-ɔ́ɔ̀n/. Strangely enough, the exact same set of enclitics surface with no H(L) tone(s) after a host that displays another pattern of recessive accentuation (8b) or a host that has a lexically pre-specified tonal melody on its final syllable, e.g. *hodós, pylɔ́ɔ̀n* (8c):

(8)   a. $\mu\mu^H.\mu^L\mu^{L\%}$ *host + accented disyllabic clitic*

                    daímɔɔn tinós   'someone's god'
                    elpídɔɔn tinɔ́ɔ̀n   'of some (GEN.PL) hopes (GEN.PL)'
                    (cf. daímɔɔn tis   'some god')

         b.   *host V(C)# + accentless clitic*

                    ántʰrɔɔpós tis   'some man'
                    ántʰrɔɔpós tinos   'someone's man'
                    ɛɛ́koosá tinɔɔn   'I heard them (GEN.PL)'
                    óìkós tis   'some house'
                    óìkós tinos   'someone's house'

         c.   *host V́C/V́V̀C# + accentless clitic*

                    hodós tis   'some street'
                    hodós tinos   'someone's street'
                    pʰɔ́ɔ̀s ti   'some light'
                    pʰɔ́ɔ̀s tinos   'someone's light
                    pylɔ́ɔ̀n tinɔɔn   'of some (GEN.PL) gates (GEN.PL)'

Obviously, the examples in (8b) are problematic under Itô & Mester's tonal antepenultimacy analysis. If the final mora of the host is reserved for the L%, then the insertion of the H in this exact position is unexpected to say the least. Moreover, the presence of the H in the final syllable seems to affect the tonal pattern of the following enclitic, which surfaces with no tone whatsoever, (8b–c), as opposed to the tonal behavior of the same clitic in the context of a VV(C)-final host.

       By general acknowledgement, Ancient Greek enclitics are extremely resilient to analyses that do not resort to some kind of special stipulation in order to tackle their various accentual peculiarities (see Warburton 1970, Sommerstein 1973, Steriade 1988, Golston 1990, Halle 1997, Blumenfeld 2004, and also the discussion in Section 4). In the next section, we will show that Itô & Mester's account can be easily preserved provided it is amended with a richer representational apparatus and a more fine-grained layering of the ω.

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[10] The Ancient Greek enclitic stock includes: (a) the indefinite *tis, ti* 'someone, something' in all its inflected forms; (b) the oblique cases of the personal pronouns, e.g., *me* (1ACC.SG), *moi* (1DAT.SG); (c) the present indicative of the verbs *pʰɛɛmí* 'I say' and *eimí* 'I am' (except for 2sg forms); (d) several indefinite adverbs, e.g., *poú* 'somewhere'; (e) several postpositive conjunctions and particles, e.g., *dé* 'but', *te* 'and', *gár* 'for, namely'. For a complete list, see Probert (2003) and Revithiadou (2013).

A second set of problematic data includes the so-called *σωτῆρα*-words and, particularly, those that end in a consonant cluster (9). In such words, the H must retract to the first mora of a heavy penultimate, if the final is light. Retraction affects both lexically specified and recessively assigned H tones but, crucially, only vocalic moras count as light. More specifically, roots that have a lexically pre-specified HL melody at their final syllable, e.g. /sɔɔtɛɛ^{HL}r-∅/ *sɔɔtɛɛ́r* 'savior-NOM.SG', /gʰyy^{HL}p-s/ *gʰyýps* 'vulture-NOM.SG', shift their H to the head mora when combined with a light inflection, e.g. *sɔɔtɛ̀ɛ̀ra* 'savior-ACC.SG' (cf. *sɔɔtɛɛ́rɔ̀ɔn* 'savior-GEN.PL'), *gʰýỳpes* /gʰyy^{HL}p-es/ 'vulture-NOM.PL'. Furthermore, H retraction affects VC-final roots like /kɛɛryk-/ 'orator' which surface as *kɛ́ɛ̀ryks* 'orator-NOM.SG', and not as *kɛɛ́ryks* (kɛɛ^{H}ry^{L}k$_μ$$^{L\%}$s), as predicted by the tonal antepenultimacy account. Itô & Mester address words like the ones in (9) in a footnote and consider them to result from a retraction that applies at a later stage, intimating that more than one stratum may be required for the analysis of Ancient Greek accentuation (see Kiparsky 2003, also Noyer 1997).[11]

(9)   *σωτῆρα-VCC# words*
    a.   *kɛ́ɛ̀ryks*   /kɛɛryk-s/   'orator-NOM.SG'
    b.   *katɛ́ɛ̀lips*   /katɛɛlip-s/   'terrace-NOM.SG'
    (cf. *kapádoks* 'Cappadocian-NOM.SG' (2c); *lipótʰriks* 'hairless-NOM.SG' (2d))

Puzzlingly, enclitic constructions with σωτῆρα-VCC words (10a), which is the focus of our discussion in this article, pattern accentually with words that end either in a long vowel (10b) or in a consonant cluster (10c) but, significantly, not with σωτῆρα-words of the former type (i.e. V-final) (10d–e). The fact that *kɛ́ɛ̀ryks* and *daímɔɔn* pattern alike in encliticization leads us to conclude that the mora contributed by the intrametrical consonant and the vocalic one are equivalent, at least for the purposes of accent assignment in enclitics, but certainly not for the σωτῆρα-type of H retraction.

(10)   a.   *kɛ́ɛ̀ryks tinós*   'someone's orator'
        b.   *daímɔɔn tinós*   'someone's god'
        c.   *kapádoks tinós*   'someone's Cappadocian'
        d.   *sɔɔtɛ̀ɛ̀rá tinos*   'someone's savior (ACC.SG)'
        e.   *gʰýỳpés tinos*   'someone's vultures (NOM.PL)'

        The aforementioned issues will be addressed and offered an explanation in the ensuing section on the basis of an analysis that implements gradient phonological representations (Smolensky & Goldrick 2016) and a prosodic structure that contains enough layers to accommodate all attested enclitic patterns.

3 Preserving Tonal Antepenultimacy

3.1 Gradient symbolic representations and moraic strength

As mentioned in Section 2.1, word-prefinal consonantal moras as well as final vocalic moras are treated alike by Itô & Mester because they can equally foster the L$_\%$:

(11)   a.   daímɔɔn   /daímɔɔn/   CVV^H.CV^{L}V$^{L\%}$C   'god-NOM.SG'
        b.   kapádoks   /kapadok-s/   CV.CV^H.CV^{L}C$_μ$$^{L\%}$C[12]   'Cappadocian-NOM.SG'

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[11] Itô & Mester point out that they are not aware of an alternative to a stratal analysis of the σωτῆρα Law, e.g. by means of OO-constraints (2016: 10, fn 11).

[12] There is an interaction between voicing and tone to the extent that it has been claimed that Low tone and [voice] are the same feature (e.g. Halle & Stevens 1971, Duanmu 1990, Bradshaw 1999, among others). For example, the spreading of a Low tone may be blocked by an intervening voiceless obstruent and, vice versa, the spreading of a High tone may be blocked by an intervening voiced obstruent (see Hyman & Schuh 1974, Tang 2008, Lee 2008, and many others for case studies). However, even

The equivalence of consonantal and vocalic moras is further substantiated by the tonal patterns of host+clitic constructions (see 10b–c), where both *daímɔɔn* and *kapádoks* are followed by a clitic that bears a H tone, as opposed to words ending in a light syllable (e.g. 8b) or words with a lexically specified tone (e.g. 8c). However, the discussion on σωτῆρα words has revealed that H retraction is sensitive to weight projected by vocalic elements only, as illustrated in (12), and not by consonants, regardless of how many they appear word finally.

(12) a. $k\acute{\epsilon}_\mu\epsilon_\mu ry_\mu ks$ *$k\epsilon\acute{\epsilon}ryks$ 'orator-NOM.SG'   CC#
      b. $p^hilosp\acute{\epsilon}_\mu\epsilon_\mu ly_\mu\eta ks$ *$p^hilosp\epsilon\acute{\epsilon}ly\eta ks$ 'fond of grottoes-NOM.SG'   CCC#

According to Smolensky & Goldrick's (2016) *Gradient Symbolic Representations* (GSR) model, the underlying phonological representations of morphemes (i.e. roots, affixes) consist of elements (i.e. segments, moras, tones, etc.), each of which has a specific numerical value – ranging from 0 to 1.0 – that reflects its differential degree of robustness. This value defines for each, say, segment token its *activation level* (AL).[13] Segments with an activity strength of 1.0 are strong enough to be pronounced and are impervious to change, as opposed to segments with an AL below 1.0, which remain silent. Interestingly, the realization of elements with a lower than 1 AL is subject to the satisfaction of certain conditions. For instance, a segment may acquire the extra strength it needs via fusion with a neighboring segment; alternatively, it may also get it from the Grammar, namely *Gen*, in the form of strength insertion/epenthesis (Smolensky & Goldrick 2016: 17–18).

    Building on the premises of GSR, we propose that an intrametrical (i.e. non-final) consonant in a coda position in Ancient Greek can indeed project a mora but, alas, a weaker one compared to vowels. This is because the consonant itself is not strong enough to project a mora with AL 1. Let us randomly assign to this consonant and its projected mora the AL value 0.5 (<1.0). The moraic make-up of words like the one in (11b) is therefore shaped as follows:

(13) μ_1 μ_1 μ_1 $\mu_{0.5}$
         | | | |
       $k a_1 p á_1 d o_1 k_{0.5} s$

As mentioned above, in order for a consonantal $\mu_{0.5}$ to be pronounced and, consequently, host the $L_\%$, the consonant must get the extra strength it needs from *Gen*. Activity insertion registers as a violation of DEP. More specifically, for a candidate in which the consonant /$k_{0.5}$/ surfaces as [k_1], *Gen* must add $1.0 – 0.5 = 0.5$AL to the inherent strength of the consonant. This is exactly the degree of DEP violation that must be indicated in the tableau for the strength enhancement of /$k_{0.5}$/. The same DEP violation should be indicated for the increase of /$k_{0.5}$/'s mora strength, raising the total of AL insertion to 1.0. The representation in (14a) depicts the weak input consonant which projects an equally weak and thus unpronounceable mora (14a), whereas (14b) illustrates the output form where the corresponding consonant and mora have been added supplementary activity strength.

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in languages where such interactions do occur, the association of a Low tone with an obstruent is not uncommon. Lee (2008: 179–182), for instance, shows that CVO(bstruent) syllables in Thai surface with L and HL tones (contra to the dictates of *VOICELESSOBSTRUENT/L). Although tone cannot be phonetically realized on a coda stop, Gordon (2001) has shown on the basis of a phonetic experiment that in certain tone systems (e.g. Hausa) a CVO syllable can even support a HL tone through the lengthening of the preceding vowel. Based on this information, therefore, the association of $L_\%$ with the mora of a voiceless consonant, although marked, is cross-linguistically attested.

[13] Smolensky & Goldrick (2016) do not address the source of an element's activity strength but Inkelas (2015), who proposes a similar representational model of strength scales, maintains that strength reflects the robustness of a phonological element's storage in memory. Here we take a more conservative view and consider AL values to be simply lexically specified.

(14)   a.   *Input with weak C & μ*   b.   *Output with strength enhanced C & μ*   *DEP violation*

μ_1 μ_1 μ_1 $\mu_{0.5}$ μ_1 μ_1 μ_1 μ_1 0.5 for final $\mu_{0.5}$
  | | | | | | | ⋮
k a $_1$ p a $_1$ d o $_1$ k $_{0.5}$ s   k a $_1$ p a $_1$ d o $_1$ k $_1$ s   0.5 for /k$_{0.5}$/

Activity increased moras projected by also activity increased consonants are associated to their sponsors via dotted association lines, as opposed to vocalic moras, which are linked with the vowels via straight lines. This difference in the type of association in essence reflects a distinction in the relation that is established between elements that share a morphological affiliation and those that do not. For instance, inherent properties of segments that are automatically projected during phonological computation (e.g. features, moras, pre-linked tones, etc.) are part of the same morphological exponent as their sponsors.[14] In reference to our example, vocalic moras share the same affiliation as the vowels they are projected from, an underling relation that is signaled here with the use of straight lines. Consonantal moras, on the other hand, contain – besides their inherent strength – epenthetic AL inserted during phonological computation. More precisely, they include segmental and moraic activity that is not part of the exponent a particular morpheme materializes with, hence the use of dotted association lines. Dotted associations will also be used to represent recessively assigned tones, as opposed to inherent, lexically-specified ones (see examples in 3), which are associated to their sponsors by means of straight lines.

Finally, in this article, instead of ranked constraints, we employ a *Harmonic Grammar* (Legendre et al. 1990, Legendre et al. 2006, Pater 2008/2016, among others) where Itô & Mester's constraints, stated in (6), are assigned a specific *weight* (*w*).[15] The tableau in (15) illustrates the computation of two candidate outputs, one with enhanced strength on its final consonant and mora (15a) and a more faithful one (15b).

(15) /ka$_1$pa$_1$do$_1$k$_{0.5}$-s/ HLL$_%$		AR-L$_%$	CONTIGUITY-T	CRISPEDGE-σ/T	NOLAPSE-L$_%$/μ	DEP	*H*
		w:5	*w*:4	*w*:3	*w*:2	*w*:1	
☞ a. H LL$_%$ ⋮ ⋮ ⋮ μ_1 μ_1 $\mu_1\mu_1$ k a p á d o k$_1$ s						−1	**−1**
b. H L L$_%$ ⋮ ⋮ ⋮ μ_1 μ_1 μ_1 $\mu_{0.5}$ k á p a d o k$_{0.5}$ s		−1					**−5**

Candidate (15b) ends in a weak mora which forces the boundary L$_%$ to be aligned to the pre-final μ_1 in violation of ALIGNRIGHT-L$_%$. Clearly, this candidate is less harmonic than (15a) which solves the problem by inserting a total AL of 1.0, i.e. 0.5 AL to /k$_{0.5}$/ and 0.5 AL to its mora. The epenthetic activity strikes a −1 penalty to DEP but still the *H* of (15a) is better than the *H* of (15b).

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[14] The theoretical framework this distinction is based on is *Colored Containment* (van Oostendorp 2006, Revithiadou 2007, Zimmermann 2017), which postulates that, first, the whole input (e.g. segments, features, prosodic nodes *and* their association relations) must be reconstructable from the output at any time and, second, elements and relations that are part of a morpheme's exponent share the same morphological affiliation or, else, *color*, in contrast to those inserted during phonological processing, which are considered epenthetic.

[15] Following Legendre et al. (2006) and Coetzee & Pater (2008) we convert violation marks to negative integer scores.

The major gain for implementing gradient representations is that at the surface both consonantal and vocalic moras appear to be equally strong word-finally, which explains their common tonal behavior as far as enclitic constructions are concerned. Another welcome result of this analysis is that it captures the inertness of word-medial consonantal moras with respect to tone assignment in words like, for example, $a^H\boldsymbol{nt}^hr\mathfrak{o}^L\mathfrak{o}^Lpo^{L\%}s$ (*$an^H t^hr\mathfrak{o}^L\mathfrak{o}^Lpo^{L\%}s$). Such coda consonants are enhanced enough to be pronounced but their moras remain weak ($\mu_{0.5}$) because in this particular environment they need not be strengthened, as opposed to final moras which are activated due to the pressure exercised by NOLAPSE-$L_\%/\mu$.

To get back to σωτῆρα words, gradient representations give us the means to formulate the law at hand by making direct reference to the inherent strength of moras. In particular, we propose that H retraction is enforced by a constraint that prohibits a H tone to be associated to the non-head mora of a heavy syllable if followed by the last strong mora (μ_1) of the ω:
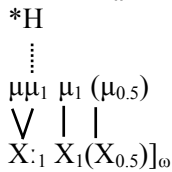
(16)   *The Σωτῆρα Law*
        *H
        ⋮
        $\mu\mu_1$ μ_1 ($\mu_{0.5}$)
        V | |
        $X_{:1}$ $X_1(X_{0.5})]_\omega$
        "Do not associate the H to the non-head mora if followed by the last μ_1 of the ω.'

This parochial constraint is made sensitive to the AL of elements that project moras of equal strength. In Ancient Greek, only vowels and diphthongs are strong enough to automatically project μ_1's. In other words, the constraint in (16) requires the HL melody to be realized as a contour when the final syllable is light with the proviso, however, that the relevant moraic material is projected by inherently strong elements. A consequence of this assumption is that consonantal moras, which are not automatically projected by an element with inherent AL 1, fall outside the purview of the Σ-law.

The following tableau indicates that the Σ-Law weighs more than all other constraints discussed so far, including *CONTOUR-T/σ ("No contour tone in the same syllable').[16] Candidate (17a) is the winner despite the violation of CRISPEDGE-σ/T. Violation of CONTIGUITY-T also generates a less harmonic output, namely (17b). Finally, candidate (17c) is also expelled because, by having the H associated to the non-head mora, it disobeys the Σ-LAW. All candidates included in the tableau enhance the AL of /$k_{0.5}$/ and its mora so that AR-$L_\%$ can be satisfied. However, the increase of activity strength has no bearing on the satisfaction of the Σ-LAW, because this constraint is sensitive to input strength only.

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[16] That *CONTOUR-T/σ ("No contour tone in the same syllable') has a relative high weight in the language is also evidenced by the fact that contour tones, although attested in Ancient Greek, arise only in certain environments, namely, in short words that consist of a HEAVY <(LIGHT)> syllable(s) like, for instance, (H) $p^h\acute{\mathfrak{o}}\grave{\mathfrak{o}}s$ 'light', H<L> *óikos* 'house', and in tonally pre-specified suffixes, e.g. gen.pl /-$\acute{\mathfrak{o}}\grave{\mathfrak{o}}$n/.

	Σ-LAW	AR-L%	*CONTOUR-T/σ	CONTIGUITY-T	CRISPEDGE-σ/T	NOLAPSE-L%/μ	DEP	*H*
	w:9	w:5	w:5	w:4	w:3	w:2	w:1	
(17) /kɛːₗryₗkˌₛ-s/ HLL% ☞ a. H L L% [representation] μμₗ μₗ μₗ kɛːₗryₗkₗs [kɛ́ɛ̀ryks]			−1		−1		−1	**−9**
b. HL L% [representation] μμₗ μₗ μₗ kɛːₗry ₗkₗs [kɛ́ɛ̀ryks]			−1	−1			−1	**−10**
c. H L L% [representation] μμₗ μₗ μₗ kɛːₗryₗkₗs [kɛɛ́ryks]	−1						−1	**−10**

To sum up, in this section we maintained that consonantal and vocalic moras are integrally different because they are projected by segments with a different degree of strength. On the surface, such disparities in the level of a segment's activity are evened out due to the supplementary strength added by the Grammar to pre-final coda consonants. Nonetheless, the intrinsic difference between the two types of moraic material is pertinent to tonal processes that are sensitive to the source of a mora's strength, such as the σωτῆρα retraction.

3.2 A re-analysis of ánthrɔɔpos-type words: Evidence from enclitic constructions

So far, we have established that on the surface VV- and VCC-final words end in a string of at least two strong moras. Interestingly, it is exactly this group of words that are followed by enclitics that surface with a tone (H or HL), as shown in (18). Here we will argue that an enclitic can surface with a tone only if the preceding word ends in a L%, that is, realizes the full HL+L% tonal melody within its domain. It remains an open question for now whether the H in *tinós* is inherent or not (although a dotted association line is used in the representation below). The tonal melody of the gen.pl form *tinɔ́ɔ̀n* is lexically-assigned by virtue of the inflectional suffix /-ɔ́ɔ̀n/. Enclitic tonal patterns will be discussed in detail in Section 3.3.

(18)   H   L L%   H   H L
         ┊ ╱┤ ┊   ┊   ││
     [μ(μ). μ μ]ω + tinos/tinɔɔn
     ka.pa.   doks
       dai.   mɔɔn
         kɛɛ. ryks

Contra to the data in (18), words that end in a light syllable are always followed by toneless clitics, even if the specific clitic form has a lexically pre-specified HL tone itself (e.g. *tinɔ́ɔn*). Curiously, in this setting the final syllable of the host surfaces with a H, which is totally unanticipated under Itô & Mester's analysis.

(19)   H   L   H
          ⋮   ∧   ⋮
        (μ)μ.   μμ   μ   + tinos/tinɔɔn
          an.   tʰrɔɔ. pos
          ɛɛ.   koo.   sa
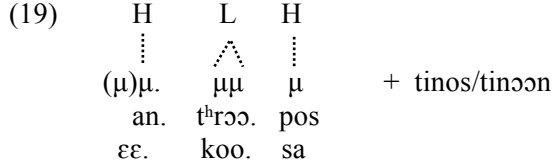
The solution we put forward here is quite straightforward: The lexical words in (19), as opposed to the ones in (18), have final syllable extrametricality (see, e.g., Steriade 1988). As a result, the final mora is not available to L$_{\%}$, therefore the boundary tone is forced to land on material added post-lexically at the right side of the string, i.e. the clitic. In this case, lexical word extrametricality is revoked and the tonal melody re-applies to the extended string, as shown below:

(20)   H   L   H   L L$_{\%}$
          ⋮   ∧   ⋮   ⋮ ⋮
         [μ.   μμ   μ   + tinos]$_{\omega}$
          an.   tʰrɔɔ. pos
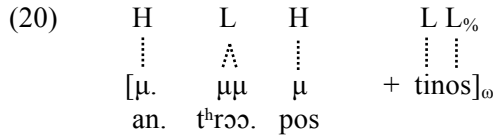
In short, we argue that the major difference between the structures in (18) and (19) is that in the latter the enclitic incorporates into the ω of the host, whereas in the former it prosodifies in a different fashion, to be discussed in Section 3.3. In the ensuing paragraphs, we present the technical details of the analysis for the data in (19).

We commence by recasting Itô & Mester's analysis of recessive accent in *ántʰrɔɔpos*-like words (see examples in 1) according to the course of action outlined above. Within a GSR framework, extrametricality can be viewed as a positional reduction of a mora's strength. In a way, our perspective resembles Hyde's (2001) conception of extrametricality as gridless moras, that is, moras that fail to project a mora-level gridmark. More specifically, the mora projected by the short final vowel becomes unavailable because it loses a critical portion of its strength in violation of MAX (Smolensky & Goldrick 2016: 18) under the pressure exercised by the constraint NONFIN-μ$_{1Lex}$. This constraint forbids final light moras to be strong, i.e. μ$_1$, and is indexed to refer strictly to lexical words. It should be noted that the degree of MAX violation is the sum of the violation of the relevant 'gradient' symbols a representation is built of. Assuming somewhat arbitrarily that 0.1 is just the bare minimum required for NONFIN-μ$_{1Lex}$ to be satisfied, we calculate the deletion of the positional loss of activity of the final μ$_1$ as a 0.1 violation of MAX and the total loss of the activity of L$_{\%}$ as a 1.0 violation. The total violation of MAX is therefore 1.1. This leads us to the conclusion that, in the present grammar, where NONFIN-μ$_{Lex}$ weighs more than the other constraints, including MAX, it is more important to not realize L$_{\%}$ at all (21a) than to have it linked to a non-final mora (21c). Of course, candidate output (21b) is the least harmonic one because it defies the constraint that compels moras to become weak word-finally. An output that satisfies NONFIN-μ$_{Lex}$ but surfaces with a contour tone like (21d) is also less harmonic than the winning candidate.

		NONFIN-$\mu_{1\text{LEX}}$	AR-$L_\%$	*CONTOUR-T/σ	CONTIGUITY-T	CRISPEDGE-σ/T	NOLAPSE-$L_\%$/μ	MAX	*H*
		w:7	*w*:5	*w*:5	*w*:4	*w*:3	*w*:2	*w*:2	
(21) /$a_1 n_{0.5} t^h r\mathfrak{o}:_1 p o_1 s$/ $H_1 L_1 L_{1\%}$	☞ a. H L $L_{0\%}$ ┊ ∧ $\mu_1\,\mu_{0.5}$ $\mu\mu_1$ $\mu_{0.9}$ $a_1\,n_{0.5}\,t^h\,r\mathfrak{o}:_1\,p\,o_1\,s$ [$\acute{a}nt^h r\mathfrak{o}:pos$]				−1			−1.1	**−6.2**
	b. H L $L_{1\%}$ ┊ ∧ ┊ $\mu_1\,\mu_{0.5}$ $\mu\mu_1$ μ_1 $a_1\,n_{0.5}\,t^h\,r\mathfrak{o}:_1\,p\,o_1\,s$ [$\acute{a}nt^h r\mathfrak{o}:pos$]	−1			−1				**−13**
	c. H $LL_{1\%}$ ┊ ┊┊ $\mu_1\,\mu_{0.5}$ $\mu\mu_1$ $\mu_{0.9}$ $a_1\,n_{0.5}\,t^h\,r\mathfrak{o}:_1\,p\,o_1\,s$ [$\acute{a}nt^h r\mathfrak{o}:pos$]		−1		−1			−0.1	**−9.2**
	d. HL $L_{0\%}$ ┊┊┊ $\mu_1\,\mu_{0.5}$ $\mu\mu_1$ $\mu_{0.9}$ $a_1\,n_{0.5}\,t^h\,r\mathfrak{o}:_1\,p\,o_1\,s$ [$ant^h r\acute{\mathfrak{o}}\grave{\mathfrak{o}}pos$]			−1				−1.1	**−7.2**

The tableau in (22) exemplifies the tonal pattern of the same word when an enclitic is added post-lexically (Taylor 1990, 1996, Condoravdi & Kiparsky 2001, Goldstein 2010, among others). Evidently, $L_\%$ does not have to be silenced here because the positional restriction on final moras is lifted; the original strength of the mora can no longer be affected by the positional subtraction of its AL triggered by NONFIN-$\mu_{1\text{LEX}}$. Moreover, the new target of $L_\%$ is not liable to the demands of NONFIN-μ_{Lex} because it is a function word.

	NONFIN-μ_{1LEX}	AR-L%	CONTIGUITY-T	CRISPEDGE-σ/T	NOLAPSE-L%/μ	MAX	*H*
	w:7	*w*:5	*w*:4	*w*:3	*w*:2	*w*:2	
(22) $[a^Hnt^hrɔ^Lɔ^Lpos]_ω$ tinos[17] $H_1L_1L_{1\%}$ ☞ a. H L $L_{1\%}$ ⋮ ⋮ ⋮ μ_1 μ_1 μ_1 ánt^{h}rɔːpos tinos $[a^Hnt^hrɔ^Lɔ^Lpo^Hs\ ti^Lno^{L\%}s]_ω$							**0**
b. H L $L_{0\%}$ ⋮ ⋮ μ_1 μ_1 μ_1 ánt^{h}rɔːpos tinos $[a^Hnt^hrɔ^Lɔ^Lpo^Hs\ ti^Lnos]_ω$						−1	**−2**

To sum up, we have offered a re-analysis of the problematic, under the tonal antepenultimacy account, pattern of *ánt^{h}rɔɔpos*-like words, rendered both in isolation and in enclitic contexts. The hub of our proposal is that the moraic and, by extension, the tonal make-up of the word end plays a pivotal role in the type of prosodic structure the host will form with its enclitic. More specifically, *ánt^{h}rɔɔpos*-type words were shown to have moras of diminished strength at their right side, so that the target TBU of L% is no longer tangible.[18] The immediate consequence of this situation is that such words form a plain ω with no boundary tone. In the context of an enclitic, however, the extrametricality condition is lifted and the clitic amalgamates with the host into a unified ω, which now provides the appropriate setting for L% to be realized. The discussion so far leads us to the somewhat tentative conclusion that there exist two types of ω's in Ancient Greek: those that have a weak, toneless right edge and those that end in a L%. The latter are constructed post-lexically, whereas the former lexically. In the ensuing section, we take a closer look at the prosodic pattern of enclitic constructions with words like *daímɔɔn* and *kapádoks* as their host, and provide our interpretation of the relevant data.

3.3 Enclitic structures with VV/VCC-final hosts and prosodic adjunction

Recessive tone assignment in words like *daímɔɔn* and *kapádoks* applies as anticipated: the HL+L% constellation is realized at the last three moras of the word with the H residing on the antepenultimate mora. Interestingly, when a clitic is added post-lexically, it surfaces with a tone either on its final syllable,

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[17] Incorporation of the clitic intimates that ALIGNRIGHT(LexW, R; ω, R) (McCarthy & Prince 1993) has a low weight in this grammar compared to PARSE-INTO-ω (Itô & Mester 2009: 139), which requires both the host and the clitic to be parsed into a single ω. Since the focus of our discussion is on the tonal pattern of the respective structures, the constraints that determine their prosodic organization are omitted from the tableau.

[18] Words with a pre-specified tone, e.g. *hodós tinos* 'some street' (8c), pattern with *ánt^{h}rɔɔpos*-like words. In such words the final mora is lexically pre-linked to the H of the HL tonal contonation, *hodo$^{H(L)}$s*, leaving the L component floating. Post-lexically, though, a disyllabic clitic offers a suitable host for both the L and the L%, i.e. *hodo^{H}s ti^{L}no$^{L\%}$s*. The suppression of pre-associated HL in clitics like *tinɔ̂ɔn*, e.g. *pylɔ̂ɔn tinɔɔn* 'of some (GEN.PL) gates (GEN.PL)' (8c), has been difficult to explain in previous accounts. Here we adhere to the following interpretation: Accented inflections are cross-linguistically more prone to be suppressed (Alderete 1999, Revithiadou 1999), which in the present framework is interpreted as having a low AL. However, the presence of L% as a boundary tone provides, via some sort of fusion, the extra boost to the L component of the HL melody – but, crucially, not to H – to reach an AL of 1.0. The end result is therefore an output clitic with a L, and not an HL, tone.

e.g. *kapádoks tinós*, *daímɔɔn tinós* or with a HL pre-specified tone on its inflection, e.g. *elpídɔɔn tinɔ̂ɔn*. On the basis of these data, one is led to ask: Why do clitics appear with a H(L) in this specific environment and, moreover, what kind of prosodic constituent do they form with their host?

We start by addressing the presence of a H on the last syllable of the function word. In contrast to lexical words, clitics do not display a recessive tone pattern, a rather peculiar property that has impelled researchers to propose that they are subject to a different accentual rule than lexical words (see Steriade 1988, Golston 1990, Blumenfeld 2004, among others, and Section 4 for a brief overview). Here we put forward the claim that clitics are toneless (unless they are inflected with the gen.pl suffix /-ɔ̂ɔn/) but in the environments in question surface with a boundary tone, namely $H_\%$. This hypothesis naturally raises a question on the type of prosodic boundary $H_\%$ signifies and, more specifically, whether it is a *phonological phrase* (φ) boundary (23a) or the boundary of an extended ω (23b). We will argue in favor of the representation in (23b) and thus for ω-adjunction.

(23)   a.   *φ-adjoined clitic*   b.   *ω-adjoined clitic*

daímɔɔn tinós   daímɔɔn tinós   (Selkirk 1995)
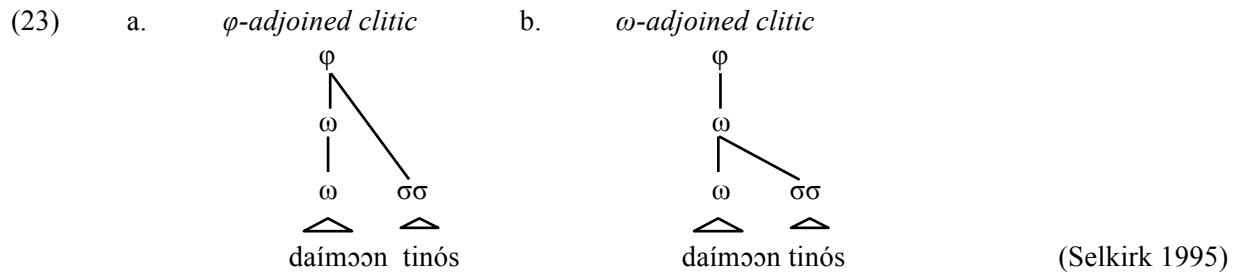
The rationale behind the appeal to ω-adjunction is twofold: First, in the Ancient Greek literature evidence from segmental processes and the metrics supports the view that clitics are not φ-attached (see Goldstein 2010 and references cited therein). Second, having the same clitic prosodify at the level of the ω or the φ, depending on the tonal configuration of the host, finds – to my knowledge – no empirical support from cross-linguistic evidence. For one thing, a major gain of employing adjunction is that it allows us to accommodate differences in the accentual phonology of enclitic constructions by simply enforcing additional layers of structure. This line of thinking is in accord with Itô & Mester's (2007, 2009) sparse version of the *Prosodic Hierarchy* (Selkirk 1981, Nespor & Vogel 1986, among others) which includes fewer prosodic categories but, importantly, makes a crucial use of adjunction and relational notions such as *maximal* and *minimal* projections of categories. As depicted in (24), by including prosodic adjunction in our parsing apparatus, we can get the largest projection of ω, namely the 'maximal ω' (ω^{max}, 'ω not dominated by ω') and the smallest projection of ω, that is, the 'minimal ω' (ω^{min}, 'ω not dominating ω').

(24)   *Prosodic adjunction at ω*

⟵ *maximal projection*

⟵ *minimal projection*

(Itô & Mester 2007, 2009)
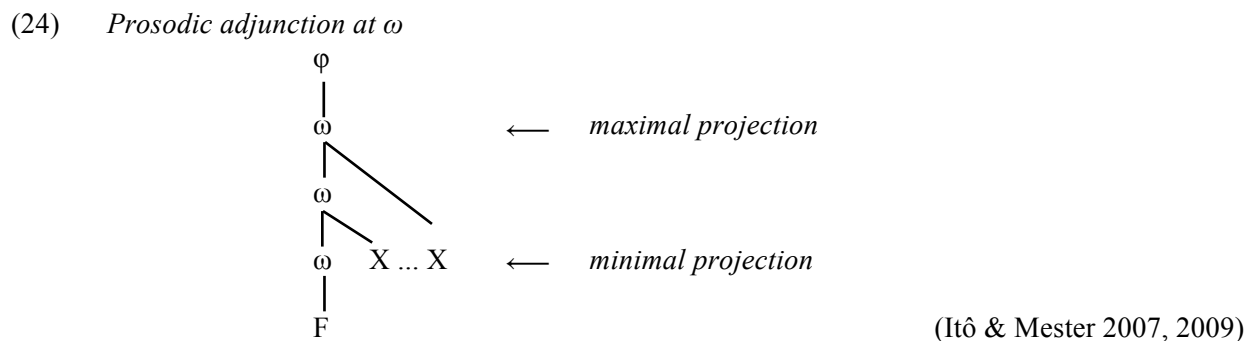
All these layers represent the different ways material can be prosodified at the level of the ω. So far, we have shown that *ánthrɔɔpos*-type words incorporate the enclitic in a single ω, the right edge of which is signaled by a $L_\%$. Here, we will argue that *daímɔɔn*- and *kapádoks*-type words are prosodically organized into an extended ω together with the clitic, namely a ω^{max}, which is demarcated by a $H_\%$. The tableau in (25) explicates post-lexical tone assignment in the input string /[dai^{H}mɔ^{L}ɔ$^{L\%}$n]$_\omega$ tinos/. The

focal point here is obviously the tonal behavior of the clitic. The constraint ALIGNRIGHT-H$_\%$/ω^{max} compels the alignment of H$_\%$ to the rightmost mora within the ω^{max} domain. Needless to say, realization of H$_\%$ in the pre-final mora (25b) or annihilation of its strength (25c), which is tantamount to deletion, results in less harmonic outputs.

		AR-H$_\%$	MAX	H
		w:5	w:2	
(25) [dai^{H}mɔ^{L}ɔ$^{L\%}$n]$_\omega$ tinos H$_\%$	☞ a. H$_{1\%}$ ⋮ μ$_1$ μ$_1$ [dai^{H}mɔ^{L}ɔ$^{L\%}$n]$_\omega$ tinos [[dai^{H}mɔ^{L}ɔ$^{L\%}$n]$_\omega$ tino$^{H\%}$s]$_\omega^{max}$			**0**
	b. H$_{1\%}$ ⋮ μ$_1$ μ$_1$ [dai^{H}mɔ^{L}ɔ$^{L\%}$n]$_\omega$ tinos [[dai^{H}mɔ^{L}ɔ$^{L\%}$n]$_\omega$ ti$^{H\%}$nos]$_\omega^{max}$	−1		**−5**
	c. H$_{0\%}$ μ$_1$ μ$_0$ [dai^{H}mɔ^{L}ɔ$^{L\%}$n]$_\omega$ tinos [[dai^{H}mɔ^{L}ɔ$^{L\%}$n]$_\omega$ tinos]$_\omega^{max}$		−1	**−2**

The lack of tone in monomoraic/monosyllabic clitics in the same environment is attributable to an OCP constraint which prevents adjacent T%'s:

		AR-H$_\%$	OCP-T$_\%$	MAX	H
		w:5	w:3	w:2	
(26) [dai^{H}mɔ^{L}ɔ$^{L\%}$n]$_\omega$ tis H$_\%$	☞ a. L L$_\%$ H$_{0\%}$ ⋮⋮ ⋮ μμ$_1$ μ$_1$ [dai^{H}mɔɔn] tis [[dai^{H}mɔ^{L}ɔ$^{L\%}$n]$_\omega$ tis]$_\omega^{max}$			−1	**−2**
	b. L L$_\%$ H$_{1\%}$ ⋮⋮ ⋮ μμ$_1$ μ$_1$ [dai^{H}mɔɔn] tis [[dai^{H}mɔ^{L}ɔ$^{L\%}$n]$_\omega$ ti$^{H\%}$s]$_\omega^{max}$		−1		**−3**

By embracing adjunction and the relational notion of projection, three different types of ω in Ancient Greek can now be identified: (a) ω^{max}, which is signaled by the H$_%$ (27a); (b) ω, which is demarcated by the L$_%$ (27b); and (c) ω^{min}, which is designated by extrametricality, that is, the weakening of the final mora and the consequent silencing (non-realization) of the boundary tone (27c). Curiously, the Ancient Greek ω, unlike ω^{min} and ω^{max}, is constructed either at the lexical or at the post-lexical level, depending on the moraic composition of a word's right edge.

(27)   a.   ω^{max}:   daímɔɔn tinós   [[dai^{H}mɔ^{L}ɔ$^{L%}$n]$_ω$ tino$^{H%}$s]$_ω$^{max} 'someone's god' (8a)
       b.   ω: ánthrɔɔpós tinos   [a^{H}nthrɔ^{L}ɔ^{L}po^{H}s ti^{L}no$^{L%}$s]$_ω$ 'someone's man' (8b)
                         hodós tinos   [hodo^{H}s ti^{L}no$^{L%}$s]$_ω$ 'some street' (8c)
                         daímɔɔn   [dai^{H}mɔ^{L}ɔ$^{L%}$n]$_ω$ 'god' (2b)
       c.   ω^{min}:   ánthrɔɔpos   [a^{H}nthrɔ^{L}ɔ^L<pos>]$_ω$^{min} 'man' (1c)

4 Alternative accounts of Ancient Greek accentuation, and conclusions

Inspired by Itô & Mester's tone-based approach of the Ancient Greek recessive pattern, we advanced a modified version of their analysis in order to empirically cover data from enclitic constructions and the so-called σωτῆρα words. In this section, we will review two metrical analyses of the same data, and will discuss them in relation to the analysis offered in this article.

According to metrical accounts, Ancient Greek is a mixed system: a metrical apparatus determines the position of the accented mora, whereas tonal constraints decide on the distribution of tones to these metrically prominent positions. Steriade (1988), for instance, offers a rule-based analysis of Ancient Greek accentuation that posits a set of foot formation rules which first render extrametrical both the word-final consonant ([C]) and the word-final light syllable (<CV[C]>), and then build a quantity insensitive trochee at the right edge of the word: *(anthrɔɔ)<po[s]>, (oi)<ko[s]>*. The H is associated to the metrically prominent syllable of such a foot (indicated with underlined font): *(a^{H}nthrɔɔ)<po[s]>, (o^{H}i)<ko[s]>*. Moreover, intrametrical (i.e. non-final) consonants project a mora and, given that the extrametricality condition is weight sensitive, VC[C]-final syllables are visible to the foot formation rule: *ka(pa^{H}dok)[s]*. It is worth emphasizing that this analysis can derive the word pattern of σωτῆρα words without any additional stipulations: *(kɛ^{H}ɛryk)[s]*. To account for the three-mora restriction attested in VV[C]-final words, however, Steriade resorts to a special *mora rule*, which is designed to cause a left-dominant nuclei to shift rightwards, so that the H will end up being associated to the second mora of the heavy nucleus, i.e. $(μ^Hμ.μμ) → (μμ^H.μμ)$: *an(thrɔ^{H}ɔpoo) → an(thrɔɔ^{H}poo)*.

By exception, a structure-building rule that constructs right-headed quantity insensitive feet is in effect in enclitic constructions. Thus, enclitic material is parsed into right-headed feet with the H occupying the head position of such an iambically-shaped foot: *ka(pa^{H}doks) (tino^{H}s), (kɛ^{H}ɛryks) (tino^{H}s)*. Subminimal feet are permitted and receive a H tone as well: *(a^{H}nthrɔɔ)(po^{H}s) (ti^{H}s), (o^{H}i)(ko^{H}s) (tino^{H}s)*, but they are subject to de-stressing under clash: *(a^{H}nthrɔɔ)(po^{H}s) tis, (o^{H}i)(ko^{H}s) tinos*.

Although descriptively successful, a major problem with Steriade's analysis, pointed out by Sauzet (1989), is the discrepancy between the quantity-insensitive footing, on the one hand, and the quantitative sensitive aspects of the language, on the other, such as the dependence of extrametricality and the mora rule on the weight of the final syllable, and so on. This inconsistency in the design of the analysis extends to enclitic accentuation. Post-lexical feet not only are totally impervious to weight distinctions but they are also iambically shaped and often sub-minimal, contra to the cross-linguistic expectations on canonical iambs (e.g. Hayes 1980, 1995). In our analysis none of these problems arises. The same pattern of recessive accentuation applies globally but different outputs are generated depending on the moraic configuration of the host, which has an effect on the distribution of boundary tones and, by extension, to the emergence of a layered ω.

Golston (1990), building on Sauzet's (1989) analysis of the Ancient Greek recessive pattern, assumes a H+L*contonation that associates to the specific positions of moraic trochees, built iteratively

from right to left.[19] (Final consonants are also considered extrametrical.) More specifically, the L component of the H+L* pitch accent is linked to the head of the rightmost foot, whereas the H is realized on the immediately preceding vocalic element: *(a^{H}n)(t^{h}rɔ^{L*}ɔ)po[s], an(t^{h}rɔ^{H}ɔ)(po^{L*}o), (kɛ^{H}ɛ)(ry^{L*}k)[s]*.[20] To account for enclitic accentuation, Golston has to make a few unwarranted stipulations: First, disyllabic enclitics are considered to be lexically specified with a floating H, e.g., *^{H}tinos*, which ends up being realized on the preceding host,[21] provided its final syllable does not carry an accent/tone itself: */(a^{H}n)(t^{h}rɔ^{L*}ɔ)pos ^{H}tinos/ → (a^{H}n)(t^{h}rɔ^{L*}ɔ)po^{H}s tinos*. Otherwise, the H sponsored by the clitic is realized within the clitic: *(dai^H)(mɔ^{L*}ɔn) (ti^{H}nos), (kɛ^{H}ɛ)(ry^{L*}ks) (ti^{H}nos)*. However, because a foot clash situation is created in this context, the H of the clitic is forced to move rightwards, yielding on the surface outputs with a H on the final syllable of the disyllabic clitic: *(dai^H)(mɔ^{L*}ɔn) (tino^{H}s)* and *(kɛ^{H}ɛ)(ry^{L*}ks) (tino^{H}s)*, respectively.

Second, all finally-accented words (e.g. *hodo^{H}s, pylɔ^{H}ɔn*) – even those that are traditionally considered recessively accented (e.g. *p^{h}ɔ^{H}s* 'light-NOM.SG', *pa^{H}is* 'child-NOM.SG') – are taken to be lexically associated to a H*, the sole motivation of which is to block the floating H of the clitic from docking on the last syllable of the host: *ho(do^{H}s) ^{H}(tinos)*. Besides the fact that there in no obvious reason as to why the H+L* contonation has to split between two different feet, with the L tone being associated to the foot-head, contra to cross-linguistic tendencies that favor H tones in metrically strong positions (see de Lacy 2002), the analysis offered for the enclitic data introduces several ad hoc assumptions which diminish its explanatory force. In sharp contrast, our analysis enjoys a broader empirical coverage and provides a uniform interpretation of the accentual patterns attested in both word and enclitic constructions.

To conclude, we have presented some thoughts on the possible ways Itô & Mester's treatment of recessive accentuation in Ancient Greek can be successfully extended to cover more empirical data. We have shown that many creases pertaining to certain recessive and enclitic patterns can be easily ironed out if our analytical tools are enriched with gradient symbolic representations and the concept of phonological adjunction. Gradient representations, for instance, help us differentiate the accentual behavior of seemingly equivalent moraic representations, whereas adjunction provides the necessary layering to accommodate all types of ω's the Ancient Greek grammar constructs at the lexical and at the post-lexical level. We have put these ideas to work in examining some aspects of Ancient Greek accentuation but there is no doubt that more research needs to be done in order to acquire a deeper understanding of the language's accentual grammar.

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[19] The gist of their analysis is also adopted by Kiparsky (2003) and Blumenfeld (2004).
[20] The author does not explain how the contour HL tone surfaces on the head mora of *(kɛ^{H}ɛ)* in σωτῆρα words like *kέɛryks*.
[21] Blumenfeld (2004) also treats enclitics as pre-accenting.

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Stratified Faithfulness in Harmonic Grammar and Emergent Core-Periphery Structure[*]

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Foundational work by Ito & Mester (1995ab, 1999, 2001, 2008) connects core-periphery phonology, in which different lexical strata in a language tolerate different degrees of 'foreign' phonological structure, to a ranked hierarchy of markedness constraints against which faithfulness constraints are ranked differently for different strata. Implementing a version of the Stratified Faithfulness model in Harmonic Grammar takes advantage of cumulative interaction between specific and general faithfulness constraints (Jesney & Tessier 2011) to solve two remaining problems: how to make core-periphery structure a soft bias rather than an absolute requirement, and how to formalize the consistency of faithfulness rankings across strata that is a necessary condition for productive core-periphery phonology.

Keywords: loanword phonology, stratified lexicon, Harmonic Grammar, cumulative constraint interaction, indexed constraints

1 Introduction

Early in the development of Optimality Theory (OT; Prince & Smolensky 1993/2004; McCarthy & Prince 1995), work pioneered by Ito & Mester (1995ab, 1999) established a key conceptual insight: a language with a stratified lexicon that has a phonologically productive CORE-PERIPHERY STRUCTURE, where successive lexical strata tolerate increasingly 'foreign' phonological properties, can be modeled in terms of a HIERARCHY OF MARKEDNESS CONSTRAINTS (surface well-formedness constraints). Constraints against properties that are 'less foreign,' or more CORE, are ranked lower, and so the relevant structures are more easily tolerated in loanword phonology. Constraints against properties that are 'more foreign,' or more PERIPHERAL, are ranked higher, and so the structures that violate these constraints are more aggressively nativized.

While the notion of a markedness-constraint hierarchy as the backbone of a core-periphery phonology is intuitively appealing, however, the formal implementation of this insight in a constraint-based grammar has proven not to be entirely straightforward. In particular, Fukazawa, Kitahara, & Ota (1998) argue that a language with a stratified phonology is best modeled with distinct sets of faithfulness constraints indexed to each stratum, so as to allow for different faithfulness versus markedness rankings in different strata simultaneously—rather than, for example, with a cogrammars model in which a single set of constraints is literally reranked for different strata (as in Ito & Mester 1995a; see also, e.g., Inkelas & Zoll 2007). However, Fukazawa et al. (1998) and Ito & Mester (1999) go on to demonstrate that this OT STRATIFIED FAITHFULNESS model requires additional ranking stipulations if it is to enforce a strict core-periphery structure. Given a markedness hierarchy $M_1 \gg M_2 \gg M_3$, there is a logically possible faithfulness ranking (see §2) that leads to satisfaction of *low*-ranking M_3 but violation of *high*-ranking M_1, producing surface forms that fall outside the intended core-periphery patterning—that is, IMPOSSIBLE NATIVIZATIONS (Ito & Mester 1999, 2001) that preserve a 'more-foreign' property while nativizing a 'less-

foreign' one. In other words, without additional metaconditions on possible rankings, the OT Stratified Faithfulness model actually allows for non-core-periphery patterns, even in the presence of a strict markedness hierarchy.

Hsu & Jesney (2017a) develop an alternative approach to core-periphery phonology in the framework of Harmonic Grammar (HG; Legendre, Miyata, & Smolensky 1990; Pater 2009). Their WEIGHTED SCALAR CONSTRAINTS model likewise incorporates a markedness-constraint hierarchy to establish which of the phonologically marked properties are 'more foreign' and 'less foreign.' But this model proposes only a single set of faithfulness constraints, plus a scaling factor that boosts the weight of each faithfulness constraint in proportion to the 'distance' of the form it is evaluating from the lexical core. Such an approach allows faithfulness to take increasingly greater priority over markedness requirements as forms become more peripheral, without positing multiple sets of stratum-specific faithfulness constraints. Crucially, in Hsu & Jesney's (2017a) version of the Weighted Scalar Constraints model,[1] the relative weighting relations among faithfulness constraints can never change across strata. This guarantees that no surface form can ever satisfy a lower-weighted markedness constraint while violating a higher-weighted one. Impossible nativizations are excluded, and core-periphery phonology is strictly enforced, without any need for extrinsic stipulations on the relative weighting of faithfulness constraints.

In summary, the OT Stratified Faithfulness model *cannot enforce* a strict core-periphery structure without additional metaconditions on faithfulness rankings across strata, while the Weighted Scalar Constraints model predicts that every stratified lexicon *necessarily* has a strict core-periphery structure. But empirical evidence suggests that what is really needed is an intermediate position. On the one hand, at least some speakers of a number of languages, including Japanese, judge productively that impossible nativizations —which fall outside a strict core-periphery structure—are dispreferred (see Ito & Mester (1999, 2001) on loanwords in Japanese and German and the continuum of registers in Jamaican Creole English; Pinta (2013), Smith & Pinta (2017) on loanwords in Paraguayan Guaraní). On the other hand, Fukazawa et al. (1998) summarize a number of markedness implicational relations in the Japanese lexicon which, taken together, show that the lexical strata in Japanese do not in fact form a strict core-periphery structure across all dimensions of markedness; see also Ito & Mester (1995b), who note that the Mimetic stratum and the Sino-Japanese stratum do not form a subset/superset relation, and Kawahara, Nishimura, & Ono (2003), who argue that the Sino-Japanese stratum is even less marked than the Native stratum in certain respects.

This paper implements a version of the Stratified Faithfulness model in Harmonic Grammar that builds on the insights of previous approaches, but has two advantages. First, the HG Stratified Faithfulness model is able to account for both kinds of stratified phonologies: those that do, and those that do not, have core-periphery structure. Second, the formal properties of HG make it simple for this model to encode an EMERGENT PREFERENCE for core-periphery structure, which accounts for the existence of productive impossible-nativization effects without treating core-periphery structure as a universal requirement on stratified phonologies. The formal implementation of this emergent preference takes advantage of CUMULATIVE CONSTRAINT INTERACTION between specific and general faithfulness constraints in HG, in the tradition of work by Jesney & Tessier (2011) on other types of specific/general faithfulness interactions.

First, §2 presents background on core-periphery phonologies, the OT Stratified Faithfulness model, and the role of consistent faithfulness rankings across strata in enforcing strict core-periphery structure. The properties of the HG Stratified Faithfulness model are presented in §3, and its predictions are explored in

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[1] Hsu & Jesney (2017b) introduce a revised version of the Weighted Scalar Constraints model that allows for limited divergence from a strict core-periphery structure; essentially, since each constraint can have its own scaling factor, the relative priority of any two constraints can change places across strata, but no more than one time.

a series of learning simulations in §4. The emergent preference for core-periphery structure is formally modeled in §5. Finally, conclusions and implications are discussed in §6.

2 Core-periphery structure and consistent faithfulness rankings

As Ito & Mester (1995ab, 1999, 2001, 2008) observe, a language with a phonologically stratified lexicon —in which there are lexical classes that differ in their phonological characteristics—often displays a CORE-PERIPHERY STRUCTURE: there is a phonologically restricted subset of the lexicon at the core, with increasingly less-restricted strata toward the periphery. This situation is illustrated in the following Venn diagram for (part of) the Japanese lexicon, based on the discussion in Ito & Mester (1999), which represents the subsets of lexical forms for which each of the markedness constraints is enforced.

(1)   Lexical strata in a core-periphery structure
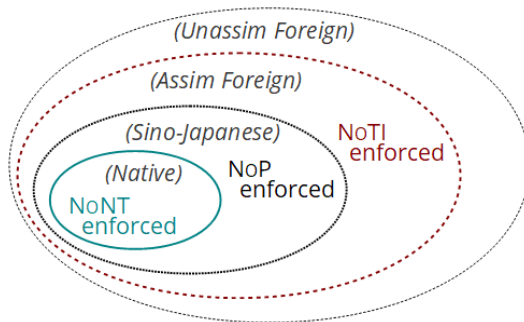
In the core stratum, 'Native', all three markedness constraints are enforced: NoNT, NoP, and NoTI. In each subsequent stratum, progressively fewer markedness constraints are enforced: NoP and NoTI in 'Sino-Japanese' (old loans from Chinese languages), only NoTI in 'Assimilated Foreign' (older and/or more nativized modern loans, chiefly from European languages), and none of the three in 'Unassimilated Foreign' (newer and/or less nativized modern loans). These constraints are defined in (2), following Ito & Mester (1995a, 1999); see these works for examples and discussion. See also Irwin (2011) for a recent overview of the history and synchronic characteristics of lexical strata in Japanese.

(2)   Markedness constraints in the Japanese stratified lexicon

   (a) NoNT   Assign one violation for every sequence of [+nasal] [–voice]

          ('No nasal–voiceless obstruent sequences'); Hayes (1999), Pater (2001)

   (b) NoP   Assign one violation for every singleton (non-geminate) [p]

   (c) NoTI   Assign one violation for every sequence of [Coronal, –son] [i]

          ('Coronal obstruents are palatal before [i]')

In a constraint-based framework, such as OT or HG, a phonological RESTRICTION (predictable pattern; lack of contrast) is enforced by highly ranked or weighted markedness constraints (M), whereas a phonological CONTRAST (unpredictable pattern; lack of restriction) is enforced by highly ranked or weighted faithfulness constraints (F). A language in which different lexical strata have distinct but productive patterns of restriction and contrast is therefore particularly interesting: in such a language, the relative domination hierarchy between markedness and faithfulness constraints differs in the different

strata. Specifically, when lexical stratum *A* has a productive restriction that lexical stratum *B* does not have, we conclude that M » F for *A* but F » M for *B*. In the OT Stratified Faithfulness model (Fukazawa 1997; Fukazawa, Kitahara, & Ota 1998; Ito & Mester 1999, 2001, 2008), there is a distinct set of faithfulness constraints indexed to each lexical stratum. This allows for the grammar to simultaneously specify M » F_A for stratum *A*, enforcing a restriction, but F_B » M for stratum *B*, allowing contrast, so that the full ranking for the language has F_B » M » F_A.

The faithfulness constraints that conflict with the markedness constraints in (2), and take priority over them in the more peripheral strata of Japanese, are defined in (3).

(3)   Faithfulness constraints in the Japanese stratified lexicon

    (a) IDENT[voi]   Assign one violation for every pair of corresponding segments that differ in their value for [±voice] (McCarthy & Prince 1995)

    (b) IDENT[p]   *informally:* Assign one violation for every [p] that surfaces as [h]

        (formally, this might be IDENT[Labial], or IDENT[±continuant], or a cumulative effect of the two if implemented in HG)

    (c) IDENT[ant]   Assign one violation for every pair of corresponding segments that differ in their value for [±anterior]

In the OT Stratified Faithfulness model, the lexical strata in (1) can be analyzed in terms of the markedness ranking NoTI » NoP » NoNT, stratum-specific versions of the faithfulness constraints in (3) for strata *U*, *A*, *S*, and *N*,[2] and rankings between opposing markedness and faithfulness constraints as in (4) (Ito & Mester 1999). The markedness constraints, which enforce phonological restrictions if undominated, are shown in bold.

(4)   OT Stratified Faithfulness rankings for the core-periphery phonology in (1)

    (a)   Unassimilated Foreign:
        IDENT[ant]$_U$ » **NoTI**   IDENT[p]$_U$ » **NoP**   IDENT[voi]$_U$ » **NoNT**

    (b)   Assimilated Foreign:
        NoTI » IDENT[ant]$_A$ IDENT[p]$_A$ » **NoP**   IDENT[voi]$_A$ » **NoNT**

    (c)   Sino-Japanese:
        NoTI » IDENT[ant]$_S$ **NoP** » IDENT[p]$_S$ IDENT[voi]$_S$ » **NoNT**

    (d)   Native:
        NoTI » IDENT[ant]$_N$ **NoP** » IDENT[p]$_N$ **NoNT** » IDENT[voi]$_N$

While the OT Stratified Faithfulness model is capable of representing a language with a strict core-periphery structure, as in the subset of the Japanese lexicon seen in (1) and (4), it is not capable of excluding a language that falls outside this structure (Fukazawa et al. 1998; Ito & Mester 1999). Even with the markedness constraints ranked in the relevant domination hierarchy NoTI » NoP » NoNT, nothing systematically excludes the existence of an additional stratum *X* in which outputs *satisfy* the low-ranking NoNT but *violate* the high-ranking NoTI. Such a stratum would have the ranking in (5); the

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    [2]Alternatively, a set of non-indexed, general faithfulness constraints could be used in place of a set of faithfulness constraints indexed to the core stratum (Native); see Ito & Mester (1999: note 38) for discussion.

effects of this ranking are seen in (6). Unfaithful structures in output forms are shown with **bold underline**, and (relevant) faithful structures are shown with *italic underline*.

(5)   Constraint ranking for the non-core-periphery stratum *X*

Ident[ant]*X* » NoTI » NoNT » Ident[voi]*X*

(6)   Stratum *X* optimal candidate violates high-ranking NoTI, satisfies low-ranking NoNT

/tinta/*X*	Ident[ant]*X*	NoTI	NoNT	Ident[voi]*X*
→ a. *tin**d**a*		*		*
b. **tɕ**in**d**a	*w	L		*
c. *tinta*		*	*w	L
d. **tɕ**in*t*a	*w	L	*(w)	L

This non-core-periphery stratum *X* is possible as long as the faithfulness constraints that conflict with the ranked markedness constraints NoTI » NoNT are themselves independently rankable. In the OT Stratified Faithfulness model, there is no simple non-stipulative way to prevent a high-ranking Ident[ant]*X* from dominating NoTI, rendering it inactive, while Ident[voi]*X* is still ranked below NoNT.

Ito & Mester (1999) and Fukazawa et al. (1998) explore metaconditions on faithfulness rankings that would prevent a stratum like *X* from arising, and Hsu & Jesney's (2017a) Weighted Scalar Constraints model ensures that such a stratum is not formally possible. The key insight behind both the Stratified Faithfulness ranking metaconditions and the Weighted Scalar Constraints approach is to ensure that *the hierarchy among faithfulness constraints is consistent* from stratum to stratum. In terms of the example in (6), this restriction would exclude any stratum *X* in which Ident[ant]*X* » Ident[voi]*X*, which in turn excludes the ranking in (5) that creates the non-core-periphery pattern.

However, the outright formal exclusion of a language with a non-core-periphery pattern is not in fact desirable (see, e.g., Fukazawa et al. 1998; Inkelas & Zoll 2007). For example, a fuller picture of the lexicon of Japanese includes the Mimetic stratum, consisting of sound-symbolic and other expressive forms. Crucially, the Mimetic and the Sino-Japanese strata do not stand in a subset/superset relationship: NoNT applies only to Mimetic (and Native) forms, and NoP applies only to Sino-Japanese (and Native) forms.[3] This situation is shown in the Venn diagram in (7), after Ito & Mester (1995b: 823).

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[3]Ito & Mester (1995a: 190) actually argue that Mimetic forms do not in fact have a ranking equivalent to Ident[p]*M* » NoP, because [p] can occur only in initial position in this stratum, making the relevant faithfulness constraint a positional one (e.g., Beckman 1999), along the lines of Ident[p]-σ1*M*. However, the simplified analysis as given in (7) is still useful for the purposes of the learning simulation in §4.4, where it provides an example of a schematic language with a non-core-periphery structure. As for the phonological analysis of lexical strata in actual Japanese, the broader point still remains that the Mimetic and Sino-Japanese strata do not stand in a subset/superset relation.

(7)   Non-core-periphery structure in the Japanese lexicon, with Mimetic forms
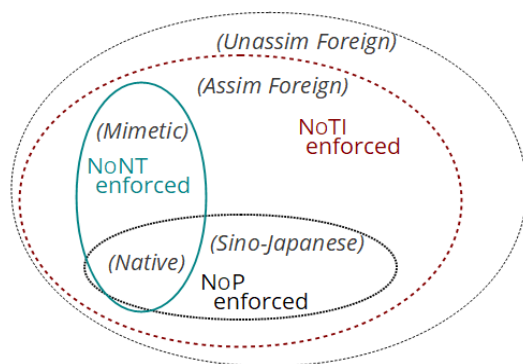
On the other hand, a model of stratified phonology that assigns no preference at all to strict core-periphery structure is too weak. Fukazawa et al. (1998) suggest that existing cases of core-periphery structure are merely epiphenomenal, in that new strata are only created when markedness-violating loanwords are encountered, so diachronically later strata typically happen to be more phonotactically permissive. But this explanation does not account for the existence of *productive* impossible-nativization effects (Ito & Mester 1999, 2001; Pinta 2013, Smith & Pinta 2017)—for at least some speakers of some languages, nativization patterns that fall outside a strict core-periphery structure are actively dispreferred. Such effects show that the phonological grammar does, in some way, *prefer* to maintain a core-periphery structure for a stratified lexicon.

The HG Stratified Faithfulness model, introduced in the following section, finds a middle ground. In learning simulations exploring this model, not only does the learner acquire the markedness hierarchy underpinning a core-periphery structure. Crucially, the basis for a preference for a hierarchy of cumulative faithfulness weights that is consistent across lexical strata likewise emerges automatically, unless there is overt evidence to the contrary. This approach thus accounts both for the existence of stratified phonologies that do not have a strict core-periphery structure, and also for the existence of speakers with productive impossible-nativization effects.

3 The HG Stratified Faithfulness model

Harmonic Grammar (HG; Legendre, Miyata, & Smolensky 1990) differs from Optimality Theory (Prince & Smolensky 1993/2004) in that HG constraints are weighted rather than strictly ranked. This difference allows HG to show CUMULATIVE CONSTRAINT INTERACTION, also known as 'gang effects': the violations of a set of lower-weighted constraints can, under the right conditions (Pater 2009, 2016), 'gang up' and assign a higher overall penalty than the violation of a higher-weighted constraint.

Jesney & Tessier (2011) demonstrate that such cumulative constraint interaction plays a fundamental role in establishing the overall influence of specific and general constraints in the grammar of a language. For example, consider a language in which stressed syllables resist a place-assimilation process that targets unstressed syllables. Place assimilation of a segment in a stressed syllable would violate both a general faithfulness constraint, IDENT[Place], and its positional version indexed to stressed syllables (Beckman 1999), IDENT[Place]-σ́. Crucially, in HG, neither of these IDENT constraints alone actually needs to outweigh the constraint driving place assimilation, as long as the *cumulative* weight of the two is higher than that of the assimilation constraint.

The HG STRATIFIED FAITHFULNESS model proposed here extends this insight to account for stratified phonology, with or without a core-periphery structure. The model includes general faithfulness constraints, not indexed to any stratum, along with stratum-specific faithfulness constraints. Because the learner begins with the Initial State weighting relation of w(M) > w(F) (Smolensky 1996; Jesney & Tessier 2011), any learning datum whose target surface form shows faithfulness effects will initially produce a non-target output (i.e., an error) for the learner, triggering an incremental increase in weight for all relevant faithfulness constraints and a decrease for all relevant markedness constraints. For example, a learning datum such as /inta/S→[inta]S, indexed to the Sino-Japanese stratum, provides evidence for promoting faithfulness to voicing above the markedness constraint NoNT. But this will raise the weight not only of IDENT[voi]S, but also of general IDENT[voi], until the cumulative weights of the two constraints are enough to overcome NoNT.

The crucial consequence of modeling stratified phonology with a cumulative interaction involving general faithfulness constraints is that, because such constraints are relevant to all strata, the relative frequency with which any given general faithfulness constraint is promoted over the course of grammar-learning depends on the proportion of strata in which it is satisfied. This in turn means that, when the learner is exposed to a language that has a strict core-periphery structure, not only the markedness constraints *but also the general faithfulness constraints* end up with a relative weighting that reflects this structure. As discussed in §5 below, thanks to cumulative constraint interaction in HG, it is this relative hierarchy among the general faithfulness constraints that biases the grammar toward adherence to strict core-periphery structure *even for a potential novel stratum,* giving rise to impossible-nativization effects. Before this discussion of the emergent core-periphery bias, however, the next section (§4) first presents a series of learning simulations, to confirm that a simulated learner with an HG Stratified Faithfulness grammar behaves as predicted when it is exposed to a core-periphery phonology and a non-core-periphery phonology.

4 HG-GLA learning simulations

Learning simulations were carried out in the HG Stratified Faithfulness model for three schematic languages: a language with a strict core-periphery structure in which all strata contain the same number of lexemes; a language with a strict core-periphery structure in which the most peripheral stratum has a higher proportion of lexemes; and a language that has a non-core-periphery structure.

A version of the Gradual Learning Algorithm (Boersma & Hayes 2001) implemented for Harmonic Grammar (the HG-GLA; Jesney & Tessier 2011, Boersma & Pater 2016) was trained on each schematic language in order to simulate the acquisition of the constraint weights needed for each grammar.[4] To preview the results, both strict core-periphery languages ended up with a general-faithfulness hierarchy that supports a bias against impossible nativizations (as discussed in §5 below), and even the non-core-periphery language was successfully acquired.

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[4]These learning simulations make two key simplifying assumptions—as, implicitly, do Ito & Mester (1995ab, 1999), and Hsu & Jesney (2017a)—namely, that the learner knows which lexemes belong to which strata, and that the learner has access to the correct underlying forms for unfaithful outputs. For further discussion of how the strata themselves might be identified and modeled by a learner, see Fukazawa et al. 1998; Pater 2005, 2010; and Hayes (2016).

4.1 The schematic target languages

The three schematic languages used in the learning simulations are simplified versions of the grammar of Japanese as analyzed by Ito & Mester (1995ab, 1999). Each language has either four or five lexical strata, which are distinguished by their patterns of enforcement of the three markedness constraints defined in (2) above. The lexical strata are summarized in (8), where '*' indicates that a constraint is *not enforced* in the stratum in question and '✓' indicates that a constraint *is enforced*.

(8)   Lexical strata in the schematic target languages

Stratum		NoNT	NoP	NoTI
U	Unassimilated Foreign	*	*	*
A	Assimilated Foreign	*	*	✓
S	Sino-Japanese	*	✓	✓
M	Mimetic (where relevant)	✓	*	✓
N	Native	✓	✓	✓

As discussed in §2, a language with all five strata does not form a strict core-periphery structure, because neither the Mimetic nor the Sino-Japanese stratum is a subset of the other in terms of markedness constraint domains. The learning simulations included both strict core-periphery languages with no Mimetic stratum, as in (9)(a) (repeated from (1)), as well as the full non-core-periphery system, as in (9) (b) (repeated from (7)).

(9)   Structure of the stratified lexicon in the schematic target languages

(a)   Strict core-periphery structure: Mimetic stratum removed (languages #1, #2)
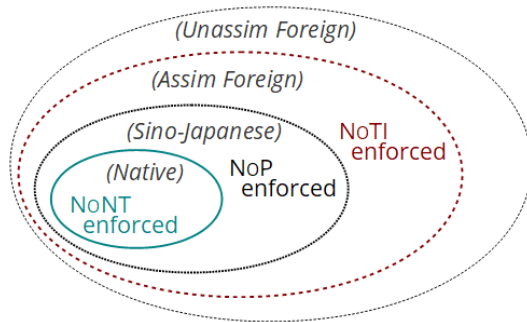
(b)   Non-core-periphery structure: Mimetic stratum included (language #3)
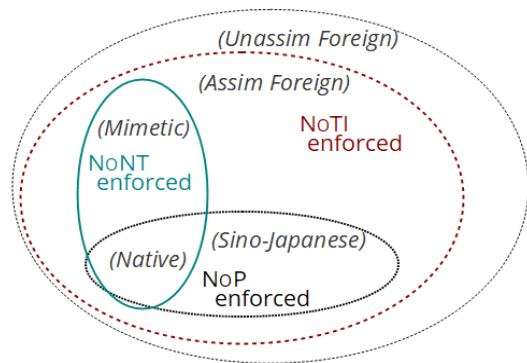
The faithfulness constraints used in the learning simulations are those defined in (3) above. As discussed in §3, in the HG Stratified Faithfulness model, each faithfulness constraint has a general version as well as a specific version indexed to each stratum. The constraint set used here includes a set of stratal faithfulness constraints for the Native (core) stratum, although in the schematic languages under consideration, this is not formally necessary. Since the Native stratum satisfies all three markedness constraints, showing no effect of faithfulness for any of the properties under discussion, this stratum could be modeled using the general faithfulness constraints only (and indeed, the weights of the faithfulness constraints indexed to the Native stratum remain zero in all of the learning simulations).

The complete constraint set used in the learning simulations is therefore as given in (10).

(10)   Constraint set for learning simulations

(a) Markedness constraints	NoNT	NoP	NoTI
(b) General faithfulness constraints	IDENT[voi]	IDENT[p]	IDENT[ant]
(c) Stratal faithfulness constraints			
• Unassimilated Foreign	IDENT[voi]$_U$	IDENT[p]$_U$	IDENT[ant]$_U$
• Assimilated Foreign	IDENT[voi]$_A$	IDENT[p]$_A$	IDENT[ant]$_A$
• Sino-Japanese	IDENT[voi]$_S$	IDENT[p]$_S$	IDENT[ant]$_S$
• Mimetic (where relevant)	IDENT[voi]$_M$	IDENT[p]$_M$	IDENT[ant]$_M$
• Native	IDENT[voi]$_N$	IDENT[p]$_N$	IDENT[ant]$_N$

The schematic languages presented to the learner consist of three words assigned to each stratum, for a total of twelve words (in the four-stratum, strict core-periphery languages) or fifteen words (in the five-stratum, non-core-periphery language). Each word has exactly one structure that violates one of the markedness constraints under discussion—a [nt] sequence, a singleton [p], or a [ti] sequence—in its input (underlying) form. Whether or not this structure surfaces faithfully in the target language depends on the stratum to which the word is assigned, as summarized in (8) above. Inputs and outputs for each word are given in (11); unfaithful structures in output forms are shown with **bold underline**, while (relevant) faithful structures are shown with *italic underline*.

(11)   Words in the schematic target languages

Stratum	/nt/ sequence	singleton /p/	/ti/ sequence
U Unassimilated Foreign	/inta/$_U$ → [in*t*a]$_U$	/paku/$_U$ → [*p*aku]$_U$	/mati/$_U$ → [ma*t*i]$_U$
A Assimilated Foreign	/inta/$_A$ → [in*t*a]$_A$	/paku/$_A$ → [*p*aku]$_A$	/mati/$_A$ → [ma**tɕi**]$_A$
S Sino-Japanese	/inta/$_S$ → [in*t*a]$_S$	/paku/$_S$ → [**h**aku]$_S$	/mati/$_S$ → [ma**tɕi**]$_S$
M Mimetic (where relevant)	/inta/$_M$ → [in**d**a]$_M$	/paku/$_M$ → [*p*aku]$_M$	/mati/$_M$ → [ma**tɕi**]$_M$
N Native	/inta/$_N$ → [in**d**a]$_N$	/paku/$_N$ → [**h**aku]$_N$	/mati/$_N$ → [ma**tɕi**]$_N$

Three different learning scenarios were considered. The first (§4.2), as a baseline case, was a strict core-periphery language (no Mimetic stratum) with a uniform distribution of lexical items across strata. The second (§4.3) was still a strict core-periphery language, but had more lexical items in Unassimilated Foreign than in the other strata, in order to explore the effect of a non-uniform distribution of lexical items on the relative weights of the constraints. The third (§4.4) was a language with all five strata,

including Mimetic, and a uniform distribution of items across strata; this language was included in order to confirm that a non-core-periphery structure could be acquired, and if so, to determine its effect on the relationships among the constraint weights.

HG-GLA learning simulations were carried out in Praat (version 5.4.16; Boersma & Weenink 2015) and were structured like those of Jesney & Tessier (2011). Initial weights were set at 100 for the markedness constraints and at 0 for the faithfulness constraints. This difference encodes the M » F initial-state bias required for learning restrictive grammars in the absence of overt alternations (Smolensky 1996) and assigns the faithfulness constraints weights that are low enough to avoid unintended cumulative effects (Jesney & Tessier 2011). Plasticity, the amount by which a constraint's weight is raised or lowered at each learning step where the target output is not yet selected, was set at 1.0 for the markedness constraints and 0.2 for the faithfulness constraints; Jesney & Tessier (2011) demonstrate that weights must change more quickly for markedness constraints than for faithfulness constraints in order once again to prevent unwanted types of cumulative constraint interaction involving faithfulness. Finally, since there is no variation in the schematic languages under consideration, evaluation noise was set at 0, there was no plasticity decrement ('number of plasticities' was set at 1), and relative plasticity spreading was set at 0. The decision strategy used was 'LinearOT', which excludes negative values for weights, and the reranking method was 'Symmetric All', which means that each time a learner's output failed to match the target-language output, all constraints favoring the learner's current output had their weights lowered and all constraints favoring the target-language output had their weights raised (according to the relevant plasticity settings). There were 100,000 learning data presented in each learning simulation, chosen randomly according to the frequency distribution of forms in the target language. Five separate simulations were run for each schematic language to confirm that the grammars were converging consistently on the end-state pattern; as is discussed in more detail below, the resulting grammars were indeed consistent.

4.2 Schematic language #1: Strict core-periphery structure, uniform distribution

The first schematic language tested has a strict core-periphery structure among lexical strata, and its lexical items are evenly distributed among strata so that information from each stratum has the same degree of influence on the learning trajectory. This target language corresponds to (9)(a), with no Mimetic stratum; thus, there are no faithfulness constraints for stratum *M*, and no lexical items with the *M* index. The relative frequency of all 12 remaining lexical items (see (11)) was set at 1.

A representative set of HG-GLA weights learned for each constraint (the results from one of the five simulations) is shown in (12). Also shown is the sum of the weight of each stratal faithfulness constraint and the weight of its associated general faithfulness constraint, representing the cumulative faithfulness interaction, as well as the difference between this cumulative faithfulness weight and the weight of the antagonistic markedness constraint (*F–M*) for each phonological pattern. It is this last value that determines whether a particular structure is realized faithfully or nativized in a given stratum. If the *F–M* value is positive, then the faithfulness constraints (cumulatively) are weighted higher than the conflicting markedness constraint, and the relevant structure is faithfully preserved. If the *F–M* value is negative, then the markedness constraint's weight is higher than the combined weights of the general and stratal faithfulness constraints, and the relevant structure is nativized.

Final constraint weights might in principle differ somewhat across multiple learning simulations, since the order in which forms are encountered by the learner might result in weights being distributed differently among constraints. As it turns out, however, the results of the five simulations for this language scenario were very consistent (the range of weights for each constraint across the five simulations is shown in (12)). There was almost no variation for either the markedness constraints or the

general faithfulness constraints: NoTI, NoP, IDENT[ant], and IDENT[p] had the same weights in all five simulations; NoNT differed by 1 and IDENT[voi] by 0.2 (one learning step each) across simulations. The stratal faithfulness constraints showed a little more variability; specifically, in cases where multiple strata are exempt from the same markedness requirement, the relative weight of the (non-zero) stratal faithfulness constraints will vary a bit from simulation to simulation. This happens because individual learning simulations differ in exactly how many forms from each stratum are encountered by the learner, and in which order, during the phase before the general-faithfulness weights are raised enough to help the stratal faithfulness constraints overcome the markedness constraints—leading to differences across simulations in how far the different stratal faithfulness constraints have their weights raised before target forms are always produced and learning stops. But even here, the most variation seen, for IDENT[voi] constraints, was 2.6 for Assimilated Foreign, 2 for Unassimilated Foreign, and 1.8 for Sino-Japanese, or 13, 10, and 9 learning steps respectively. As a comparison, the constraints whose weights changed the most were NoNT and IDENT[voi], each changing by 80 or 81 learning steps per simulation.

(12)   HG-GLA outcome: Core-periphery language, uniform distribution

category	constraint	representative weight	range	cumulative faithfulness	F–M	outcome
markedness constraints	NoTI	28	0			
	NoP	22	0	—	—	—
	NoNT	19	1			
general faithfulness constraints	IDENT[ant]	14.4	0			
	IDENT[p]	15.6	0	—	—	—
	IDENT[voi]	16.2	0.2			
Unassimilated Foreign	IDENT[ant]U	14.4	0	28.8	0.8	*faithful* [ti]U
	IDENT[p]U	7	1.4	22.6	0.6	*faithful* [p]U
	IDENT[voi]U	7	2	23.2	4.2	*faithful* [nt]U
Assimilated Foreign	IDENT[ant]A	0	0	14.4	−13.6	**nativized** [tɕi]A
	IDENT[p]A	8.6	1.4	24.2	2.2	*faithful* [p]A
	IDENT[voi]A	5	2.6	21.2	2.2	*faithful* [nt]A
Sino-Japanese	IDENT[ant]S	0	0	14.4	−13.6	**nativized** [tɕi]S
	IDENT[p]S	0	0	15.6	−6.4	**nativized** [h]S
	IDENT[voi]S	4.2	1.8	20.4	1.4	*faithful* [nt]S
Native	IDENT[ant]N	0	0	14.4	−13.6	**nativized** [tɕi]N
	IDENT[p]N	0	0	15.6	−6.4	**nativized** [h]N
	IDENT[voi]N	0	0	16.2	−2.8	**nativized** [nd]N

The constraint weights from (12) are plotted in (13), with lexical strata along the *x* axis and constraint weights along the *y* axis. Markedness constraints and general faithfulness constraints are labeled at the left edge of the plot; markedness constraints are plotted with filled symbols, and their antagonistic faithfulness constraints are plotted with the corresponding open symbols. Where a stratal faithfulness constraint has a non-zero weight, that weight is plotted as an *addition to* the value of the weight of the general faithfulness constraint, representing their cumulative constraint interaction. This cumulative faithfulness weight is plotted with the same symbol as the general version of the faithfulness constraint,

and is connected to the general-faithfulness weight by a vertical line. Finally, a horizontal line is plotted at the weight of each markedness constraint in order to emphasize the value that the cumulative weight of the opposing faithfulness constraints (general and stratal) would have to surpass in order for the structure in question to be realized faithfully.

(13)   Relationships among weights: Core-periphery language, uniform distribution
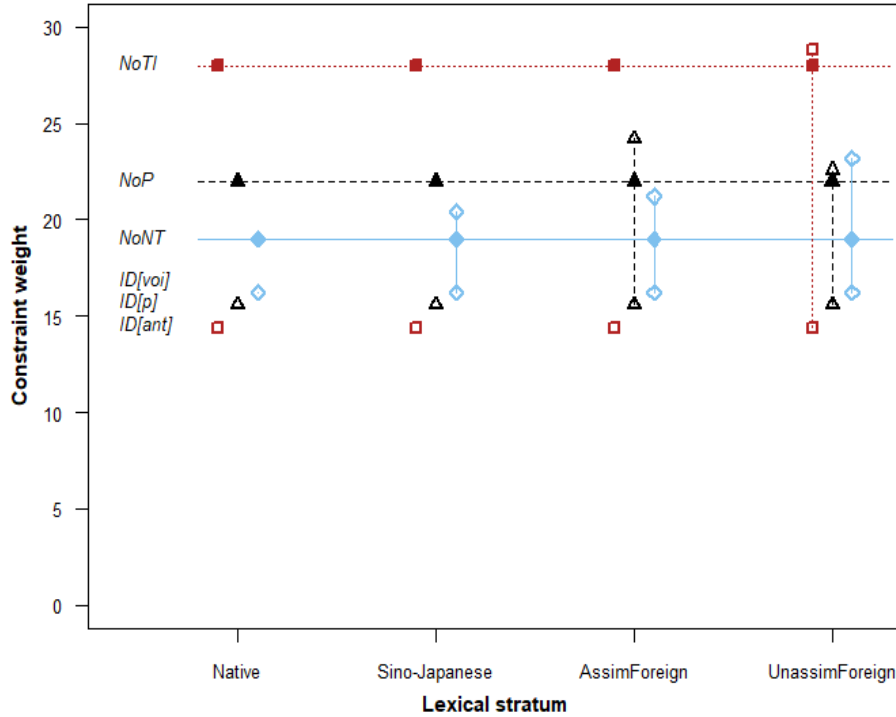
The results in (12) and (13) show that the relative weights among the markedness constraints are equivalent to the markedness rankings that would be proposed in the original OT Stratal Faithfulness model—a domination hierarchy that parallels the markedness subset/superset relation among the lexical strata. In other words, the markedness constraint that is violated in the most strata, NoNT, is weighted lowest, and the one that is enforced in the most strata, NoTI, is weighted highest: $w(\text{NoTI}) > w(\text{NoP}) > w(\text{NoNT})$. Likewise, the general faithfulness constraints are ordered in exactly the relationship that would be enforced by a metacondition on cross-stratum faithfulness ranking in the original OT Stratified Faithfulness model. IDENT[voi], the general faithfulness constraint that is relevant to the contrast preserved in the most strata, is weighted highest, and IDENT[ant], relevant to the contrast that is preserved only in the most peripheral stratum, is weighted lowest: $w(\text{IDENT}[\text{voi}] > w(\text{IDENT}[\text{p}]) > w(\text{IDENT}[\text{ant}])$. Conceptually, it is clear why the HG-GLA produces these results. The markedness constraint that is violated in the most strata will undergo the most demotion in weight over the course of learning, and will therefore end up lowest. Conversely, the general faithfulness constraint that is satisfied in the most strata will undergo the most promotion in weight, and will end up highest.

The role of stratal faithfulness constraints in the current model, on the other hand, is very different from the role that they play in the OT Stratified Faithfulness model. Here, the stratal faithfulness constraints enter into gang effects with the general faithfulness constraints, and this cumulative interaction affects how the specific faithfulness constraints are weighted. Unsurprisingly, the stratal versions of faithfulness constraints that are violated in a particular stratum are weighted at zero, since the learner sees no

evidence that they are ever active. However, the stratal faithfulness constraints with non-zero weights show a pattern that is essentially the *inverse* of that among the general faithfulness constraints: $w(\text{IDENT[ant]}) > w(\text{IDENT[p]}) > w(\text{IDENT[voi]})$. Again, given the nature of the HG-GLA, it is clear why this is so. As discussed above, general IDENT[voi] is weighted highest among the general faithfulness constraints, and the conflicting markedness constraint NoNT is weighted lowest among the markedness constraints—target forms from all but the Native stratum realize voicing faithfully in /nt/ clusters, so IDENT[voi] is promoted the most and NoNT is demoted the most. This means that the additional 'boost' needed for any given stratum-specific version of IDENT[voi] to make the cumulative voicing-faithfulness weight higher than that of NoNT is smaller than that needed for IDENT[p], which in turn is smaller than that for IDENT[ant].

In summary, when an HG-GLA learner is exposed to a language with a stratified lexicon that has a strict core-periphery structure and a uniform distribution of forms across strata, the markedness constraints form a domination hierarchy that mirrors the core-periphery structure, and the general faithfulness constraints fall into a reverse hierarchy so that the faithfulness constraint supporting the most-marked property (according to the markedness hierarchy) is ranked the lowest. This general-faithfulness hierarchy plays a key role in the emergent core-periphery preference, as discussed in §5 below.

4.3 Schematic language #2: Core-periphery structure, non-uniform distribution

The second schematic language is designed to examine the effect of a case in which a peripheral stratum makes up the majority of the lexicon, to see whether this changes the relationships among the markedness constraints or among the general faithfulness constraints as compared to the baseline case with an even distribution of forms across strata. The target language once again corresponds to (9)(a), with no Mimetic stratum. This time, however, the relative frequency of lexical items across strata was manipulated so that the words in the most peripheral stratum, Unassimilated Foreign, were presented to the learner five times as frequently as those from the other three strata.

Results are shown in (14) and (15). Here again, there was little variability in the final weights assigned to each constraint across the five learning simulations, so the values for one representative simulation are presented in the discussion (and the range for each constraint across simulations is included in (14)).

(14)   HG-GLA outcome: Core-periphery language, non-uniform distribution

category	*constraint*	*representative weight*	*range*	*cumulative faithfulness*	*F–M*	*outcome*
markedness constraints	NoTI	28	0	—	—	—
	NoP	20	1			
	NoNT	18	2			
general faithfulness constraints	IDENT[ant]	14.4	0	—	—	—
	IDENT[p]	16	0.2			
	IDENT[voi]	16.4	0.4			
Unassmilated Foreign	IDENT[ant]U	14.4	0	28.8	0.8	*faithful* [ti]U
	IDENT[p]U	11.8	1.4	27.8	7.8	*faithful* [p]U
	IDENT[voi]U	10.4	2.2	26.8	8.8	*faithful* [nt]U

category	constraint	representative weight	range	cumulative faithfulness	F–M	outcome
Assimilated Foreign	IDENT[ant]$_A$	0	0	14.4	−13.6	**nativized** [tɕi]$_A$
	IDENT[p]A	4.2	1.2	20.2	0.2	*faithful* [p]$_A$
	IDENT[voi]$_A$	2.8	2.2	19.2	1.2	*faithful* [nt]$_A$
Sino-Japanese	IDENT[ant]$_S$	0	0	14.4	−13.6	**nativized** [tɕi]$_S$
	IDENT[p]$_S$	0	0	16	−4	**nativized** [h]$_S$
	IDENT[voi]$_S$	3.2	0.8	19.6	1.6	*faithful* [nt]$_S$
Native	IDENT[ant]$_N$	0	0	14.4	−13.6	**nativized** [tɕi]$_N$
	IDENT[p]$_N$	0	0	16	−4	**nativized** [h]$_N$
	IDENT[voi]$_N$	0	0	16.4	−1.6	**nativized** [nd]$_N$

(15)   Relationships among weights: Core-periphery language, non-uniform distribution
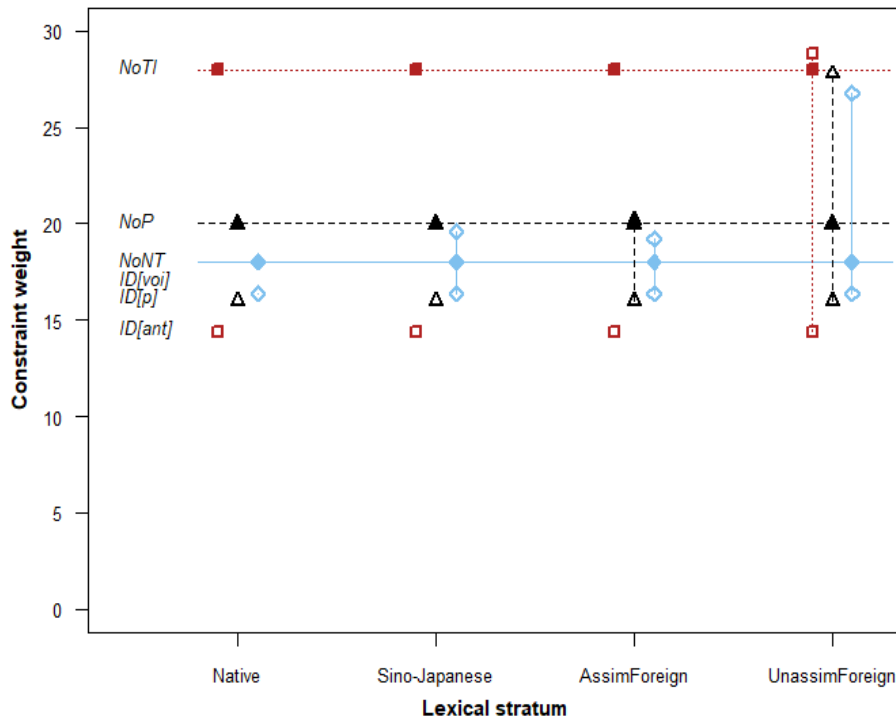
The results of this set of simulations are not qualitatively different from those discussed in §4.2, even though this time the majority of the lexicon belongs to the Unassimilated Foreign stratum, and so the learner was exposed to more faithful than unfaithful forms for all three phonological structures at hand.

The main difference for this schematic language seems to be that the weights for all faithfulness constraints specific to the Unassimilated Foreign stratum are relatively high—even those for IDENT[voi]$_U$ and IDENT[p]$_U$, which have ended up with much higher weights than are objectively needed, given the final weights of general IDENT[voi] and IDENT[p]. Conceptually, forms from stratum U were encountered so frequently in the course of the learning simulation that the weights of IDENT[voi]$_U$ and IDENT[p]$_U$ were

increased nearly every time those of their general counterparts were increased; as a result, the *U* faithfulness constraints contribute about half of the general+stratal cumulative faithfulness weight that would be needed to outweigh the conflicting markedness constraints for Unassimilated Foreign forms. As learning progressed, however, encounters with target forms from other strata—where the stratal faithfulness constraints had not had their own weights raised so quickly, and so non-target forms were still being selected—would continue to raise the weights of general IDENT[voi] and IDENT[p].

For the patterns of greatest interest here, however, there is essentially no difference between this core-periphery language and the one with a uniform distribution of lexical items. Among the markedness constraints we see w(NoTI) > w(NoP) > w(NoNT), while among the general faithfulness constraints we see w(IDENT[voi]) > w(IDENT[p]) > w(IDENT[ant]), just as for the first core-periphery language. This comparison shows that under the HG Stratified Faithfulness approach, any language with a strict core-periphery structure, regardless of the relative sizes of the different strata, will give the learner an HG grammar in which both the markedness hierarchy and the general faithfulness hierarchy reflect that core-periphery structure.

4.4 Schematic language #3: Non-core-periphery structure

The final set of learing simulations is designed to examine the constraint weights acquired for a language with a non-core-periphery structure. This time, the target language corresponds to (9)(b), including the Mimetic stratum. There are five lexical strata and five sets of stratum-specific faithfulness constraints, but the Mimetic and Sino-Japanese strata do not stand in a subset/superset relationship: as shown above in (8) and (11), singleton [p] is tolerated in Mimetic forms, and nasal–voiceless obstruent sequences are tolerated in Sino-Japanese forms, but not vice versa. The relative frequency of all lexical items for this schematic language was set at 1, so the lexicon was evenly distributed among the lexical strata.

Results are shown in (16) and (17); as above, one representative set of weights is reported here, and the range of weights assigned across the five simulations is also given in (16).

(16)   HG-GLA outcome: Non-core-periphery language

category	constraint	representative weight	range	cumulative faithfulness	F–M	outcome
markedness constraints	NoTI	28	0	—	—	—
	NoP	20	1			
	NoNT	20	0			
general faithfulness constraints	IDENT[ant]	14.4	0	—	—	—
	IDENT[p]	16	0.2			
	IDENT[voi]	16	0			
Unassimilated Foreign	IDENT[ant]$_U$	14.4	0	28.8	0.8	*faithful* [ti]$_U$
	IDENT[p]$_U$	5.4	1.8	21.4	1.4	*faithful* [p]$_U$
	IDENT[voi]$_U$	5.8	1	21.8	1.8	*faithful* [nt]$_U$
Assimilated Foreign	IDENT[ant]$_A$	0	0	14.4	–13.6	**nativized** [tɕi]$_A$
	IDENT[p]$_A$	5.2	2	21.2	1.2	*faithful* [p]$_A$
	IDENT[voi]$_A$	5.8	1.2	21.8	1.8	*faithful* [nt]$_A$

category	constraint	representative weight	range	cumulative faithfulness	F–M	outcome
Sino-Japanese	IDENT[ant]$_S$	0	0	14.4	−13.6	**nativized [tɕi]$_S$**
	IDENT[p]$_S$	0	0	16	−4	**nativized [h]$_S$**
	IDENT[voi]$_S$	4.4	1.8	20.4	0.4	*faithful [nt]$_S$*
Mimetic	IDENT[ant]$_M$	0	0	14.4	−13.6	**nativized [tɕi]$_M$**
	IDENT[p]$_M$	5.4	1.8	21.4	1.4	*faithful [p]$_M$*
	IDENT[voi]$_M$	0	0	16	−4	**nativized [nd]$_M$**
Native	IDENT[ant]$_N$	0	0	14.4	−13.6	**nativized [tɕi]$_N$**
	IDENT[p]$_N$	0	0	16	−4	**nativized [h]$_N$**
	IDENT[voi]$_N$	0	0	16	−4	**nativized [nd]$_N$**

(17)   Relationships among weights: Non-core-periphery language
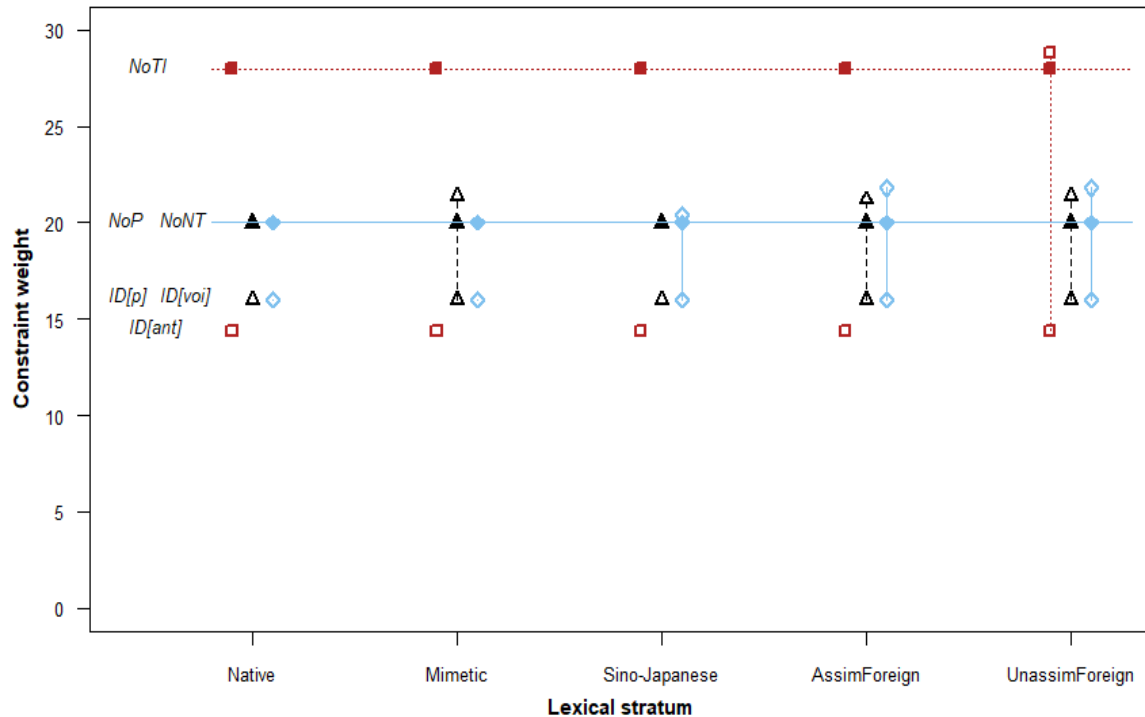
NoTI has the highest weight among the markedness constraints, and IDENT[ant] has the lowest weight among the general faithfulness constraints, as in the previous learning scenarios. This time, however, the general constraints pertaining to singleton [p] and to post-nasal voicing are tied: NoP and NoNT have the same weight, as do IDENT[p] and IDENT[voi]. The ties have come about because singleton [p] and faithful [nt] are permitted in the same number of strata: [p] in Mimetic, Assimilated Foreign, and Unassimilated Foreign, and [nt] in Sino-Japanese, Assimilated Foreign, and Unassmilated Foreign. As for the stratal faithfulness constraints, in each case where they are relevant (have a weight greater than zero), they have been apportioned just enough weight to allow for the cumulative effects between the general and the stratum-specific faithfulness constraints to overcome the opposing markedness constraints.

Thus, the HG Stratified Faithfulness model presented here allows an HG-GLA learner to acquire a set of weights for markedness, general faithfulness, and stratal faithfulness constraints that accurately models even a non-core-periphery language. When there is no strict core-periphery structure in the language being acquired, there will not be a strict domination hierarchy among the markedness constraints or among the general faithfulness constraints. Still, even this schematic language shows a final ranking that is as nearly consistent with core-periphery structure as the learning data will permit.

4.5 Summary: Learning simulations

The learning simulations described in this section have tested the HG Stratified Faithfulness model against a set of schematic languages with stratified phonologies. Results show that not only the stratum-defining markedness constraints, but also the relevant general faithfulness constraints, are ordered by the learner in a domination hierarchy that is determined by the number of lexical strata in which each constraint is enforced.

One implication of these findings is that even a language with a *non*-core-periphery phonology, in which not all lexical strata stand in a subset/superset relation, can be learned—a desired outcome, since languages with this pattern are attested.

For languages that do have a core-periphery structure, this direct connection between the number of strata in which a constraint is enforced and the relative weight of that constraint has additional implications. First, because no two of the stratum-distinguishing markedness constraints are enforced in the same number of strata, no two of them will have the same weight.[5] This establishes a strict domination hierarchy among the markedness constraints, capturing Ito & Mester's (1995ab, 1999) fundamental insight that a core-periphery phonology has such a markedness hierarchy as its underpinning.

The second implication for the learning of a strict core-periphery language is the most novel contribution of the HG Stratified Faithfulness model: the general versions of the faithfulness constraints that are relevant for distinguishing among strata are likewise ordered by the learner in a strict domination hierarchy. As demonstrated in the following section, this general-faithfulness hierarchy provides the basis for the grammar's emergent preference for core-periphery structure, thereby accounting for productive impossible-nativization effects, without invoking the formally complex type of metacondition on faithfulness rankings that is necessary in the OT Stratified Faithfulness model. Moreover, the current model predicts that even languages with only a partial core-periphery structure can still show limited impossible-nativization effects, which is consistent with reports of such effects in Japanese by Ito & Mester (1999).

5 Core-periphery structure as an emergent bias

The results of §4 show that a HG Stratified Faithfulness learner, when exposed to a stratified phonology with a core-periphery structure, acquires a domination hierarchy among the general faithfulness constraints that reflects that core-periphery structure. This section now proposes a means by which such a general-faithfulness domination hierarchy creates an EMERGENT BIAS toward maintaining strict core-

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[5]This wording is a minor simplification for ease of exposition. In a language where two markedness (or two faithfulness) constraints are both satisfied in the same *set* of strata—not just the same *number* of strata—the learner would assign them the same weight, but this scenario is still consistent with the language having a strict core-periphery phonology, and is clearly distinct from the case of NoP and NoNT in (9)(b) and the associated learning simulation in §4.4.

periphery structure in any new lexical strata that might be added to the language. This emergent bias, made possible by cumulative constraint interaction in HG, correctly predicts the existence of productive impossible-nativization effects.

An impossible-nativization effect, as discussed by Ito & Mester (1999, 2001), is the rejection or dispreference by native speakers of a form in which a lower-ranked (lower-weighted) markedness constraint is enforced but a higher-ranked (higher-weighted) one is not, resulting in the *nativization* of a 'less-foreign' property along with the *faithful preservation* of a 'more-foreign' property. Impossible-nativization candidates are inconsistent with strict core-periphery structure, but as shown in (6) above, repeated here as (18), the OT Stratified Faithfulness model cannot on its own rule out the introduction of a novel stratum X in which an impossible-nativization candidate is optimal.

(18)   Stratum X optimal candidate violates high-ranking NoTI, satisfies low-ranking NoNT

/tinta/X	IDENT[ant]X	NoTI	NoNT	IDENT[voi]X
→ a. tinda		*		*
b. tɕinda	*w	L		*
c. tinta		*	*w	L
d. tɕinta	*w	L	*(w)	L

Under OT Stratified Faithfulness, the only way to prevent any lexical strata from ever allowing the mapping /tinta/X → [tinda]X—an impossible nativization, given the established markedness ranking of NoTI » NoNT—is to introduce a metacondition that keeps the ranking among the faithfulness constraints consistent across strata. In (18), this would prevent IDENT[ant]X from dominating IDENT[voi]X, given evidence for IDENT[voi] » IDENT[ant] in other strata. Without IDENT[ant]X » IDENT[voi]X, candidate (a) cannot win.

Unfortunately, it becomes complex and stipulative to formulate a requirement (or even, for better empirical accuracy, a soft bias or defeasible preference) that IDENT[voi]Z » IDENT[ant]Z for all strata Z merely because there is some stratum Q where IDENT[voi]Q » IDENT[ant]Q. (See Ito & Mester (1999) and Fukazawa et al. (1998) for two different formal implementations of such a metacondition.) The problem is that the entire effect of faithfulness to the feature [±anterior] for any given stratum Z is due to one constraint, IDENT[ant]Z, and likewise for [±voice] and IDENT[voi]Z.[6] Crucially, there is no intrinsic relationship between IDENT[ant]Z for stratum Z and IDENT[ant]Q for any other stratum Q; they operate entirely independently in the constraint hierarchy. As a result, defining and enforcing a metacondition on ranking relationships across strata poses a thorny problem.

In the HG Stratified Faithfulness model introduced here, by contrast, there is a direct formal relationship between the relative degree of faithfulness to [±voice] versus [±anterior] in stratum Z and that in stratum Q. First, if the preservation of /ti/ is a property of only the most-peripheral stratum, but the preservation of /nt/ is a property of all but the most-core stratum, then *general* IDENT[voi] is satisfied in more strata than *general* IDENT[ant], and so the grammar *already includes* the general-faithfulness hierarchy w(IDENT[voi]) > w(IDENT[ant]) (see §3 and §4). Second, because of cumulative constraint interaction in HG, these general faithfulness constraints actually contribute to the outcome of the M-vs-F competition

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[6]In the language under consideration, a general IDENT[ant] or IDENT[voi] constraint would be dominated by the antagonistic markedness constraint, NoTI or NoNT respectively, and would therefore play no role in the phonology. If these general faithfulness constraints were not dominated, then /t/-palatalization and post-nasal voicing would never occur, and so would not be diagnostic of lexical strata in the first place.

in *all* strata. That is, the weight of the 'faithfulness effect' for [±voice] in stratum *Z* is the sum of the weights of stratal IDENT[voi]*Z and general IDENT[voi]*, and likewise for [±anterior].

With these pieces in place, the only additional proposal needed in order for the model to encode a bias toward core-periphery structure is a requirement that, if any novel stratum is added to the grammar after the ordinary process of language acquisition is complete—as might occur in a situation of novel language contact (a new wave of loanwords), or perhaps in an experimental setting (a nonce-loan nativization experiment)—then ALL FAITHFULNESS CONSTRAINTS INDEXED TO THAT STRATUM ARE ASSIGNED EQUAL WEIGHT, in the absence of overt evidence to the contrary. In terms of the current example, if all FAITH*Z* constraints for a novel stratum *Z* are assigned the same weight, then the domination hierarchy $w(\text{IDENT[voi]}) > w(\text{IDENT[ant]})$ among the general faithfulness constraints is carried over to the faithfulness relations for stratum *Z*: $(w(\text{IDENT[voi]}) + w(\text{IDENT[voi]}Z)) > (w(\text{IDENT[ant]}) + w(\text{IDENT[ant]}Z))$, because $w(\text{IDENT[voi]}Z) = w(\text{IDENT[ant]}Z)$. This principle of Uniform Weight by Stratum, along with cumulative constraint interaction and the emergent general-faithfulness hierarchy, thus ensures that faithfulness domination relations remain consistent even in a novel stratum (in the absence of overt evidence to the contrary).

As an example, consider schematic language #1, with a strict core-periphery structure, which was discussed in the learning simulation reported in §4.2. The end-state weights for the markedness constraints NoTI and NoNT, and the general faithfulness constraints IDENT[voi] and IDENT[ant], are repeated in (19) (from (13)), but now a new stratum *Z* is added to the language, and its possible effects are considered. By the principle of Uniform Weight by Stratum, all faithfulness constraints indexed to novel stratum *Z* are assigned the same weight, but three different scenarios can be distinguished (Z_1–Z_3).

(19)   Novel stratum *Z* introduced for Language #1

category	*constraint*	*weight*	*cumulative faithfulness*	*F–M*	*outcome*
markedness	NoTI	28.0	—	—	—
	NoNT	19.0			
general faithfulness	IDENT[ant]	14.4	—	—	—
	IDENT[voi]	16.2			
Stratum Z_1	IDENT[ant]Z_1	$w < 2.8$	*c.f.* < 17.2	< 0	/tinta/Z_1 → [**ʨind**a]Z_1
	IDENT[voi]Z_1		*c.f.* < 19.0	< 0	
Stratum Z_2	IDENT[ant]Z_2	$2.8 < w < 13.6$	$17.2 < $ *c.f.* $ < 28.0$	< 0	/tinta/Z_2 → [**ʨin̪t**a]Z_2
	IDENT[voi]Z_2		$19.0 < $ *c.f.* $ < 29.8$	> 0	
Stratum Z_3	IDENT[ant]Z_3	$w > 13.6$	*c.f.* > 28.0	> 0	/tinta/Z_3 → [t̪in̪t̪a]Z_3
	IDENT[voi]Z_3		*c.f.* > 29.8	> 0	

If the novel stratum *Z* is introduced with a weight for all stratal faithfulness constraints that is some value less than 2.8 (stratum 'Z_1'), then the cumulative weights of both IDENT[ant] + IDENT[ant]Z_1 and IDENT[voi] + IDENT[voi]Z_1 are low enough for the markedness constraints NoTI and NoNT to take priority, leading to nativization of both 'foreign' properties: /tinta/Z_1 → [**ʨind**a]Z_1. If the weights for stratum *Z* faithfulness constraints have some value greater than 13.6 (stratum 'Z_3'), then the cumulative weights of both IDENT[ant] + IDENT[ant]Z_3 and IDENT[voi] + IDENT[voi]Z_3 are high enough to overcome the antagonistic markedness constraints, leading to preservation of both properties: /tinta/Z_3 → [t̪in̪t̪a]Z_3. Finally, if the stratum *Z* faithfulness weights are given a value between these two points (stratum 'Z_2'), then IDENT[voi] + IDENT[voi]Z_2 will overcome NoNT, but IDENT[ant] + IDENT[ant]Z_2 will still be outweighed by NoTI,

leading to nativization of the 'more-foreign' /ti/ sequence but preservation of the 'less-foreign' /nt/ sequence: /tinta/$Z2$ → [**tɕ**in*t*a]$Z2$.

As desired, the impossible-nativization mapping /tinta/ → [*t*in**d**a] is not a possible outcome for stratum Z. The only way for this form to be chosen would be if IDENT[ant]Z had a weight greater than 13.6 while IDENT[voi]Z had a weight less than 2.8. While such weights could be acquired in the presence of overt evidence, this is not a possible state of affairs for a newly introduced or hypothetical stratum under Uniform Weight by Stratum. Thus, the model correctly accounts for the fact that impossible-nativization effects — a dispreference for impossible-nativization mappings—can be productive.

In fact, even a language without a strict core-periphery structure, such as schematic language #3 (§4.4), is predicted to show limited impossible-nativization effects. As discussed above, there is no domination relation between the general faithfulness constraints IDENT[p] and IDENT[voi] in this language, because of the non-superset/subset relation between the Mimetic and Sino-Japanese strata. However, even this language has an end state in which IDENT[ant] has a higher weight than either IDENT[p] or IDENT[voi]. This predicts that speakers of language #3 would in fact find the mapping /tinta/ → [*t*in**d**a] to be an impossible nativization, since this requires a reversed hierarchy in which faithfulness to [±anterior] takes preference over faithfulness to [±voice]. This prediction is consistent with the fact that some speakers of Japanese, which has only a partial core-periphery structure along the lines of language #3, do show impossible-nativization effects (Ito & Mester 1999; see also Smith & Muratani in prep.).

6 Conclusions and implications

The HG Stratified Faithfulness model successfully allows both core-periphery and non-core-periphery structure to be acquired for a stratified phonology, depending on the patterns in the learning data. In addition, because Harmonic Grammar allows for cumulative constraint interaction, the HG Stratified Faithfulness approach provides a much simpler way to enforce the consistent faithfulness ranking across strata that is required for a grammar with a strict core-periphery structure. A domination hierarchy among the general faithfulness constraints, which emerges automatically during the acquisition of a language with a core-periphery phonology, can be straightforwardly projected to any novel stratum—thereby preserving strict core-periphery structure—by means of the formally simple principle of Uniform Weight by Stratum.

The schematic examples considered in this paper are all quite simple, so it is left to future work to explore interesting questions of increased complexity. For example, what happens to the markedness and general-faithfulness domination hierarchies when the same faithfulness constraint conflicts with multiple markedness constraints at different points in the hierarchy, such as IDENT[voi] in Japanese, which actually conflicts not only with low-priority NoNT, but also with higher-priority NoDD (Ito & Mester 1995ab, 1999)?

More investigation is also needed into just how learners assign forms to strata in the course of language acquisition, but for promising directions to pursue, see Fukazawa et al. (1998), Pater (2005, 2010), and, using weighted constraints and a Maximum Entropy learner to assign forms to strata in English, Hayes (2016). Ito & Mester (1995b: 824, 1999:70) note that, while some of the lexical strata in Japanese are highly cohesive, others show more gradient or fuzzy boundaries; this observation certainly has implications for the acquisition of stratified phonology as well.

The wide-ranging implications and general relevance of these remaining questions go far beyond the phonological analysis of a loanword-rich lexicon (although that topic is interesting in its own right), thereby highlighting the foundational nature of Ito & Mester's original insight, at the beginning of

constraint-based phonology, relating core-periphery structure and its 'hierarchy of foreignness' (Kiparsky 1968: 132) to an explicit hierarchy of markedness constraints in a constraint-based formal grammar.

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NOMINAL CLASSES AND PHONOLOGICAL AGREEMENT IN TAGBANA[*]

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In addition to total vowel harmony and nasal harmony, Tagbana, a Senufo language spoken in Côte d'Ivoire, and more especially the dialect called Fròʔò, has a pervasive consonantal agreement in its nominal domain: the morphologically 'dependent morphemes' (in terms of concord, Corbett 1991) or 'associate morphemes' (Hockett 1958) of nominal heads agree in their articulator and [±continuant] features. This is a special case of alliterative concord, because the head noun plays no role in the alliteration. Besides the consonantal agreement features, these free associate morphemes have their own vocalic features and their own [±voice] feature. The paper starts with a review of nominal classes in Fròʔò and the morphological structure of simple nouns. It is proposed that Fròʔò has a partly non-concatenative morphology and that a standard Distributed Morphology analysis cannot fully account for the phonology of the resulting morphemes. In the second part, the role of phonology is investigated. It is proposed that well-formed morphemes are the result of partial or deficient phonological specifications in need of repair. The phonological approach is couched in an optimality-theoretic framework (see Saba Kirchner 2010 and Bye & Svenonius 2012, among others, for different languages). Part of the final specification of these morphemes is due to phonological repairs needed to fulfill markedness and faithfulness constraints, and the filling in of features due to vowel and nasal harmony, as well as consonant epenthesis.

Keywords: Alliterative concord, Tagbana, morphology and phonology, nominal classes

1 Introduction

We propose a morphological and phonological analysis of agreement in the seven nominal classes of Tagbana (sometimes spelled Tagwana) and more specifically in the dialect called Fròʔò (or Katiola), spoken around the town of Fronan in Côte d'Ivoire. According to Glottolog (Hammarström, Bank, Forkel & Haspelmath 2018), Tagbana is a West African Senufo language. It has been strongly influenced by Gur and Mande languages. A purely morphological analysis delivers deficient phonological structures with non-concatenated features and segments. It is the task of phonology to order the features present in the morphological specification and to repair or fill in the deficient segments.

Almost all language families of the Niger-Congo phylum have nominal classes expressed by affixes called class markers (CM). In many Niger-Congo languages, a noun may belong to a specific class because of the semantic characteristics of its referent; see Creissels (1991:91ff) for examples. However, in Fròʔò, as in other Senufo languages, semantic categories only play a secondary role in the distribution of nouns into classes (see Traoré in prep for more on this topic). Nominal classes are defined here on the basis of agreement that nouns trigger on other elements associated with the nominal domain (the

'associated words' of Hockett 1958). Agreement is a relation between two or more elements: a controller and one or more targets (or agreeing elements), i.e. an adjective, a pronoun etc., that receive their class by virtue of this agreement relation; see Corbett's (1991:4-5) definition of concord in (1).

(1)   Class concord
      A nominal expression that is in a relationship of syntactic dependence with the noun carries the class mark of the noun: determiner, adjective, interrogative, pronoun etc.

Frò?ò presents an extensive morphological and phonological nominal concord based on identical consonantal features on all morphemes associated with a noun, depending on their nominal class. We call this phenomenon 'consonantal agreement' for lack of a better term. As for the morphological structure, we propose an analysis in the framework of Distributed Morphology (Halle & Marantz 1993). The morphosyntactic features obey the principle of 'syntax all-the-way-down' proposed by Halle & Marantz (1993) and Bobaljik (2015), among others. Regarding the phonology, it has non-concatenative properties. The phonological form of morphemes is determined by abstract morphological features, and the surface form is a compromise between faithfulness to the pairing between morphological and phonological form (Vocabulary Insertion) and phonological markedness principles. The pervasive consonantal agreement of Frò?ò is non-local and differs from local consonant harmonies as described by Walker (2000a,b, 2001), Rose & Walker (2004), Hansson (2001) and Bennett (2015) for instance. In this paper, it is analyzed as an epiphenomenon of the morphology and phonology of the nominal domain (see Féry & Moskal 2018 for a typology of alliterative concord, in which Frò?ò finds a marginal place).

Nominal classes in Frò?ò are primarily identified on the basis of their phonological properties. The associated morphemes of a nominal head acquire their phonological shape by fusion of different phonological features expressing morphological features plus default phonology. Specifically, the initial consonants of these morphemes agree with each other. Agreement takes the form of distinctive features, as for example privative features for the articulator [labial], [coronal] and [dorsal] and binary [±continuant]. Examples of consonantal agreement are given in (2) with the identificational construction. This construction consists of a noun (lexical root + class marker CM, as in (4)), followed by an anaphoric pronoun (PRO) and an identificational particle (ID).

(2)   a. jē-**gē**   **kī**   **gī**   b. jē:-**rē**   **tí**   **dī**
         month-CM5   PRO5   ID5   month-CM6   PRO6   ID6
         'It is the month/moon.'   'It is the months/moons.'
      c. ɲṹ-**mṹ**   **pī**   **bī**
         water-CM7   PRO7   ID7
         'It is the water.'

In (2)a-b, the singular and plural CMs of classes 5 (singular) and 6 (plural) are suffixed to the lexical root *jē-* 'month'. The pronouns and the identificational particles are free morphemes following the noun. CM, pronoun and identificational particle share the same nominal class, and they agree with each other in some of their consonantal features. In (2)a, their initial consonant is [dorsal, -continuant], and in (2)b, the agreeing feature is [coronal]. In (2)c, the lexical root, *ɲṹ-* is followed by the CM of class 7 *-mṹ*. The anaphoric pronoun is *pī* and the identificational particle is *bī*. In this case, all three initial consonants are [labial, -continuant].[1]

There is also a regular total vowel harmony between the last vowel of the lexical root (henceforth V_{ROOT}) and the first vowel of the CM (V_{CM}), all features of V_{ROOT} being copied to V_{CM}, including tone. Only the length can differ; see (2)b, where [e] is lengthened by the following [r], an effect that we do not

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[1] The tones are indicated in all examples. There are three level tones, high (H) ' '', mid (M) ' ˉ ' and low (L) ' `'. In this paper, we do not provide an analysis of the tonal system of the language; see Traoré, Rialland & Féry (in prep) for the tonal structure of Frò?ò.

discuss here. In the examples in (2), the vowel of the free morphemes is always [i]. The quality of the vowel is determined by the morphemes themselves, and it is not the result of vowel harmony.

Before turning to the phonological properties of the nominal classes, let us briefly introduce the phonemic inventory of Fròʔò. The consonants are shown in Table 1. There are 22 consonants, 11 of which are stops and three of which are voiceless fricatives. There is no voiced fricative. The 11 stops are divided into voiceless and voiced ones, which can take five places of articulation: labial, alveolar, palatal, velar and labio-velar. Two laryngeals are included among the obstruents: [ʔ] and [h]. Additionally, there are eight sonorants, four of which are nasal. The remaining sonorants are two glides, [j] and [w], and two liquids, [l] and [r]. The Fròʔò consonant system is close to that of other Senufo languages, although some differences emerge as well: voiced fricatives exist in other Senufo languages, as for example in Nafara and Tyebara (see Mensah & Tschabale 1983).

Table 1. Fròʔò consonants		labial	alveolar	palatal	velar	labio-velar	glottal
Plosive	voiceless	p	t	c	k	kp	ʔ
	voiced	b	d	ɟ	g	gb	
Fricative		f	s				h
Nasal		m	n	ɲ	ŋ		
Glide				j		w	
Lateral			l				
Rhotic			r				

Fròʔò has seven 'plain' vowels, which can be long in some environments, in particular before a heteromorphemic [r], as shown in (2)b. All vowels can be lengthened by a following [r] (or [l]), but length is not distinctive. All vowels have nasal correspondents, except for the mid [+ATR] [e] and [o], which are never nasalized; thus all in all there are 12 vowels, as shown in Table 2. There is no [ATR] harmony in Fròʔò.

Table 2. Fròʔò vowels
 a. Short vowels   b. Nasal vowels
i   u   ĩ   ũ
  e   o
   ɛ   ɔ   ɛ̃   ɔ̃
      a   ã

Nominal phrases may include further morphemes, like adjectives, indefinite articles (there is no definite article), demonstratives, numerals, quantifiers, interrogatives and possessive pronouns. The canonical order of these morphemes appears in (3). Examples will be given below. Numerals and quantifiers are invariant, while all other words are morphologically and phonologically associated morphemes, and vary according to the nominal class of the head noun.

   (3)   Nominal template in Fròʔò
       (Possessive) – Nominal root – (adjective) – CM – (numeral/quantifier) – (demonstrative)
(pronoun) – (identificational particle)

In the remainder of this article, we investigate the morphological and phonological aspects of nominal classes and nominal domains in Fròʔò, paying special attention to the phenomenon of alliterative concord. A 'nominal domain' includes all morphemes that agree with a particular head noun plus possible

modifiers of the noun. The next section gives an overview of nouns and nominal classes in this language and provides a morphological analysis in the framework of Distributed Morphology. Section 3 describes alliterative concord in the nominal domain and emphasizes the shortcomings of a purely morphological approach to agreement. In particular, the morphological approach needs a phonological account to explain how the different pieces resulting from Vocabulary Insertion are organized into phonological outputs. Section 4 contains the complementary phonological account. Vowel and nasal harmonies as well as consonant epenthesis are the subject of this section. Finally, Section 5 compares alliterative concord from a typological perspective and shows how Tagbana differs from other languages with alliterative concord. It also contains a conclusion.

2 Nouns and nominals

We adopt a version of Distributed Morphology (DM) for explaining how words—specifically nouns—acquire their category (see Halle & Marantz 1993, Halle 1990, Noyer 1997, Pesetsky 1995, Embick & Noyer 2007 Nevins 2010, Embick 2010, Bobaljik 2015, Moskal 2015, among others). According to DM, there are three kinds of morphemes: first, lexical items or roots—morphemes without category—which are part of the language-dependent open lexicon; second, category-defining nodes n^0, v^0, and a^0; and third, functional morphemes bearing their own category. We come back to the final category in Section 3 and concentrate in this section on the first two categories.

A lexical root X has the form shown in (4)a. It acquires its category by adjunction of a category-defining functional head, n^0 (for noun) in (4)b, that combines with the root (Marantz 2007). In sum, a lexical root in Frò?ò does not have a category all by itself. It acquires its nominal status by combining with an overt or a covert class marker (CM), i.e. the category-defining functional head n^0 (see Smith 2015, among others, for this view).

(4)   a. √root

              n
             /\
        b. √root n^0
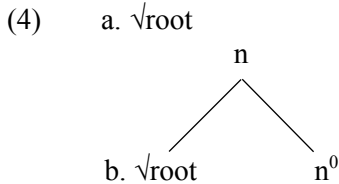
An example of a simple lexical root appears in (5). The lexical root *tì* needs a class marker to become a noun meaning 'tree' or 'wood'. In the examples, the class markers are CM5 or CM6, that is class markers of class 5 or 6, and the nouns formed in this way are themselves of class 5 (singular) or 6 (plural).

(5)   tī-ʔī   tī:-rī
      tree-CM5   tree-CM6
      'tree'   'trees'

As already mentioned, Frò?ò has seven nominal classes that are recognizable by the phonological form of their CM and associated morphemes. The first six classes come in pairs of singular and plural and class 7 includes mass nouns lacking a plural. In the present paper and following Creissels (1991), we call 'gender' the combination of a singular and a plural form.[2]
We follow suggestions by Clamens (1952) and by Miehe (2012) for Tagbana.[3] The nominal classes of Frò?ò are a subset of those proposed by Miehe, Reineke & Winkelmann (2012) in their introductory

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[2] We are well aware that the notion of 'gender' does not have the same meaning in African languages as in European languages, but we choose to follow the Africanist tradition.
[3] Miehe's survey is based entirely on Clamens' notes, which are not glossed and with which the first author of the present article does not always agree (see also Manessy 1996 for this judgment). Miehe classifies Tagbana as a Gur language, a proposal

chapter to the noun classes in Gur. Their proposal is based on Manessy's (1962, 1996) reconstruction work, which itself leans on the Bantu tradition. Our classes 1 and 2 (gender 1) roughly correspond to the Gur classes 1-2 of Miehe et al. (2012), our classes 3 and 4 (gender 2) to their classes 5-6, our classes 5 and 6 (gender 3) comprise their classes 12, 15 and 21, and our class 7 (gender 4) comprises their classes 14 and 22-23.

In Table 3, examples of the seven classes are listed with their class markers and examples of nouns for each class (for a more detailed survey, as well as a comparison with Miehe et al.'s proposal, see Traoré in prep). A typical root is mono- or disyllabic, regardless of the nominal class it acquires. If it is longer, it is most probably a compound. The class marker adds a syllable—or two in class 2 and class 4, the plurals of genders 1 and 2, respectively.

The vowel of the V_{CM} is typically a total copy of the V_{ROOT}. However, in disyllabic [-hele], [-bele] for class 2 and [-gele] for class 4 the vowel is prespecified as [e]. In class 4, one of the two possible CMs starts with a glottal stop, and the vowels are in total harmony with the V_{ROOT}, even though there are two vowels; see also the examples in (10).

Table 3. Overview of the nominal classes of Fròʔò and the class markers

Class markers (CM)	Examples of nouns of each class	
Class 1 (sg. of gender 1) CM: [-lV] , [-ŋV], [-hV]	hō-lō elephant-CM1	wótìɔ̀.1 python
Class 2 (pl. of gender 1) CM: [-lV] , [-hele], [-bele]	hō-bēlē elephants-CM2	wótìɔ̀-hélé pythons-CM2
Class 3 (sg. of gender 2) CM: [-lV]	lā:-lā belly-CM3	kpē-lē knife-CM3
Class 4 (pl. of gender 2) CM: [-ʔVlV], [-gele]	lā-ʔālā bellies-CM4	kpē-gēlē knives-CM4
Class 5 (sg. of gender 3) CM: [-gV], [-ŋV], [-ʔV]	jē-gē month-CM5	āfɔ̃́-ŋɔ̀̃ new thing-CM5
Class 6 (pl. of gender 3) CM: [-rV]	jē:-rē months-CM6	āfɔ̃́:-rɔ̀̃ new things-CM6
Class 7 (sg. of gender 4) CM: [-mV], [-bV]	ɲṹ-mṹ water-CM7	wɛ̄-bɛ̄ foliage-CM7

Nominal classes 1 and 2 (gender 1) contain the largest number of nouns. In contrast to genders 2 and 3, gender 1 can partly be characterized in semantic terms: the referents of the nouns of these classes include most human beings and other living beings, as well as animate and inanimate objects relating to humans. Moreover, this gender also contains loanwords. However not all the referents corresponding to this description are included in gender 1, as there are also animals or objects related to humans belonging to the other genders.

Class 1 nominal roots (the singular) usually form a noun by suffixing a CM, but there is also a non-negligible number of nouns that do not take an overt CM; these are followed by '.1' indicating that they belong to class 1. Lack of a CM is much more frequent in class 1 than in the other classes. An additional complication of this class is that the CM can take several forms by varying its onset consonant (C_{CM}). It can be a lateral [l], a nasal [ŋ] or [h].[4] As in all classes, total vowel harmony between V_{ROOT} (the last vowel of the root, which is the trigger) and V_{CM} (the target) is the rule.

Class 2 (plural of class 1) can also take different forms. In contrast to the other classes, class 2 nouns do not respect clear formation rules. The largest group of class 2 nouns have a CM starting with [l]

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that differs from the classification in Glottolog. It is thus not an understatement to claim that the present article, Traoré & Féry (2018) and Traoré (in prep) are the first linguistic studies of Fròʔò.

[4] It is the nouns themselves that determine the CM they take, i.e. a noun within class 1 always appears with the same CM consonant. If there is systematic phonologically or morphosyntactically conditioned allophony here, we could not identify it.

and a vowel harmonizing with the V_ROOT. The root vowels are often different in the singular (class 1) and in the plural (class 2). In short, gender 1 is not homogeneous as far as the noun (nominal root + optional CM) is concerned. Some examples appear in (6) to (9). In (6), words with a CM—both singular and plural— and in (7), words without a CM in the singular are listed.

(6) Gender 1 nouns with -lV_CM in the singular (class 1) and -lV_CM in the plural (class 2)

Sg.	Pl.	Sg.	Pl.
pɔ̄-lɔ̄	pīɛ̄:-lɛ̄	cɛ̄-lɛ̄	cīɛ̄:-lɛ̄
male-CM1	males-CM2	woman-CM1	women-CM2
hɔ́-lɔ́	húɔ́:-lɔ́		
mouse-CM1a	mice-CM2		

(7) Gender 1 nouns without a CM in the singular (class 1) and with -lV_CM in the plural (class 2)

Sg.	Pl.	Sg.	Pl.
nṹ.1	nĩ̄:-lĩ̄	gànṹ.1	gànĩ̄:-lĩ̄
mother	mothers-CM2	rat	rats-CM2
tō.1	tīē:-lē	nṹbūō.1	nṹbīē:-lē
father	fathers-CM2	friend	friends-CM2

As already mentioned, class 2 plural CMs may have a specific form: -bēlē or -hēlē. With these CMs, there is no vowel harmony between V_ROOT and V_CM. V_CM is always [e], regardless of the V_ROOT. Examples illustrating these plural formations appear in (8) and (9). The nouns in (9) are di- or trisyllabic and they do not differ in their singular and plural forms. The nouns that take -hēlē as their plural CM have no singular CM. The class is indicated with ".1" following the lexical root.

(8) Class 1 nouns with a CM in the singular and CM *bēlē* in the plural

Sg.	Pl.	Sg.	Pl.
hō-lō	hō-bēlē	nằbɔ̃-ŋɔ̃	nằbɔ̃-bēlē
elephant-CM1	elephants-CM2	stranger-CM1	strangers-CM2
kằ-ŋằ	kằ-bēlē		
gecko-CM1	geckoes-CM2		

(9) Class 1 nouns without a CM in the singular and *hēlē* CM in the plural

Sg.	Pl.	Sg.	Pl.
lēɲĩ̄ɛ̃.1	lēɲĩ̄ɛ̃-hélé	wótìɔ̀.1	wótìɔ̀-hélé
snake	snakes-CM2	python	pythons-CM2
tōkpɔ̀.1	tōkpɔ̄-hélé	ɟà:rà.1	ɟà:r-hélé[5]
grandfather	grandfathers-CM2	lion	lions-CM2

Classes 3 and 4 (gender 2) are more regular. In gender 2, the singular and the plural nominal roots are generally identical. This is also true of gender 3.

In class 3 nouns, the onset consonant of the CM is always the lateral [l]. Moreover, total vowel harmony always applies between V_ROOT and V_CM.

Class 4 nouns are formed in two different ways. The plural CM is either -ʔVlV, as in (10), or -gélē, as in (11).[6] Total vowel harmony applies between V_ROOT and both vowels in -ʔVlV, but in -gélē, the CM vowels are prespecified as [e].

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[5] The final a in ɟà:rà is not retained in the plural. Some vowels are weak and delete easily. This concerns especially V_CM and V_ROOT in total harmony with each other (see Traoré & Féry 2018 for vowel elision).

[6] With -gélē as CM4, the vowel of the nominal root is always a front mid vowel.

(10) Classes 3 and 4: Plural CM is -ʔVlV

Sg.	Pl.	Sg.	Pl.
lā:-lā	lā-ʔālā	ɲĩ̋ɛ̃-lɛ̃	ɲĩ̋ɛ̃-ʔɛ́lɛ̃
belly-CM3	bellies-CM4	eye-CM3	eyes-CM4

(11) Classes 3 and 4: Plural CM is -géle

Sg.	Pl.	Sg.	Pl.
cɛ̃̄-lɛ̃	cɛ̃̄-gélē	hɛ̀̃-lɛ̃	hɛ̀̃-gélē
calabash-CM3	calabashes-CM4	kidney-CM3	kidneys-CM4
kpē-lē	kpē-gēlē		
knife-CM3	knives-CM4		

In class 5 (the singular of gender 3) as well, V_{ROOT} is generally copied into V_{CM}. Thus, in most cases, total vowel harmony applies between the last vowel of the root and the vowel of the class morpheme. The C_{CM} can take different forms: it is either [g], [ŋ] or [ʔ]; see (12) to (14), respectively. We address the allophonic variation between [g] and [ŋ] in Section 4.2.2 below. There are also a small number of nouns of this class that have no overt CM; see (15) for examples.

Class 6 plural nouns always end with CV:-rV, where rV is the class morpheme. Vowel harmony is again total between the long V_{ROOT} and the V_{CM} (except for length, which is not copied). There is no consonantal allophony in the form of the CM. All nouns of this class have C_{CM} [r].

(12) Class 5 C_{CM} is [g] and class 6 C_{CM} is [r]

Sg.	Pl.	Sg.	Pl.
jē-ge	jē:-rē	wɛ̄-gɛ̄	wɛ̄:-rɛ̄
month-CM5	months-CM6	medicine-CM5	medicines-CM6
tɔ̀-gɔ̀	tɔ̀:-rɔ̀		
earthworm-CM5	earthworms-CM6		

(13) Class 5 C_{CM} is [ŋ] and class 6 C_{CM} is [r]

Sg.	Pl.	Sg.	Pl.
ɲì̃-ŋì̃	ɲì̃:-rì̃	pì-ŋì̃	pì:-rì̃
moment-CM5	moments-CM6	tam-tam-CM5	tam-tams-CM6
āfɔ̃̄-ŋɔ̀̃	āfɔ̃̄:-rɔ̀̃		
new thing-CM5	new things-CM6		

(14) Class 5 C_{CM} is [ʔ] and class 6 C_{CM} is [r]

Sg.	Pl.	Sg.	Pl.
tī-ʔī	tī:-rī	lɔ̄-ʔɔ̄	lɔ̄:-rɔ̄
tree-CM5	trees-CM6	river-CM5	rivers-CM6
frù-ʔù	frù:-rù		
mat-CM5	mats-CM6		

(15) Class 5 has no C_{CM} and class 6 C_{CM} is [r]

Sg.	Pl.	Sg.	Pl.
ɟīō.5	ɟīō -:rō	ɲĩ̄ɔ̃.5	ɲĩ̄ɔ̃-:rɔ̃
house	houses-CM6	mouth	mouths-CM6

In contrast to all other classes, class 7 nouns share a clear semantic property. This class contains mass or uncountable nouns, which have no plural. Accordingly, only singular forms are found here. The nouns of this class also have total vowel harmony between V_{ROOT} and V_{CM}. C_{CM} is usually [m]. In some instances, it

is [b]; see (17).[7] As can be seen in (16), the vowels preceding and following C$_{CM}$ [m] are often nasal themselves. However, as (18) shows, nasal harmony is not obligatory. Recall from Section 1 that [e] has no nasal equivalent, which explains the absence of nasal harmony in *lē-mē* and *hiē-mē*. However, the vowels of *lā-mā* are not nasal either, even though [a] does have a nasal equivalent. The generalization is that if V$_{ROOT}$ is nasal, then nasal harmony applies, but V$_{ROOT}$ does not need to be nasal, even if it is followed by a nasal; see Section 4.2.2 for more on the subject.

(16) Class 7 nouns (C$_{CM}$ is [m])

ɲũ̀-mṹ	cɛ̃̀-mɛ̃̀	gbã̀-mã̀
water-CM7	knowledge-CM7	recovery-CM7

(17) Class 7 nouns (C$_{CM}$ is [b])

wɛ̄-bɛ̄	kàtià-bù
cheek-CM7	foliage-CM7

(18) Class 7 nouns (no nasal vowels)

lā-mā	lē-mē	hiē-mē
belly-CM7	burial-CM7	family-CM7

Class 7 nouns and their dependent morphemes again have a clear harmonizing feature, namely [labial]; C$_{CM}$, pronoun and identificational particle share this feature. Labiality in class 7 is always realized with the feature [-continuant], which accounts for the alternation between stop and nasal. The feature [nasal] is optional.

Once a lexical root takes a specific CM, it acquires the class of the CM, and all dependent morphemes agree with it. Lexical roots without an overt CM nevertheless belong to a specific class, as easily verified by the phonological form of their dependent morphemes. Functional morphemes depend on the class of the noun they refer to, which means that if a noun had no class, it could not be referred to by pronouns, articles, relative pronouns etc. In sum, it is not possible for a noun to lack a class.

In some cases, a CM plays the role of a derivational morpheme. It can attach to different lexical roots and induce semantic shifts. Consider the nominal doublets in (19). The lexical root *cie-* can attach to CM1 and mean 'woman', as in (19)a, and the same root can also attach to CM7 *-mũ̀*, as in (19)b. In this case, the noun has the meaning of 'womanhood, property of being a woman'. The same doublet is illustrated with the lexical root *pì* 'child'. Notice that, when it this CM is derivational, it has a specified form *-mũ̀*.

(19) a. cɛ̃̄-lɛ̄   b. clɛ̃̄-mũ̀
      woman-CM1   woman-CM7 'womanhood'
   c. pì-ɔ̀   d. pì-mũ̀
      child-CM1   child-CM7 'property of being a child'

Diminutives and augmentatives are formed by affixing CM3 and CM5, as illustrated in (20). We saw in (7) that *gànṹ̄* 'rat' in its neutral meaning belongs to class 1, and has a covert CM.

(20)

gànṹ̄.1	gànṹ̄:-lṹ̄	gànṹ̄-ʔṹ̄
rat	rat-CM3 'small rat'	rat-CM5 'big rat'

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[7] This CM may indicate a different historical origin for these words, and this may imply that different classes came together at a certain stage in the history of the language. When the class marker is a stop, the corresponding identificational construction is invariably formed with the stops as well.

Lexical roots that are primarily used as verbs (without a CM, but in combination with an auxiliary) can easily become nominal by attachment to a nominal CM, as illustrated in (21). It is not yet clear what determines the choice of CM for each individual verb.

(21) a. cā   →   cā-lā
         to.look.for   search-CM3
         'to look for'   'search'
    b. wɛ̀lɛ́   →   wlɛ̀.ʔɛ̀
         to.bark   'bark-CM5'
         'to bark'   'barking'
    c. tá̃ʔá̃   →   tá̃ʔá̃-mṹ
         to.walk   walk-CM7
         'to walk'   'the fact of walking'

Turning now to the phonological properties of the class markers, at least in classes 3, 5, 6 and 7, the same articulatory features [labial], [coronal] and [dorsal] as the ones found for the associate morphemes are present in the C_{CM}. This is of course no accident, rather it is part of the pervasive articulatory specification for the classes.[8] In the overview (22), V stands for a vowel that is the result of total harmony of V_{root}, thus the last vowel of the lexical root. Only the CMs of classes 2 and 4 have a prespecified vowel [e] in their disyllabic allomorphs.[9]

(22)   Class markers
      a. [CM CLASS 1]   ⟺   {[ŋV], [nV], [rV], [lV], Ø}
      b. [CM CLASS 2]   ⟺   {hele, bele, [-lV]}
      c. [CM CLASS 3]   ⟺   [lV]
      d. [CM CLASS 4]   ⟺   {[ʔVlV], gele}
      e. [CM CLASS 5]   ⟺   {[gV], [ŋV], [ʔV], Ø}
      f. [CM CLASS 6]   ⟺   [rV]
      g. [CM CLASS 7]   ⟺   [mV]

Table 4 provides an overview of the consonantal features in each class, together with the morphemes of the so-called identificational constructions that we already encountered in (2) (pronoun and identificational particle) in boldface. The next section discusses the phonological properties of functional morphemes. It should be noted that pronouns and identificational particles can be used without the overt noun and still agree with the class marker; see (26) for an example with the pronoun.

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[8] There is more to be discovered in the phonological form of the CMs. We strongly suspect that some of the specific forms are due to diachronic changes and lexicalized forms; see Dombrowsky-Hahn (2015) and Miehe et al. (2012) for some remarks on this issue in related languages.

[9] Notice that that the class markers with fixed vowels are all disyllabic (only one disyllabic CM has harmonizing vowels). A reviewer hypothesizes a relationship between the size of CM and the presence of a prosodic boundary (foot or prosodic word) that interferes with conditions for vowel harmony (see also Urbanczyk 2006 on root-size affixes). We have no answer to this problem at this stage.

Table 4. Agreeing consonantal features of two functional morphemes

Consonantal features	Example of identificational construction			
Class 1: [w] [labial, consonantal, vocalic]	hō-lō elephant-CM1 'It is the elephant.'	**wī** PRO1	**wī** ID1	
Class 2: [p, b] [labial, -continuant]	hō-bēlē elephant-CM2 'It is the elephants.'	**pē** PRO2	**bɛ̄** ID2	
Class 3: [l] [lateral]	bùò-lò granary-CM3 'It is the granary.'	**lí** PRO3	**lī** ID3	
Class 4: [k, g] [dorsal, -continuant]	bùò-ʔólō granary-CM4 'It is the granaries.'	**kē** PRO4	**gɛ̄** ID4	
Class 5: [k, g] [dorsal, -continuant]	jē-ge month-CM5 'It is the month/moon.'	**kī** PRO5	**gī** ID5	
Class 6: [t, d] [coronal, -continuant]	jē:-rē month-CM6 'It is the months/moons.'	**tí** PRO6	**dī** ID6	
Class 7: [m, p, b][10] [labial, -continuant, ([nasal])]	ɲũ̄-mũ̄ water-CM7 'It is the water.'	**pī** PRO7	**bī** ID7	(or **mĩ̄ mĩ̄**)

3 Associate functional morphemes

In this section, we present a formal approach to the consonantal agreement of associate functional morphemes. First, section 3.1 introduces the morphosyntactic features of functional morphemes. Section 3.2 reviews the agreeing phonological features for all associate morphemes of classes 5 and 6 (gender 3) and sums up the phonological agreeing features of all classes. In section 3.3, it is shown how the abstract morphological features are paired with phonological exponents in the DM operation of Vocabulary Insertion.

3.1 Morphosyntactic features of functional morphemes

In Distributed Morphology, besides lexical roots and the category-defining nodes n^0, v^0 and a^0, a third category consists of functional morphemes bearing their own category. These morphemes are accounted for in morphosyntactic terms. Whether such morphemes are pronouns, demonstratives, interrogatives etc. is established in the syntax and expressed by means of abstract syntactic features; see Moskal (2015) for the difference between lexical roots and functional morphemes in other languages. Some of the morphological categories needed in Fròʔò are listed in (23).

(23)   a. [pronoun]   b. [interrogative]   c. [demonstrative]

Inflection begins in syntax, by combining abstract elements according to general principles. As an example, a pronoun associated with several inflectional features has an articulated morphosyntactic

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[10] In the identificational construction, pronoun and identificational particle have two alternative forms: *pī bī* or *mĩ̄ mĩ̄*. These two forms appear to be in free variation. Notice that in the variant with [m], the following vowel is nasal, while it is oral when following [p] and [b]. This strongly suggests nasal harmony.

representation. The assignment of nouns or pronouns to one of the seven nominal classes of Frɔ̀ʔò is determined by such syntactic abstract features, as illustrated in (24).

Pro5

(24)   [PRO]   [CLASS 5]
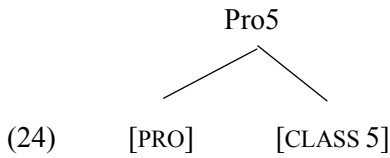
Class markers define nominal classes but are also the bearers of number. The abstract feature [SG] may fuse with [CLASS 5]; see (25). We do not indicate number in the following, as singular and plural are intrinsic to their respective classes, as shown above.

Pro5

(25)   [pro]   [class 5, sg]
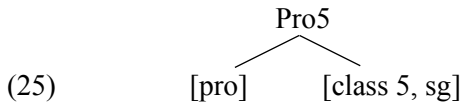
3.2 Functional morphemes

Table 5 sums up the functional morphemes for all seven classes. In this section, we concentrate on functional morphemes of classes 5 and 6, in boldface in Table 5, for illustration.

Table 5. Dependent morphemes in the seven nominal classes

	Pronoun/ Possessive	Identifica-tional particle	Interro-gative	Indefinite article	Demon-strative/ Relative pronoun	Deictic particle
Class 1 [w]	wī	wī	wíʔí	wà	ŋā̰̄	wè
Class 2 [p, b]	pē	bɛ̄	béʔélé	pè:lè	bɛ̄ʔɛ̄lɛ̄	bē
Class 3 [l]	lī	lī	líʔí	là	lā	lè
Class 4 [k, g]	kē	gɛ̄	géʔélé	kè:lè	gɛ̄ʔɛ̄lɛ̄	gē
Class 5 [k, g]	**kī**	**gī**	**gíʔí**	**kà**	**gā**	**gè**
Class 6 [t, d]	**tī**	**dī**	**díʔí**	**tà**	**dā**	**dè**
Class 7 [m, p, b]	pī~mḭ̄́	bī~mḭ̄́	bíʔí~mḭ́ʔḭ́	pà~mà̰̀	bā~mā	bè~mè

In the rows, the morphemes are organized by classes, and in the columns by the morpheme category. In the former case, the similarity of the articulatory features is striking, and in the latter case, the syllabic templates and the quality of the vowels stand out. The phonological form of the morphemes is the result of the articulatory and continuancy features of the respective classes, as well as the voicing in the case of stops, the vowels and the syllabic templates.[11] It must be emphasized that in regard to consonant harmony on the associate morphemes, all classes are regular.

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[11] Notice that the prespecified vowel of the morphemes is always [i], [e], [ɛ] or [a], never a round back vowel.

The morphemes participating in the concord pattern are: pronouns/possessives (3.2.1), identificational/clause-ending particles (3.2.2), interrogatives (3.2.3), indefinite articles (3.2.4), demonstratives (3.2.5), relative pronouns (3.2.6) and deictic particles (3.2.7). All these morphemes acquire their consonantal form by sharing their articulatory features; in the case of classes 5 and 6, the shared features are [dorsal, -continuant] in class 5 and [coronal, -continuant] in class 6, as established in Table 4. These features arise in the right branch of (24). In contrast, the vowel and the number of syllables of each morpheme are prespecified by the morphemes themselves, and not by the class of their head noun, thus by the specification in the left branch of (24).

3.2.1 Pronouns *kí* and *tí*

The class 5 pronoun is *kí* and the class 6 pronoun is *tí*; see (26). The pronouns have the articulator feature [dorsal] in class 5 and [coronal] in class 6. Both are [-continuant]. They are monosyllabic and their vowel is [i]. There is no morphological marker for case in Fròʔò, and pronouns can be subjects, direct objects, indirect objects, possessives, obliques etc.

(26) Pronouns of classes 5 and 6

kí	nã̌	sīē	**tí**	nã̌	sīē
PRO5	AUX.PROG	go	PRO6	AUX.PROG	go
'She/he/it is going.'			'They are going.'		

Possessive articles *kī* and *tī*
Similarly, the 3rd person possessive articles *kī* and *tī* agree according to the class they are standing for. These forms are identical to the pronouns; see the examples in (27).

(27) Class 5 and 6 possessives

kī	tì-ʔí	**tī**	tì:-rí
POSS5	tree-CM5	POSS6	tree-CM6
'her/his/its tree'		'their tree'	

3.2.2 Identificational/Clause-ending particles

The identificational particles *gī* and *dī* are parts of the identificational construction; see the examples in Section 2 and in (28). They share the same consonantal features as the pronouns, except for voicing, which is not a property of the morphological feature [pronoun]. Their vowel is invariably [i] except for classes 2 and 4, where it is [ɛ].

3.2.3 Interrogatives *gíʔí* and *díʔí*

Interrogative 'which' is *gíʔí* in class 5 and *díʔí* in class 6; see (28). Its initial consonant is again the same as that of the identificational *gí* in class 5 and *dí* in class 6. The consonant of the second syllable is [ʔ], which is analyzed as the result of consonant epenthesis between two identical vowels; see Section 4.3. The interrogative is disyllabic and its vowel is [í].

(28) Class 5 and 6 *wh*-words

tī-ʔī	kì	**gíʔí**	gī	tī:rī	tì	**díʔí**	dī
tree-CM5	PRO5	WH5	ID5	tree-CM6	PRO6	WH6	ID6
'Which tree is this?'				'Which trees are these?'			

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3.2.4 Indefinite articles *kà* and *tà*

It can be seen in (29) that the indefinite article *kà/tà* starts with [k] in class 5 and with [t] in class 6. The indefinite article has the articulator feature [dorsal] in class 5 and [coronal] in class 6. The indefinite article is monosyllabic and its vowel is [à], except for classes 2 and 4, where it is [e].[12]

(29) Class 5 and 6 indefinite articles

wɛ̄-gɛ̄	**kà**	wɛ̄:rɛ̄	**tà**
medicine-CM5	INDEF.ART5	medicine-CM6	INDEF.ART6
'a medicine'		'medicines'	

3.2.5 Demonstratives *gā* and *gā:gē*; plural *dā* and *dā:dè*

Demonstrative articles of classes 5 and 6 are proximal *gā* (*gè*) and *dā* (*dè*) 'this' or distal *gā:gē* (*gè*) and *dā:dē* (*dè*) 'that'; see the examples in (30). The difference between the two is in the length of the vowel [a] and the disyllabicity of the distal form. Demonstratives show the same consonantal features as before. The pure demonstrative is just the first morpheme; the second morpheme is a deictic marker, comparable to *ci* and *là* in *celui-ci* 'this one (here)' or *celui-là* 'that one (there)' in French; see 3.2.7 for these particles without the demonstrative.

(30) Class 5 and 6 proximal demonstratives

tī-ʔī	**gā**	gè	tī-:rī	**dā**	dè
tree-CM5	DEM.ART.5	DEICT 5	tree-CM6	DEM.ART.6	DEICT6
'this tree'			'these trees'		

3.2.6 Relative pronouns *gā* and *dā*

The simple proximal demonstratives *gā* and *dā* also take the function of the relative pronoun, as illustrated in (31).[13] Again [g] and [d] are present and indicative of the class of the antecedent.

(31) Class 5 and 6 relative pronouns

a.
tī-ʔī	**gā**	mī́	nā̌	pī̀
tree	REL.PRO5	I	AUX	talk.about

'The tree that I am talking about.'

b.
tī:rī	**dā**	mī́	nā̌	pī̀
trees	REL.PRO6	I	AUX	talk.about

'The trees that I am talking about.'

3.2.7 Deictic particles

The deictic particles *gè* and *dè* were already shown in (30), as part of the distal demonstratives. They also vary according to the class of the noun they refer to. Their vowel is always [è].

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[12] There is no definite article in Frɔ̀ʔɔ̀. The CM may in some cases take the function of the definite article, although it does not fulfill this role in an unambiguous way.

[13] The sentence structure of Frɔ̀ʔɔ̀ generally has the form S Aux O V X, X being everything else.

3.3 Vocabulary Insertion

In Distributed Morphology, Vocabulary Insertion (VI) refers to the pairing of syntactic nodes with phonological representations or exponents, thus the mapping from syntax to phonological form. This pairing takes place after the morphosyntactic operations, like fusion or merger, have been completed. The functional morphemes of each class are associated with their features, which then play the role of filling in the abstract morphosyntactic information with phonological content.

The phonological form of the functional morphemes is the result of putting together several bits of morphophonological information.[14] First, the different classes are paired with the consonantal features that are specific to them and which have been reviewed in Table 4. The VI pairing between class features and their phonological features takes the form in (32). The remaining classes pair their own features. Class 7 has two variants, but so far, we have not been able to ascertain what triggers the choice of one alternant over the other in individual cases.[15]

(32) a. [CLASS 1] ⟺ [labial, +consonantal, +vocalic]
     b. [CLASS 5] ⟺ [dorsal, -continuant]
     c. [CLASS 7] ⟺ [labial, -continuant]/[labial, -continuant, nasal]

The second bit of phonological insertion concerns the voicing of the stops, summed up in Table 6. In classes 2, 4, 5, 6 and 7, the initial consonants of the functional morphemes are stops that can be voiced or voiceless. The glide of class 1 and the lateral of class 3 are always voiced: they cannot be [-voice], and are thus unaffected by this alternation. Pronouns/possessives and indefinite articles are voiceless and the other morphemes, i.e. demonstratives/relative pronouns, interrogatives, deictic particles and identificational particles, are voiced. In sum, the feature [±voice] changes according to morphological features.

Table 6. The role of voicing

Morphemes	Voicing
Pronouns/possessives, indefinite articles	[-voice]
Demonstratives/relative pronouns, interrogatives, deictic particles, identificational particles	[+voice]

Third, the vowel associated with each morpheme delivers additional phonological information specified by the morpheme itself; see Table 7. Pronouns/possessives, interrogatives and identificational particles have [i] in the singular (classes 1, 3, 5 and 7) and [e] in the plural (classes 2 and 4), except for class 6, which has [i] although it is a plural. The indefinite articles and demonstratives/relative pronouns have [a] in classes 1, 3, 5, 6 and 7 and [e/ɛ] in classes 2 and 4. Recall that the vowel of the CM is typically the result of vowel harmony, except in the cases in which it has a complete prespecification. In other words, the CM is not affected by the vowel distribution shown in Table 7.

The trisyllabic morphemes always have prespecified vowels and are thus never subject to vowel harmony. This could be related to the fact that vowel harmony generally does not iterate (the CM of class 4 being the sole exception). Most of the disyllabic morphemes have a prespecified vowel (see Kaplan 2008 for iteration in phonology).

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[14] Plus tonal information, which we ignore here.

[15] Ines Fiedler has proposed that two historically different classes may have fused into one. This hypothesis should be investigated in future research.

Table 7. Vowel distribution

Morphemes	Vowels
Pronouns/possessives Interrogatives Identificational particles	[i] in classes 1, 3, 5, 6 and 7 [e] in classes 2 and 4
Indefinite articles Demonstratives/relative pronouns	[a] classes 1, 3, 5, 6 and 7 [e/ɛ̄] in classes 2 and 4

Finally, the number of syllables is also part of the phonological exponence of morphemes, as shown in Table 8. All syllables are of the form CV (written σ_{CV} below), thus an open syllable with an onset and a simple nucleus (there are no diphthongs in Frɔ̀ʔɔ̀); see Traoré & Féry (2018) and Traoré (in prep.) for a survey of the syllable structure.[16] The morphemes are always monosyllabic in the singular (classes 1, 3, 5 and 7), except for the interrogative, which is always disyllabic in the singular and consists of the identificational particle Cí plus a syllable ʔí. The initial consonant of the interrogative is determined by the articulatory features listed in Table 5, and the second consonant is epenthetic; see Section 4.3. All pronouns, deictic particles and identificational particles are monosyllabic in the plural (classes 2, 4 and 6). Indefinites and demonstratives/relative pronouns are either mono-, di- or even trisyllabic, depending on the class. The last syllables of polysyllabic morphemes always start with [ʔ] or with [l]. We assume that [l] is prespecified, but [ʔ] is epenthetic.

Table 8. Syllabic templates (number of syllables in each morpheme)

	Syllabic templates
Monosyllabic templates	Singular (classes 1, 3, 5 and 7): all morphemes except for the interrogative Plural (classes 2, 4 and 6): pronouns/possessives, identificational particles
Disyllabic templates	Interrogative singular (classes 1, 3, 5 and 7) and plural of indefinite articles of classes 2 and 4 *pè:lè* and *kè:lè*
Trisyllabic templates	Demonstratives/relative pronouns and interrogatives of classes 2 and 4 (plural): *bɛ̄ʔɛ̄lɛ̄/ béʔélé* and *gɛ̄ʔɛ̄lɛ̄ / géʔélé*

As a result of Vocabulary Insertion of consonantal features and the information provided in Tables 6 to 8, morphosyntactic abstract morphemes in Frɔ̀ʔɔ̀ are not paired with fully specified segments or syllables but rather with several partial phonological chunks of information, as is typical for non-concatenative morphology. The phonological form of the class 5 pronoun *ki* must be analyzed as the result of two pairing operations, articulated as in (33): one for pronoun and one for class. Whether the information should be provided in the form of a syllable is open to discussion. In this case, there is no reason to assume anything else than a CV syllable that can bear the feature [-voice] and the vowel [i]. Putting the features [dorsal, -continuant] in this template leads to the fully specified syllable: *ki*.

(33)   a. [PRO]   ⟺   [-voice], [i]   or   σ
                                                              ╱╲
                                                            C   V
                                                        [-voice]   i

---

[16] The underlying syllable structure is always open, but resyllabification, and more specifically vowel deletion, can result in closed syllables in connected speech, which is ignored here. Codas are limited to sonorants.

b. [CLASS 5]   ⟺   [dorsal, -continuant]

In the case of a demonstrative/relative pronoun, the vowel is [a]. The other specifications are similar to those for the pronoun; see (34)a. And the class information remains the same. The result is again a fully specified syllable: *ka*.

(34)   a. [DEM]   ⟺   [-voice], [a]
         b. [CLASS 5]   ⟺   [dorsal, -continuant]

The class 5 interrogative *gíʔí* must contain the information that it is disyllabic. If one consonant is voiced, dorsal, and [-continuant] and one of the vowels is [i], as shown in (35), one syllable is fully specified. However the result of VI is not enough to fully specify the disyllabic template: VI only provides information for one syllable, not for two. The result of VI is thus deficient. Neither the featural content of one of the consonants nor that of one of the vowels is prespecified. We assume that the quality of the second vowel is due to vowel harmony and that the second consonant is epenthetic; see Section 4 for more detail.

(35)   a. [INTERR]   ⟺   [σ_{CV} σ_{CV}], [+voiced], [i]

$$\sigma \qquad\qquad \sigma$$

[-voice]   i   C   V

         b. [CLASS 5]   ⟺   [dorsal, -continuant]

The articulatory features inserted in other classes were listed in Table 3, and the results of VI for all morphemes listed in Tables 6 to 8 can be deduced by analogy.

Peculiarities in the phonological form of some morphemes are accounted for by specific VI rules or pairings that take precedence over the regular ones. An often-cited example of suppletion is provided for English by an abstract feature like [PLURAL], which may be realized by different phonological exponents. The ordering of more specific rules before general ones has been addressed several times in the phonology, Kiparsky's (1973) Elsewhere condition being the option chosen in DM. An alternative is the ranking of specific, context-dependent faithfulness constraints above general, context-free ones in Optimality Theory. In this framework, the choice between phonological allomorphs is best understood as a competition between different forms, and the most restricted rule must apply first in order to be applicable. In (36), *ox* forms its plural by suffixing *-en*, the most restrictive plural in this list. *Fish* and *foot* do not take any suffix. Because they list specific morphemes, the rules in (36)a-b take precedence over (36)c, the regular plural formation.

(36)   Plural allomorphy in English
         a. [PLURAL] ⟺ - en/{√ox, ...}
         b. [PLURAL] ⟺ - Ø/{√fish, √foot, ...}
         c. [PLURAL] ⟺ - /z/

A suppletive pairing in Fròʔò is the class 1 demonstrative/relative pronoun [ŋã̃], mentioned in Table 5, which has a special nasal consonant and a nasal vowel. Recall that [w] is the regular consonant of this class. We assume that [ŋã̃] is the nasalized allomorph of [wa] + [nasal]. The vowel is nasal [ã] and the preceding consonant is the result of replacing labio-velar [w], which is not allowed before a nasal vowel, by its dorsal nasal alternant. Specific Vocabulary Insertion (37)a takes precedence over (37)b by

Elsewhere. The pairing (37)a applies in class 1 demonstratives/relative pronouns, and (37)b applies in all other class 1 functional morphemes.

(37)   a. [CLASS 1]   ⟺   [dorsal, consonant, nasal] / {demonstrative/relative pronoun}
       b. [CLASS 1]   ⟺   [labial, consonant, vocalic]

A second peculiarity has to do with the exceptional di- and trisyllabic templates found in class 2 and 4 interrogatives, indefinites and demonstratives. Examples of such prespecifications are exemplified for interrogatives of classes 2 and 4 in (38).

(38)   a. [INTERR, class 2]   ⟺   [béʔélé]
       b. [INTERR, class 4]   ⟺   [géʔélé]

A third prespecification concerns the exceptional vowels in some morphemes of Table 5. For instance, in class 2 and 4 pronouns, we find [e] instead of regular [i]. These morphemes have their own prespecified vowels. This also takes the form of specific VI rules that take precedence over the elsewhere rules.

(39)   a. [PRONOUN]   ⟺   [V=e]   (class 2, class 4)
       b. [PRONOUN]   ⟺   [V=i]

The fourth singularity that was mentioned in Tables 4 and 5 concerns the free variation between [p/b] and [m] in most class 7 morphemes. This is due to optionality of the feature [nasal] in this class. We assume that VI has the form shown in (40). The feature [nasal] can be present or not, except when the CM starts with a stop. In this case, nasality is forbidden.

(40)   a. [CLASS 7]   ⟺   [labial, -continuant]   (CM = bV)
       b. [CLASS 7]   ⟺   [labial, -continuant] or [labial, -continuant, nasal]

Despite these additional specifications, it is important to notice that the initial consonant of the agreeing morphemes is always alliterating. Not a single exceptional specification affects the regularity of the initial consonant. In other words, consonantal alliteration is fully regular.

4 The role of phonology

4.1 VI instructions as inputs in an optimality-theoretic analysis

VI delivers phonological features and some structure, but not enough for completing the phonological form of the functional morphemes described above. In this section, we propose a phonological analysis of the nominal functional morphemes in the framework of constraint-based Optimality Theory (OT). The results of VI instructions play the role of inputs, and faithfulness constraints are responsible for their emergence (or phonological exponence) in the output. Markedness constraints determine whatever phonological structure is not specified by VI instructions but is needed in the output. The result of the markedness constraints is that unspecified slots—features, segments and syllable positions—are filled in. Syllable structure, vowel harmony, nasal harmony and consonant epenthesis are located in the phonological module, where syntax is no longer available; see Saba Kirchner (2010) and Bye & Svenonius (2012:428), among others, for a similar view.

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We already saw how the class 5 pronoun *kī* emerges as the result of filling a consonant with the prespecified consonantal features [-voice], [dorsal] and [-continuant] and the prespecified vowel [i], all information coming from VI; see (33) for how the prespecified features are organized in a syllable at VI. A faithfulness constraint IDENT(F) in (41) preserves the prespecified information, as shown in Tableau 1. The constraint IDENT(F) comes in two versions. The first context-free one is formulated as in (41)a, but the identity of the features present in the lexical root is more important than the identity of the features present in the functional morphemes. For this reason, the constraint-sensitive constraint IDENT(F)$_{root}$ in (41)b is needed as well, as will become clear in Tableau 5.

(41)   a. IDENT(F): Let α be a segment in the input and β be any correspondent segment of α in the output. If α has [F], then β has [F]. And if β has [F], then α has [F].
        b. IDENT(F)$_{root}$: Let α be a segment of a lexical root in the input and β be any correspondent segment of α in the output of the lexical root. If α has [F], then β has [F]. And if β has [F], then α has [F].

Markedness constraints, like ONSET, NOCODA and NUCLEUS in (42), are responsible for the fact that the consonantal features are located in the onset rather than in the coda, and that the vowel is the nucleus of the unique syllable. In the tableaux, these constraints are put together under the name SYLLABLESTRUCTURE or SYLLABLE for short. These constraints are always fulfilled in the functional morphemes: all syllables have the form CV.

(42)   Markedness Constraints (SYLLABLESTRUCTURE)
        a. ONSET: Syllables have onsets.
        b. NOCODA: Syllables have no codas.
        c. NUCLEUS: Each syllable has a vocalic nucleus.

In Tableau 1, the optimal candidate a. fulfills all constraints. This is because the information delivered by VI is sufficient to deliver the phonological content of the functional morpheme. Candidate b. has a voiced consonant and violates IDENT(F) and candidate c. violates ONSET and NOCODA. Since all constraints are fulfilled in the optimal candidate, it is not possible to establish a ranking among them. IDENT(F)$_{root}$ is not active here because the word has no lexical root.

Tableau 1. Class 5 pronoun

[-voice], [dorsal], [-continuant], [i], [σ]	IDENT-IO(F)	SYLLABLE
☞ a. kī		
b. gī	*! (voice)	
c. īk		*!*

In the functional morphemes that have been reviewed above, the prespecified consonantal features are implemented in the first consonant, and the prespecified vowel is the morpheme's first vowel. When it has to do with a single syllable, these requirements are satisfied by the constraints of (42), and there is no alternative. In the di- or trisyllabic functional morphemes, like the class 5 interrogative *gíʔi*, the input consonantal and vocalic features are also associated with the first consonant and the first vowel of the word. In this case, alternatives are available, and the position of the input features must be regulated by

constraints. We propose a constraint called ANCHOR(F) in (43) (see McCarthy & Prince 1995 for anchoring in OT). Due to the effect of SYLLABLESTRUCTURE, the consonantal features are associated with the onset, and the vocalic features with the nucleus.

(43)   ANCHOR(F): The consonantal features specified in the input are anchored to the left peripheral element of the morpheme.

The constraints at play so far have nothing to say about the form of the second syllable of *gíʔí*. The second C and V nodes are phonologically unspecified. Vowel harmony and consonant epenthesis are responsible for the remaining phonological specifications. We thus need a formal analysis for vowel harmony and for [ʔ]-epenthesis between identical vowels.[17] Harmonies are the subject of Section 4.2 and [ʔ]-epenthesis of Section 4.3.

4.2 Vowel and nasal harmonies

Vowel and nasal harmonies are pervasive in the entire phonology of Fròʔò, and many examples have been encountered in this article. We understand phonological harmony as 'a phonological effect in which feature(s) agree over a string of multiple segments'; see Rose & Walker (2011) for a slightly different definition. In such a process, at least two segments interact. This interaction may occur locally, between adjacent segments (nasal harmony), or 'at a distance' across at least one unaffected segment (vowel harmony).

　　Segments can participate in a harmony, but they can also be transparent or block the harmony process. Transparent segments are not participating segments, but they let the harmony apply across them. The blockers also do not participate, and they stop the harmony. If the harmonizing feature reaches a blocker, i.e. an incompatible segment, it stops. Incompatibility arises when a segment is already specified for the feature in question, or if it cannot carry the feature. Harmony processes are usually directional, forward or backward, from the beginning or end of a prosodic domain.[18] In Fròʔò, vowel harmony always takes place from left to right, and nasal harmony applies in both directions.

4.2.1 Total vowel harmony

In total vowel harmony or vowel copy in Fròʔò, vowels harmonize completely across a consonant, i.e. in all their features (and tone). The process is illustrated schematically in (44). In most of the examples that we have discussed in the previous sections, the trigger is V_{ROOT} and the target is V_{CM}. The process applies in the domain of a prosodic word; in the case that we are studying here, it corresponds to a noun comprising a lexical root and a CM, and in the case of a functional morpheme, the first vowel is specified by the constraints formulated above plus vowel harmony. In both cases, the second vowel takes over all vocalic features of the first one.

(44) $V_1\ C_2\ V_3\ \rightarrow\ V_1\ C_2\ V_1$

Some additional examples of vowel harmony in nouns appear in (45). V_{ROOT} (in bold), the last vowel of the lexical root, is the trigger. It harmonizes with V_{CM}, the target. In (45)b, the CM is disyllabic, and both

---

[17] In a morpheme like *béʔélé*, it must be assumed that only [b] is subject to ALIGN. The vowel [e] and [l] are prespecified. The glottal stop is epenthetic as shown for *giʔi* in Section 4.3.
[18] Another option is that an entire domain agrees in a feature without there being a clear origin and/or direction of the process. Since harmonies in Fròʔò are directional, we do not discuss this option.

vowels of the CM harmonize with V_{ROOT}.[19] As mentioned before, this is the only case of iteration of vowel harmony in the language.

(45)   a. kájĩ̋ɛ̃̄-lɛ̃̄   kɔ́gǔ̃-ŋǔ̃   kà-ʔà
             bird-CM3   knee-CM5   village-CM5

        b. ciē-ʔēlē   buo-ʔolo
             foot-CM3   granaries-CM4

All vowels may participate in total vowel harmony, including the nasal ones.[20] In other words, all features harmonize by spreading across transparent consonants. At least all consonants that start a CM are transparent, obstruents included. We assume that the target of vowel copy is unspecified prior to harmony and that vowel copy is equivalent to a feature-filling process.

        After the harmony process is completed, all segments V_1, V_2 and V_3 harmonize in all their features F. The trigger is always V_1; see (46).[21]

$$V_1 \quad V_2 \quad V_3$$

(46)   F
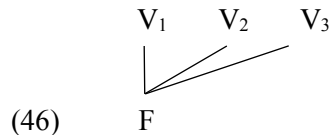
In the OT model proposed here, total vowel harmony is regulated by two constraints, HAVEFEATURES in (47)a, which requires that a vocalic position is filled in by a vowel with features, and AGREEV in (47)b, requiring total vowel harmony, see Bakovic (2000) for a similar constraint. More generally, these constraints demand that if a vowel is completely unspecified in the input, it must acquire vocalic features, and this happens as the result of copying all features from the specified vowel in the same prosodic word rather than by inserting any other vowel. In our examples, V_{ROOT} is fully specified and V_{CM} acquires the same features by fulfilling the constraints in (47). No prespecified vocalic features are changed because IDENT(F)$_{root}$ prohibits featural changes in the root.

(47)   OT constraints for vowel harmony
      a. HAVEFEATURES: Vocalic and consonantal nodes must have features.[22]
      b. AGREEV: Output vowels in the same prosodic word agree in all features.[23]

---

[19] Notice that the vowels resulting from vowel harmony are often deleted in casual speech; see Traoré & Féry (2018) for a discussion of vowel deletion.

[20] It is important to note, however, that total harmony does not apply across-the-board. In some (rare) cases, V_{ROOT} does not spread to V_{CM}, as in class 5 nouns: *jù-gò* 'head-CM5', *dã̀-gò* 'sheet-CM5'. In such cases, V_{CM} is prespecified.

[21] There is an ongoing debate in the literature about the arguments and counterarguments for spreading- vs. correspondence-based theories of copy epenthesis (see Walker 2001,Rose & Walker 2004 and Stanton & Zukoff 2018). The Frɔ̀ʔɔ̀ data presented here are compatible with both approaches.

[22] This constraint is reminiscent of Itô & Mester's (1993:201) notion of segment licensing by Root and Place.

[23] We are aware of the 'sour grapes' effect identified by McCarthy (2011) in relation with AGREEV or AGREENAS. However due to the distinction between prespecified versus unspecified segments in OT (see also Inkelas, Orgun & Zoll 1997) and because no opaque consonant blocks harmony in Frɔ̀ʔɔ̀, no sour grapes effects appear here.

Tableau 2. Total vowel harmony

kà -ʔV village-CM5	IDENT(F)$_{root}$	HAVEFEATURES	AGREEV	IDENT(F)
☞a. kà-ʔà				
b. kì-ʔì	*!			*
c. kà-ʔV		*!		
d. kà-ʔì			*!	

Some class markers do not copy V$_{ROOT}$. Instead they have a prespecified initial vowel: class 2 *hélé* or *bēʔɛ̄lɛ̄* and class 4 *gēlē* or *gēʔēlē*. In addition to the trisyllabic template, this prespecification is part of the VI instructions and has to appear as such in the input. As before, the first vowel is prespecified and the other vowels are just a copy.

As for the class 1 demonstrative *ŋɑ̄̃* the vowel is nasal and as such it is different from the unmarked one for class 1 which is oral. However, default phonology is also active in the sense that the nasality of the consonant may be the result of nasal harmony, to which we turn in the next subsection.

4.2.2 Nasal harmony (vowel-consonant harmony)

Nasal harmony differs from vowel harmony in three respects: First, a continuous string of vowels and consonants is involved, as shown in (48). Nasal harmony is thus strictly local. Second, the process is feature changing rather than feature filling. Third, both consonants and vowels can be trigger and target. In (48)a, the vowels are triggers, and in (48)b, the consonant is the trigger.

(48)   a. V$_{[nas]}$ C V$_{[nas]}$ →   V$_{[nas]}$ C$_{[nas]}$ V$_{[nas]}$
         b. C$_{[nas]}$ V   →   C$_{[nas]}$ V$_{[nas]}$

Let us start with vowels as triggers and consonants as targets, as in (48)a. In (49), a nasal consonant appears between two nasal vowels. The crucial point is that only a nasal consonant is allowed between two identical nasal vowels. This is illustrated here with the dorsal nasal and [g], but the same point can be made with the other obstruents, stops and fricatives, both voiced and voiceless. None of them are allowed between two nasal vowels.

(49)   a. fṹ-ŋṹ   'anger-CM5'   b. ɲrĩ̄-mṹ 'milk-CM7'

We assume that /g/ is phonemic and [ŋ] may be an allophone of /g/ when it is surrounded by nasal vowels. [g] can appear between two oral vowels or between an oral and a nasal vowel in both orders, as illustrated in (50) with nominal roots. In (50)a, the vowel preceding [g] is nasal and the vowel following [g] is oral, in (50)b, it is the other way around, and in (50)c, both vowels around [g] are oral.

(50)   a. kǎ̃gàlà   b. kɔ́gṹ-ŋṹ   c. kōgō
         'jackal'   'knee'   'cat'

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However, [g] does not appear between two nasal vowels, and [ŋ] is found instead; see (49).

In the allophonic relationship between [g] and [ŋ], total vowel harmony applies first, as in (51)a, resulting in two identical nasal vowels, as in (53)b. In a procedural description, the [nasal] feature that is found at both sides of [g] spreads back to the consonant, which becomes nasal as well; see (53)c.[24] In other words, the feature [nasal] originates in V_{ROOT} (the trigger) and spreads to V_{CM}, and then back to the intervocalic consonant.

	[nasal]		[nasal]		[nasal]

(51)   a. fṹ-gV   →   b. fṹ-gṹ   →   c. fṹ -ŋṹ
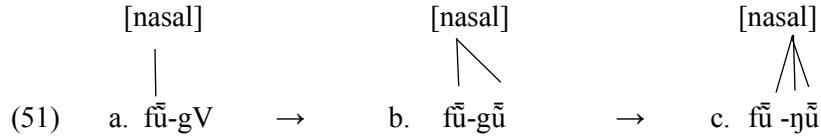
In the second type of nasal assimilation, (48)b, a nasal consonant is the trigger, and the following vowel is the target; see (52) for illustration. The example is the nasal allophone of the class 7 pronoun, the non-nasal alternant being *pī* with an oral vowel.

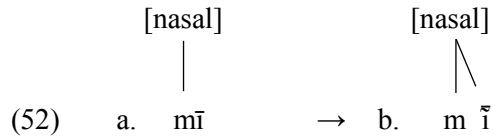|	[nasal]		[nasal]

(52)   a.   mī   →   b.   m ĩ

The nasal harmony illustrated in (52) only targets a vowel that has at least some underlying specification; it cannot affect an oral vowel resulting from total vowel harmony: such a vowel cannot be changed again by nasal harmony. Because of this restriction, oral vowels can be adjacent to nasal consonants, as was illustrated in (18) with the word *lā-mā* 'belly-CM7', but only when they are the result of vowel harmony. In this word, the oral V_{ROOT} is copied to the unspecified V_{CM}, which harmonizes with its oral specification. As such, nasal harmony cannot apply, and a sequence of a nasal consonant and an oral vowel arises, as the result of a bleeding relationship. In other words, in a derivational view, vowel harmony and nasal assimilation apply in this order, and vowel harmony bleeds nasal assimilation. Moreover, since vowel harmony is always left-to-right, there is no way that the nasality of the CM consonant can have a regressive effect on the preceding vowel, which remains oral in *lāmā*.[25]

Tableau 3 illustrates the vowel-triggered nasal harmony. Two additional constraints are needed. The first one, *[ṼObsṼ], prohibits an oral obstruent between nasal vowels; see (53)a. The second one requires that adjacent segments agree in the feature [nasal]: if a segment is prespecified for [nasal], adjacent segments are nasal as well.

(53)   a. *[ṼObsṼ]: No obstruent between nasal vowels.
        b. AGREE(nasal): Adjacent segments agree in their nasal feature

The constraint AGREE(nasal) may be violated when segments are prespecified as oral, as explained above. In the present case, the initial [f] is prespecified as such and has no nasal allophone. It remains oral and violates AGREE(nasal).

---

[24] This looks like what Lionnet (2016) calls 'subphonemic teamwork': in this case, two distinct nasal features must be present to result in nasalization of another segment.

[25] There is at least one piece of evidence for an additional regressive nasal harmony from a vowel to a consonant. The palatal glide [j] has an allophone [ɲ] before a nasal vowel: *jō* 'tell' vs. *ɲā* 'see'. These segments seem to be in complementary distribution. However, more data are needed in order to be entirely confident that this analysis is correct.

Tableau 3. Nasal harmony (vowel to consonant)

fũ- g/ŋ V V_ROOT C V_CM	IDENT(F)_root	HAVE FEATURES	*[ṼObsṼ]	AGREE (nasal)	AGREEV	IDENT(F)
☞ a. fũ-ŋũ				*		
b. fũ-gũ			*!	**		
c. fũ-gū				**	*!	
d. fũ-gV		*!		**		
e. fũ-gū	*!					*

The word *lā-mā* 'belly' with a nasal consonant between two oral vowels is illustrated in Tableau 4. As shown above, the first vowel is specified as an oral vowel, and does not change its specification due to IDENT(F)_root. The vowel is copied to the V_CM without this vowel acquiring the nasality of its onset consonant. This is the result of the ordering of AGREEV above AGREE(nasal). The effect of HAVEFEATURES is taken for granted in the following tableaux.

Tableau 4. Vowel harmony bleeds nasal harmony

lā- m V V_ROOT C V_CM	IDENT(F)_root	AGREEV	AGREE(nasal)	IDENT(F)
☞ a. lā-mā			**	
b. lā-mã̄		*!	*	
c. lã̄-mã̄	*!		*	*
d. lā-pā				

As for the consonant-triggered allophony, no additional constraint is needed. AGREE(nasal) is sufficient to guarantee that nasal features are shared with neighboring segments, as long as these segments are not the result of total vowel harmony. In Tableau 5 for *mĩ̄* 'I', it is assumed that the input vowel is unspecified for nasality and that adding a nasal feature by harmony does not violate IDENT(F)_root since the vowel undergoing harmony is not part of a lexical root. The context-insensitive IDENT(F) is ranked lower than AGREE(nasal), allowing the vowel to agree with the preceding consonant in its nasality.

Tableau 5. Nasal harmony (consonant to vowel)

/mī/ 'I, me'	IDENT(F)_root	AGREE(nasal)	IDENT(F)
☞ a. mĩ̄			*
b. mī		*	

4.3 Epenthetic [ʔ]

In this subsection, it is shown that the glottal stop in the second C is the result of [ʔ]-epenthesis. [ʔ]-epenthesis applies between identical vowels.[26] Epenthesis is needed to fill in an unspecified consonant position in the CV skeleton. It violates the DEP constraint in (54).

(54)   DEP: No epenthesis.

Returning next to the interrogative *gíʔí*, the first consonant gets the consonantal features because of ANCHOR(F) in (43). The first vowel of the interrogative is specified with all input features as shown above for *kī̄*, and the second vowel is a copy of the first by total vowel harmony. It must be noted that the form of the interrogative strongly resembles a lexical root plus a CM5, pointing to a characteristic pattern of the language beyond lexical root plus CM. Verbs also very often consist of two syllables with harmonizing vowels and a glottal stop between them.
Tableau 6 ignores candidates containing syllables that do not conform to the canonical structure CV. Candidate a. fulfills all constraints except for low-ranking DEP. Candidate b. violates SYLLABLE because the second syllable lacks an onset. Candidate c. violates ANCHOR(F). Candidate f. violates AGREEV. To eliminate candidate e., we need to guarantee that prespecified consonantal features only emerge once, and we propose to use the constraint INTEGRITY(C) to this effect (McCarthy and Prince 1995).

(55)   INTEGRITY(C): No consonantal element of the input has multiple correspondents in the output.

The template [σσ] (or [CVCV]) also needs to be fulfilled, and this is achieved with the constraint MAX-IO[σ] in (56). Candidate d. violates this constraint, because the second syllable is lacking entirely.

(56)   MAX-IO(σ): The number of syllables in the output corresponds to the number of syllables in the input.

Tableau 6. *gíʔí*: [ʔ]-epenthesis in class 5 interrogative

[+voice], [dorsal, -cont], [i], [σσ]	IDENT(F)	SYLLABLE	ANCHOR(F)	MAX-IO(σ)	INTEGRITY (C)	AGREEV	DEP
☞ a. gíʔí							*
b. gí.í		*!				*!	
c. ʔigi			*!				*
d. gí				*!			
e. gigi					*!		
f. gíʔá						*!	*

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[26] This analysis is confirmed by the neighboring dialect Katiola that has [giː] with a long vowel instead of *gíʔí*, as in many other words where a long vowel takes the place of VʔV.

This closes the survey of the phonological processes governing vowel and nasal harmonies as well as filling in deficient phonological structure in the associate morphemes of a head noun in Fròʔò.

5 Discussion and conclusion

The main topic of this article is the phonological properties of morphemes of the same nominal class in Fròʔò, the most striking aspect being the presence of recurrent articulatory features for each inflectional class, a case of alliterative concord. This pattern arises when several functional morphemes of the same class are linearized. The best answer of morphology is to reproduce the pairing between class and phonological features each time a function word is present. In (57), a longer sequence of functional morphemes, the same pairing is reproduced six times.

(57)

jē-gē	**kì**	**gíʔí**	**gī**	**gā**	**gè**
month-CM5	PRO5	which5	ID5	DEM5	CL-END.PTC5
⇕	⇕	⇕	⇕	⇕	⇕
[dor, -cont]	[dor, -cont]	[dor, -cont]	[dor, -cont]	[dor, -cont]	[dor, -cont]

'Which is this month?'

In this approach, alliterative concord is considered a purely morphological phenomenon that does not need to be given a phonological account. However, the free associate morphemes consist not only of alliterating consonantal features coming from their nominal class, but also of other morphosyntactic features paired with additional phonological features. The order of these different phonological features is not reflected in the linearization of the exponents. Instead, features are organized in a non-concatenative fashion, and if there is a hierarchy of morphological features at all, it is not crucial. Purely phonological effects across segments have been uncovered in this study as well, and an optimality-theoretic analysis has been proposed for them. Different types of vowel and consonant harmonies in the nominal domain have been explored: total vowel harmony, nasal consonant-vowel harmony and consonant epenthesis. Although they all apply in the nominal domain, they have different operational ranges. Vowel harmony concerns only two (exceptionally three) vowels separated by a transparent consonant. Nasal consonant-vowel harmony only affects a sequence of two vowels and in some cases, the consonant in-between. The domain of harmonies and consonant epenthesis seems to be limited to the prosodic word. Alliterative concord has a larger domain, and concerns all morphemes related to a head noun.

Alliterative concord is not an accident in Fròʔò, but rather it is part of the phonological system of the language. Fròʔò speakers recognize the class of nouns primarily by the initial consonant of the functional morphemes. The class markers may also help the categorization, but since they may be absent or have ambiguous forms, class markers are less reliable than agreeing functional morphemes, since they take different forms, or even be absent altogether. We propose that class markers participate in the alliterative concord rather than eliciting it.

The alliterative pattern of Fròʔò is rather atypical when we compare it to similar cases described in the literature. Alliterative patterns have been described for several languages; see for instance Fortune (1942), Nekitel (1986), Aronoff (1992), Dobrin (1995) and Dimitriadis (1997) for phonological concord in nominal classes in Arapesh and Abu' (Mountain Arapesh), Papuan languages spoken in New Guinea. In Arapesh, the last consonant of a noun is often copied into the pronoun and the verb with which it agrees, resulting in an alliterating concord pattern. This even happens with consonants newly introduced into the consonant inventory of the language through loanwords. However, this process is restricted to part of the vocabulary, which is for the most part non-alliterative.

Sauvageot (1967, 1987) cites Baïnuk, a West Atlantic language spoken in Senegal, where the first CV syllable of some words may be copied in part of its vocabulary (mainly borrowed words but

nonetheless 25% of the words) and plays the role of a gender agreement morpheme on an associate adjective or demonstrative.

Moreover, Kaye (1981), Marchese (1986, 1988) and more recently Sande (2017) show that Vata, Godié and Guébié, respectively, all Kru languages of Côte d'Ivoire, have phonologically motivated pronominal systems, in addition to other agreeing words. Non-human nouns are organized into five (for Godié or Vata) or three classes (for Guébié) according to their final vowel, and subject pronouns referring to them take five or three different shapes, depending on this vowel. Again, this kind of alliterative system is limited to a small part of the functional morphemes, although other kinds of alliterative agreement also take place in adjectives. In Guébié, the third person subject pronoun has an invariable singular form [ɔ] and an invariable plural form [wa], when it refers to a human being. The exponent of a non-human third person pronoun, however, is variable: it is [ʊ], [ɛ] or [a], where the feature [-ATR] of the dependent morpheme is lexically specified. Sande (2017:50) writes, "Non-human third person pronouns agree with their nominal antecedent not in semantic features like person or number, but in phonological features, where the final vowel of the noun stem determines the vowel of the pronoun." The choice between the three forms of the pronoun is determined by the features [±back] and [±low] of the final vowel of the stem. These features are phonologically copied from the root. When a noun ends in one of the [+back, -low] vowels [u, ʊ, o, ɔ], its corresponding pronoun is [ʊ]. When the noun ends in one of the [-back, -low] vowels [i, ɪ, e, ɛ], the pronoun is [ɛ], and when it ends in a [+back, +low] vowel [ə] or [a], the pronoun is [a].

Thus Arapesh, Baïnuk and Guébié, copy (or are faithful to) a syllable, a segment, or part of a segment as phonological agreement. However, this strategy is unavailable for Fròʔò because the alliterative features are often not literal parts of the head noun (lexical root + CM): the lexical root does not carry any of the features appearing in the alliterative concord, and the CM may or may not carry the agreeing features. In many cases, the features that are copied are not present in the CM, be it because the CM has a different phonological form, or because the CM is covert, and then absent altogether. If the alliterating features originate in the lexical root or in the CM, they can only be abstract features. These original features may be unrealized in a sentence with a pronoun or any other functional morpheme referring to a head noun; see (26) for an example of a sentence where a pronoun refers to an absent head noun. In other words, the CM sometimes participates in the alliteration but does not necessarily do so.

In sum, alliteration in Fròʔò is not a classic spreading relationship and not a reduplication or copy and deletion operation. All associate morphemes start with similar consonants, but there is no locality involved. Vowels interfere, as do words and in some cases entire constituents, see (58) for an example in which alliterative concord takes place across a relative clause. In (58)b, the pronoun *wí* refers to a person and has to agree with class 1. The referent of the pronoun *wí* does not need to be literally pre-mentioned in the discourse; it can be contextually present.

(58) a. tī-ʔī   gā   kí   tō   wā klō̄ʔō nǎ kí   nĩ́ kpã̀gna̋-ŋã̋
       tree-CM5   RC.PRO.5 PRO.5 fall.down there street on PRO.5 ASP big-CM5
       'The tree that fell down on the street is big.'
    b. wí   mǎ̀ sɛ́bɛ́ kā̰   John mǎ̀
       PRO.1 ASP book give John to
       'S/he gave the book to John.'

In future research, it will be important to establish a typology of alliterative concord, and to understand the role it plays in the different languages cited above, as well as in others. It will also be important to give a phonological account that can cover all the cases, something which has not been done so far.

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FEATURE IDENTITY AND ICY TARGETS IN MENOMINEE VOWEL HARMONY[*]

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Menominee exhibits a parasitic vowel harmony where [+ATR] harmony operates among non-low vowels. The behavior of low vowels is of particular interest. Low [+ATR] vowels block propagation of harmony and low [-ATR] vowels are transparent. This paper analyzes the pattern through the lens of surface correspondence. Feature identity is intrinsic to the mechanism of Agreement by Correspondence. This approach readily obtains both height-parasitic [+ATR] harmony and the transparent behavior of vowels that differ from non-low triggers in values for [low] and [ATR]. The lack of propagation of harmony by low [+ATR] vowels is analyzed as a case of blocking by correspondence, where these vowels function as icy targets for [+ATR] harmony. In this account, feature-value specific CORR constraints play a role in differentiating of the behavior of low vowels, contributing on a debate about the structure of constraints that drive surface correspondence.

In general terms, this study reveals that constraints that govern correspondence relations and correspondence-mediated identity provide a unified account of a complex system of parasitic vowel harmony. This approach contributes to a broad theoretical aim to maximize utilization of constraints within well-established families, with the potential to reduce complexity in Con.

Keywords: Vowel harmony, Menominee, Agreement by Correspondence, icy targets, feature identity

1 Introduction

In parasitic harmony patterns, harmony is restricted to segments that are identical for some feature. In analyses based on feature-geometric structure, spreading of the harmonizing feature is dependent on another tier or the presence of other multiply linked features (Archangeli 1985, Cole 1987, Cole & Trigo 1988, Mester 1988a, b). A strategy in more recent work employs constraints that penalize harmony between segments that differ in specification for a given feature (Cole & Kisseberth 1995a, b, Jurgec 2011a, 2013, Kaun 1995, 2004, Kimper 2011). However, in the Agreement by Correspondence approach (ABC; Walker 2000a, b, 2001, Hansson 2001, 2010, Rose & Walker 2004), feature identity is intrinsic to the mechanism that gives rise to surface correspondence, through which harmony is mediated. This property of ABC makes it particularly apt for the treatment of parasitic harmony (Rose & Walker 2004, Walker 2012).

In this paper, I revisit the case of [+ATR] harmony in Menominee in the ABC framework. This pattern has been characterized as a parasitic harmony (Nevins 2004, 2010).[1] Four types of vowel behavior are at issue: height-parasitic harmony, transparency, blocking, and height-specific non-harmony. The combination of these behaviors in the same system provides an important empirical test for any approach to harmony. The proposed analysis utilizes *feature-value specific* CORR constraints, which coerce surface correspondence among segments that are identical in a specific value of a given feature. This approach departs from an alternative where surface correspondence is driven by a constraint framed in the MAX constraint formalism, which lacks a counterpart of the feature-value specificity in CORR constraints (McCarthy 2010).

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[1] Cole (1987) and Cole & Trigo (1988) also described Menominee harmony as parasitic but with a different interpretation of the vowel contrast system and harmonizing feature.

In the ABC analysis, feature identity relationships play an essential role in characterizing vowel behavior in Menominee's harmony. First, height-parasitic harmony operates among vowels that are non-low. However, harmony is not enforced among low vowels. I characterize the lack of harmony in the latter context as "height-specific non-harmony," since [+ATR] harmony does not operate in the low stratum in contrast to the non-low stratum. The height-stratum differences follow from CORR-XX[αF] constraints that are ranked so as to enforce surface correspondence among non-low vowels but not among low vowels. The distinct behavior of low [-ATR] and [+ATR] vowels is of particular theoretical interest. Low [-ATR] vowels are transparent to harmony between non-low vowels. Transparent vowels differ from non-low [+ATR] triggers in their values for [low] and [ATR]. Owing to their lack of identity, surface correspondence is not enforced between these vowel classes, bringing about *transparency by lack of correspondence*. In contrast, low [+ATR] vowels behave as blockers of harmony. This arises through *blocking by correspondence* (Rhodes 2008, 2012, Walker 2009), where the low [+ATR] vowel is in surface correspondence with a non-low [+ATR] trigger by virtue of identity for [+ATR]. In this context, the low [+ATR] vowel functions as a type of *icy target* (Jurgec 2011a, b) by halting further harmony. In the account, feature-value specific CORR constraints contribute to differentiating the transparent versus blocking behavior of low vowels.

In the larger picture, this analysis contributes to extending the ABC approach to vowel harmony, showing that it is both viable and well suited for treating a complex parasitic pattern. It accomplishes this with a limited set of constraint families in Optimality Theory (OT; Prince & Smolensky 2004), specifically, CORR-XX[αF] and IDENT constraints. These constraints revolve around correspondence relations and correspondence-mediated feature identity, which are central constructs in OT (McCarthy & Prince 1995). A strength of the ABC analysis in contrast to alternatives that employ other constraints is that it maximizes the labor of correspondence-centered constraint families, with the potential to reduce complexity in Con. This achievement finds a parallel in work by Bennett (2013, 2015a, b) on the analysis of dissimilation. More broadly, it resonates with work by Itô & Mester (1994, 1999), which subsumes various phonotactic patterns in syllable structure under the work of a single constraint family.

This paper is organized as follows. Section 2 presents data illustrating the pattern of [+ATR] harmony in Menominee. Section 3 develops the ABC analysis. Section 4 considers alternatives in relation to issues of feature identity and maximizing the labor of limited constraint sets. Section 5 presents the conclusion.

2 [+ATR] Harmony in Menominee

Menominee, an Algonquian language, exhibits an intriguing pattern of parasitic vowel harmony that includes blocking and transparency. Bloomfield (1962, 1975) provided the original documentation and description of this language. Though Bloomfield had characterized Menominee harmony as involving raising, Archangeli & Pulleyblank (1994) and Milligan (2000) have since presented phonological and phonetic arguments that [+ATR] is the active harmonizing feature in this system, an interpretation that I adopt here. The Menominee vowel inventory is given in (1), following the transcription practice of Archangeli & Suzuki (1995). Vowels may be long or short.[2]

(1) Menominee vowels

Unround	Round		
i	u	[+ATR]	Non-low
ɪ	ʊ	[−ATR]	
ə		[+ATR]	Low
a		[−ATR]	

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[2] Additional accounts adopting an interpretation of Menominee as involving an [ATR] contrast include Nevins (2004, 2010), Walker (2009) and Rhodes (2010). The harmony pattern was treated as involving height in earlier accounts (Cole 1987, Cole & Trigo 1988, Steriade 1987, and see more recent discussion by Oxford 2016), based on the characterization in Bloomfield 1962.

Non-low and low vowels pattern differently in Menominee harmony and are addressed in turn. In preview, regressive [+ATR] harmony operates in height-parasitic fashion among non-low vowels. Low [-ATR] vowels are transparent to harmony between flanking non-low vowels, while low [+ATR] vowels block harmony in this context. In addition, [+ATR] harmony is not witnessed among low vowels. Long and short non-low vowels are discussed separately because of a surface contrast neutralization in the latter.

2.1 Long non-low vowels

I begin with forms where the target of [+ATR] harmony is a long non-low vowel. The pattern we will see evidenced here is that these vowels undergo regressive harmony when the trigger is also non-low.

In the data in (2), alternations of the long non-low vowel in the first syllable are of primary interest. In (2c), this vowel is realized as [-ATR] when there is no [+ATR] vowel in the word. In (2a–b), this vowel is realized as [+ATR] in agreement with the [+ATR] non-low vowel in the following syllable. Notice in (2b) that [ə] does not trigger [+ATR] harmony in a preceding long non-low vowel. Sequences of vowels with different heights are discussed in section 2.3. Transcriptions of the data presented here follow Archangeli & Pulleyblank (1994) (A&P) and Archangeli & Suzuki (1995) (A&S), but they also incorporate the more recent interpretation of short non-low vowels by Milligan (2000), discussed below, and her treatment of postconsonantal glides as vocalic. For completeness, forms are also given in the orthographic transcription system of Bloomfield (1962 [B62], 1975 [B75]), which reflects his characterization of vowel harmony as involving raising. Note that Bloomfield used "•" to indicate long vowels.[3]

(2)	a.	[siːpiah]	(A&P: 377)	si•piah (B75: 240)
		'river (LOC)'		
	b.	[siːpiahsɪːhsəh]	(A&S: 6)	si•piahse•hsɛh (B75: 242)
		'creek (DIM)'		
	c.	[sɪːpɪːw]	(A&P: 377)	se•pe•w (B62: §14.24, §14.158, B75: 240)
		'river'		

The (a) examples in (3–9) show further evidence of [+ATR] harmony. The long non-low vowel that undergoes harmony is underlined. Triggers may be long or short, and the trigger and target vowels may be the same or different in rounding. Morphologically related (b) examples are provided to show that the long target vowel is otherwise [-ATR]. (Short non-low vowels in (4a) and (9a) are also shown as undergoing harmony here, but I defer discussion of short vowel targets to the next section.)

(3)	a.	[aːtəʔnuːhkuwəw]	a•tɛqnu•hkuwɛw (B62: §4.66, B75: 40)
		'he tells him a sacred story'	
	b.	[aːtəʔnuːhkakan]	a•tɛqno•hkakan (B62: §14.68, B75: 40)
		'sacred story'	
(4)	a.	[puːsituaʔ]	pu•setuaq (B62: §4.66)
		'when they embark'	
	b.	[puːsɪt]	po•set (B62: §4.66)
		'when he embarks'	
(5)	a.	[apiːsiːw]	api•si•w (B62: §15.211, B75: 25)
		'he, it is black'	

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[3] Individual morpheme glosses and boundaries were not regularly notated in the sources and are not reconstructed here.

b.   [ap<u>ɪ</u>ːs]   ape•s (B62: §17.19, B75: 24)
        'black'

(6)   a.   [ni<u>ː</u>mit]   ni•mit (B62: §4.66)
        'when he dances'

        b.   [n<u>ɪ</u>ːmʊw]   ne•mow (B62: §4.66)
        'he dances'

(7)   a.   [ku<u>ː</u>niak]   ku•nyak (B62: §2.42, §4.66)
        'snow, lump of snow (PL)'

        b.   [k<u>ʊ</u>ːn]   ko•n (B62: §2.42, §4.66)
        'snow, lump of snow'

(8)   a.   [wat<u>u</u>ːhsiw]   watu•hsiw (B62: §14.110, B75: 262)
        'hot coal, ember'

        b.   [wat<u>ʊ</u>ːw]   wato•w (B62: §14.110, B75: 262)
        'ball'

(9)   a.   [uki<u>ː</u>muːhkiw]   (A&P: 381)   oki•mu•hkiw (B62: §14.276)
        'princess'

        b.   [ʊk<u>ɪ</u>ːmaːw]   oke•ma•w (B62: §14.276)
        'chief'

The examples in (10) illustrate some contexts (underlined) where harmony does not occur with potential long non-low vowel targets. A non-low [+ATR] vowel does not trigger harmony in a long non-low vowel in a following syllable (10a), nor does a non-low [-ATR] vowel trigger harmony in a preceding long non-low vowel (10b).

(10) a.   [nu<u>ː</u>k<u>ɪ</u>ːsɪk]   (A&S: 6)   nu•ke•sek (B62: §14.380)
        'Mid Sky' (man's name)

        b.   [miani<u>ː</u>hs<u>ɪ</u>ːhsak] (A&S: 6)   miani•hse•hsak (B75: 133)
        'tiny owl (DIM PL)'

To summarize, thus far [+ATR] harmony is seen to operate regressively among non-low vowels, but only long vowel targets have been examined.

2.2 Short non-low vowels

I turn next to the patterning of short non-low vowels. Again, we will see that these vowels are targets of regressive [+ATR] harmony from triggers of the same height.

In the history of study of Menominee vowel harmony, the understanding of the participation of short non-low vowels has been complicated by a surface contrast neutralization. As background on this issue, I review the insights brought by the careful analysis of Milligan (2000). Ambiguities about the target status of /ɪ/ and /ʊ/ in [+ATR] harmony arose from Bloomfield's system of orthography and phonetic mergers. Milligan's study brings to bear data and allophonic descriptions from Bloomfield (1962) and Miner (1975, 1979). The key conclusion emerging from her study is that [ATR] contrasts are not perceived in short non-low vowels except before a glottal stop. Furthermore, she hypothesizes that short non-low vowels fully participate in [+ATR] harmony, even in contexts where an [ATR] distinction is not perceived.

Phonological patterning provides evidence that underlying [±ATR] contrasts exist in short non-low vowels, even where a surface contrast is not apparently audible. One source of evidence is whether a short vowel triggers [+ATR] harmony and is therefore deduced to be [+ATR], as in (11a–b) (repeated from (2a–3a), see additional examples in section 2.1). If it does not trigger harmony in a possible triggering context, as in (12a–b), the vowel is inferred to be [-ATR].

(11)   a.   [siːpi̱ah]   (A&P: 377)   si•piah (B75: 240)
                'river (LOC)'
       b.   [aːtəʔnu̱ːhku̱wəw]   a•tɛqnu•hkuwɛw (B62: §4.66, B75: 40)
                'he tells him a sacred story'

(12)   a.   [kɪːski̱nəːhcihəw]   (A&S: 14)   ke•skenɛ•hcihɛw (B62: §18.175, B75: 92)
                'he cuts off his finger or hand'
       b.   [kɪːpu̱təciːnəːw]   (Milligan 2000: 241)   ke•potɛci•nɛ•w (B62: §18.171, B75: 90)
                'he holds him, it in his hands and rubs him, it'

A second source of evidence for the underlying [±ATR] status of a short non-low vowel comes under circumstances of prosodically conditioned alternations with long vowels. The [-ATR] quality of the short non-low vowel in the second syllable in (13a) becomes unambiguous when lengthened in (13b). The [-ATR] quality is distinguished from a [+ATR] alternant derived when harmony applies in (13c).

(13)   a.   [nɪku̱t]   (A&P: 381)   nekot (B62: §17.5)
                'one'
       b.   [nɪku̱ːtəːyaw]   (A&P: 381)   neko•tɛ•yaw (B62: §17.78)
                'one affair'
       c.   [niku̱ːtikatəːw]⁴   (A&P: 381)   neku•tikatɛ•w (B75: 156)
                'one-legged being'

As for the status of short non-low vowels as targets, Milligan (2000: 242) observed that in contexts where a contrast for [ATR] is perceptible (i.e. before [ʔ]), Bloomfield reported that short non-low vowels undergo [+ATR] harmony. This is illustrated in (14), where the short non-low vowel in the first syllable harmonizes with /u/ in the third syllable. The harmony operates across /a/, which is transparent to [+ATR] harmony, as discussed later.

(14)   a.   [ku̱ʔnatu̱aʔ]⁵   (Milligan 2000: 243)   kuqnatuaq (B62: §4.66)
                'if thou fearest them'
       b.   [ku̱ʔnat]   koqnat (B62: §4.66)
                'if thou fearest him'

When short non-low vowels occur in a syllable between a trigger and a perceptible target, such as a long non-low vowel, they do not obstruct harmony and plausibly undergo it, as shown in (15–16). Glosses flanked by "??" are constructed by Archangeli & Pulleyblank (1994). The transcriptions of the underlined vowels in (15a) and (16a) follow Milligan's hypothesis that short non-low vowels are targets of harmony in the same manner as their long counterparts. Forms in (15b) and (16b) show [-ATR] counterparts of a short non-low vowel in the paired (a) form in an environment where harmony does not apply.

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⁴ In the transcription of this word in A&P, the final vowel is short. I assume this was an unintended error and instead follow the length notated by Bloomfield (1975: 156).
⁵ Milligan transcribes the final vowel of this word as long, but I have transcribed it as short, following Bloomfield (1962: 96).

(15) a. [nɪwiːnɪpim]   (A&P: 378)   newi•nepim (B75: 276)
          '??I dirty his (my?) mouth??'
      b. [wɪːnɪpʊw]   (A&P: 378)   we•nepow (B62: §15.110, B75: 276)
          'he dirties his mouth by eating'
(16) a. [tuːhkupiahnəw]   (A&P: 378)   tu•hkopiahnɛw (B62: §15.240, B75: 258)
          'he walks with buttocks spread'
      b. [tʊːhkupəːhsɪn]   (A&P: 378)   to•hkopɛ•hsen (B75: 258)
          'he lies with buttocks spread'

In target contexts for [+ATR] harmony where an [ATR] distinction is not perceptible, Bloomfield wrote short non-low vowels that are underlying [-ATR] with the symbol corresponding to the [-ATR] form. Milligan assumes this orthographic choice represented the absence of a perceived change in [ATR] quality, but her phonological interpretation is that these vowels undergo harmony. An alternative approach could treat short non-low vowels as transparent, except before [ʔ] (e.g. Archangeli & Pulleyblank 1994, 2007, Archangeli & Suzuki 1995). However, as Milligan effectively argues, treating these vowels as transparent complicates the analysis, and concrete evidence for interpreting them as transparent is lacking. I therefore adopt her interpretation that short non-low vowels are full participants in [ATR] harmony.

In summary, the pattern of harmony discussed to this point is that harmony for [+ATR] operates regressively among non-low vowels, both long and short.

2.3 Low vowels

Low vowels do not show overt participation in [+ATR] harmony, regardless of whether a neighboring vowel is the same or different in height. First, height-parasitic [+ATR] harmony is not witnessed among low vowels, as seen in (17). (The first three examples are repeated from (3a), (13c) and (16a).) The example in (17f) also shows that in low vowel sequences [+ATR] harmony does not operate progressively, nor does [-ATR] harmony occur in either direction.

(17) a. [aːtəʔnuːhkuwəw]   a•tɛqnu•hkuwɛw (B62: §4.66, B75: 40)
          'he tells him a sacred story'
      b. [nikuːtikatəːw]   (A&P: 381)   neku•tikatɛ•w (B75: 156)
          'one-legged being'
      c. [tuːhkupiahnəw]   (A&P: 378)   tu•hkopiahnɛw (B62: §15.240, B75: 258)
          'he walks with buttocks spread'
      d. [tʊːwahkəːkhʊw]   to•wahkɛ•khow (B75: 258)
          ''he beats the waterdrum'
      e. [pahkəːsiːw]   pahkɛ•si•w (B62: §16.162)
          'he cuts him, it off'
      f. [aːpəːhtam]   a•pɛ•htam (B62: §16.13)
          'he unravels it, he reads it'

Low [-ATR] vowels appear to be transparent to harmony among non-low vowels, as shown in (18–20). In the (a) examples, [+ATR] harmony operates across [-ATR] [a(ː)]; in (20a) there are two intervening syllables with [a(ː)]. The paired (b) forms verify that the non-low vowel in the syllable preceding transparent [a(ː)] has actually undergone harmony, because it is [-ATR] in other contexts.

(18) a. [wayiːtuːhkatitua?] (A&P: 378) wayi•tu•hkatituaq (B75: 278)
          '??they work together??'

      b. [wɪːtuːhkatʊwak] (A&P: 378) we•to•hkatowak (B75: 278)
          'they consort, play, work together'

(19) a. [niciːpaːhkim] (A&P: 379) neci•pa•hkim (B75: 43)
          'cook (NOM)'

      b. [cɪːpaːhkʊw] (A&P: 379) ce•pa•hkow (B62: §14.69, B75: 43)
          'he cooks'

(20) a. [apiːsaːkamiw] api•sa•kamiw (B62: §18.178, B75: 24)
          'it is black liquid'

      b. [apɪːs] ape•s (B62: §17.19, B75: 24)
          'black'

[+ATR] harmony across /a(ː)/ is plausibly a genuine case of assimilation at a distance, that is, it skips an intervening vowel. This interpretation is supported by the fact that [+ATR] low vowels ([ə(ː)]) are attested in Menominee and are perceptibly different from [-ATR] low vowels. There is therefore not reason to expect that the reported transparency of /a(ː)/ in harmony is caused by listener error. Instrumental verification of the transparency would nevertheless be valuable.

A low [+ATR] vowel does not induce harmony in a preceding non-low vowel, as shown in (21) with examples repeated from (2b) and (13b). Furthermore, [+ATR] harmony between non-low vowels is blocked by an intervening [+ATR] low vowel. In each of the forms in (22), non-low vowel(s) preceding [ə(ː)] are [-ATR], despite a [+ATR] non-low vowel in the syllable following [ə(ː)].

(21) a. [siːpiahsɪːhsəh] (A&S: 6) si•piahse•hsɛh (B75: 242)
          'creek (DIM)'

      b. [nɪkʊːtəːyaw] (A&P: 381) neko•tɛ•yaw (B62: §17.78)
          'one affair'

(22) a. [pɪːhtəhki?taw] (A&P: 383) pe•htɛhki•qtaw (B62: §18.155, B75: 213)
          'he sticks his head in'

      b. [muːnɪhpəniːw] (A&P: 383) mo•nehpɛni•w (B62: §15.175)
          'he digs potatoes'

      c. [kɪːskɪnəːhcihəw] (A&P: 383) ke•skenɛ•hcihɛw (B62: §18.175, B75: 92)
          'he cuts off his finger or hand'

A summary of the [+ATR] harmony pattern characterized above is given in (23).

(23) i.   Non-low [+ATR] vowels (/i, iː, u, uː/) trigger regressive [+ATR] harmony.
      ii.   Non-low [-ATR] vowels (/ɪ, ɪː, ʊ, ʊː/) are targets.
      iii. Low [-ATR] vowels (/a, aː/) are transparent to harmony between flanking non-low vowels.
      iv.   Low [+ATR] vowels (/ə, əː/) do not trigger [+ATR] harmony in low or non-low vowels and they block harmony between flanking non-low vowels.

3 ABC Analysis

The approach to Menominee vowel harmony that I pursue here employs ABC (Walker 2000a, b, 2001, Hansson 2001, 2010, Rose & Walker 2004). A key formal property underlying this analysis is that

constraints enforcing surface correspondence are sensitive to featural identity, including specific values of features. This restricts interacting vowels to those that are identical along some dimension, namely, vowels that are [-low] or those that are [+ATR]. The principal aims for this analysis are characterizing the basis for the sets of vowels that pattern together and making concrete the formal mechanisms that give rise to different behaviors.

Although the originating studies for ABC focused on consonant harmony, an ABC approach has since been applied to patterns of vowel harmony (Hansson 2006a, Sasa 2009, Walker 2009, 2015, Rhodes 2012, Bowman & Lokshin 2014)[6] and tone assimilation across vowels (Shih & Inkelas 2014a, to appear), as well as a variety of other patterns (Shih & Inkelas 2014b). Originating ABC studies focused on harmonizing segments and transparent segments; however, the approach also predicts blocking effects (Hansson 2007, Rhodes 2008, 2012, Sasa 2009, Shih 2013). The ABC analysis of Menominee's harmony developed here revises and substantially elaborates on the account originally sketched in Walker 2009. Explication of the workings of the analysis and its generalized structure are wholly new here, and this account provides new constraint definitions and some new rankings.

3.1 Theoretical background and preview

An ABC analysis of harmony employs three basic types of constraints. Schematic versions are given in (24–26).

(24) CORR-XX[αF]
Let X_1 and X_2 be segments that belong to the same output and are both specified [αF]. If X_1 and X_2 are not in correspondence with each other, assign a violation.

(25) IDENT-XX[αF]
Let X_1 and X_2 be a pair of segments that are in correspondence with each other in the same output and that are chain-adjacent. If X_1 is [αF] and X_2 is [-αF], assign a violation.

(26) IDENT-IO[αF]
Let X be a segment in the input and Y be a correspondent of X in the output. If X is [αF] and Y is [-αF], assign a violation.

In the above constraints, [F] represents a binary feature.[7] I assume that these constraints may be restricted to a particular feature value α, specified as "+" or "−". The constraints in (24–25) are applicable to surface correspondence relations. CORR-XX[αF] enforces a surface correspondence relation between two segments that both have a given value α for [F], that is, two segments that are minimally similar along the dimension of the named feature and value. The format of this constraint definition follows Bennett (2013, 2015a, b) in some particulars. The next constraint, IDENT-XX[αF], enforces identity for [F] between two corresponding segments in an output when a correspondent is specified [αF]. In the definition of the IDENT constraints here, -α is taken to be the opposite feature value of [α], that is, if α is "+", -α is "−", and if α is "−", -α is "+". IDENT-XX is evaluated over chain-adjacent corresponding pairs; the correspondence chain is discussed below. In the next section, a version of IDENT-XX is introduced that is sensitive to precedence.

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[6] Apart from ABC, vowel harmony has been extensively analyzed using identity constraints enforced over vowels in the output (Baković 2000, Krämer 2003). In addition, Syntagmatic Correspondence Theory (Krämer 2003) posits surface correspondence relations among segments. However, in that approach, surface correspondence is assumed rather than being enforced by violable constraints. A focus of the account here is the role of featural identity in coercing surface correspondence relations, as in ABC. I discuss alternatives in section 4.

[7] For an alternative formulation of IDENT constraints applicable to privative features, see Pater (1999).

IDENT-IO[αF], in (26), is familiar from the original Correspondence Theory proposal, defined here in a feature-value specific form (McCarthy & Prince 1995). For simplicity, where identity for each value of a feature is not differently enforced, I will use IDENT-IO[F] (or IDENT-XX[F], as appropriate), which could be interpreted as ranking IDENT constraints for [+F] and [-F] at the same place in the hierarchy.

As a shorthand for CORR constraints that operate over vowels only (i.e. specified [+vocalic], distinct from consonantal glides, after Padgett 2008), I will use the constraint name, CORR-VV[αF], following the practice of previous studies, and I will use IDENT-VV[αF] here to refer to the constraints that operate over surface-correspondence strings (though nothing explicitly limits IDENT-VV to vowels only). The core constraint ranking schema for vowel harmony in ABC is given in (27). IO-faithfulness is dominated both by the constraint that drives surface correspondence between vowels and the constraint that enforces featural identity between surface-corresponding segments. For clarity, a second feature variable, [G], is introduced in (27), because the feature specification(s) ([αF]) that give rise to surface correspondence, as enforced by CORR-VV, are generally different from those feature(s) ([G]) for which harmony is enforced. In addition, β and γ are introduced as furthur feature-value variables in this schema to indicate that the constraints are not all restricted to the same value.

(27)   CORR-VV[αF], IDENT-VV[βG] >> IDENT-IO[γG]

Following Hansson (2006b, 2007), I assume that IDENT-XX[F] constraints are evaluated over segments that are adjacent in a surface correspondence chain. Krämer (2003) makes a similar claim in the context of Syntagmatic Correspondence Theory. A surface correspondence chain consists of an exhaustive sequence of segments that stand in a surface correspondence relation with one another in an output. Thus, in a chain of surface-corresponding vowels $[…V1_a…V2_a…V3_a…]$, where alphabetic coindexation ("a", "b", etc.) indicates surface correspondence, IDENT-VV[G] will enforce identity for [G] only between [V1, V2] and [V2, V3]. It will not evaluate identity of non-adjacent pairs in the chain, namely, [V1, V3]. Hansson has argued that this local evaluation of IDENT-XX constraints prevents unwanted typological predictions that arise under global evaluation across adjacent and non-adjacent pairs, such as majority rule effects.[8]

In preview, four configurations of surface (non-)correspondence will be discussed in the analysis of Menominee harmony.

(28)   Height-parasitic harmony: Non-low vowels

[tuːhkupiahnəw]   'he walks with buttocks spread'

Input	Output	
/…V1…V2…V3…/	[…V1$_a$…V2$_a$…V3$_a$…]	
[-A] [-A] [+A]	**[+A] [+A] [+A]**	"[A]" = [ATR]
ʊː ʊ i	**uː u i**	

(29)   Blocking by correspondence (BBC): Low [+ATR] vowels

[pɪːhtəhkiːʔtaw]   'he sticks his head in'

Input	Output
/…V1…V2…V3…/	[…V1$_b$…V2$_a$…V3$_a$…]
[-A] [+A] [+A]	[-A] **[+A] [+A]**
ɪː ə iː	ɪː **ə iː**

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(30)　Transparency by lack of correspondence (TLC): Low [-ATR] vowels

　　　[nici:pa:hkim]　　　　　'cook (NOM)'

Input	Output
/…V1…V2…V3…/	[…V1$_a$…V2$_b$…V3$_a$…]
[-A]　[-A]　[+A]	**[+A]**　[-A]　**[+A]**
ɪː　　aː　　i	**iː**　　aː　　**i**

(31)　Height-specific non-harmony: Low vowels

　　　[tu:hkupiahnəw]　　　'he walks with buttocks spread'

Input	Output
/…V1…V2 …/	[…V1$_b$…V2$_a$…]
[-A]　[+A]	[-A]　[+A]
a　　ə	a　　ə

The first configuration is for height-parasitic harmony, in (28), a classic ABC scenario of agreement among similar segments. The output here contains non-low vowels that are in the same surface correspondence chain. Through the activity of an IDENT-VV constraint, the rightmost [+ATR] vowel in this chain will trigger [+ATR] harmony in preceding vowels, with the potential to induce alternations for [ATR]. Corresponding and harmonizing vowels are bolded in the schematic illustration, and an applicable Menominee word displaying this pattern is given with the relevant vowel sequence underlined. The second configuration, in (29), is for Blocking by Correspondence (BBC). In this case, a low [+ATR] vowel intervenes between a non-low [+ATR] vowel, which is a potential harmony trigger, and a non-low [-ATR] vowel, which is a potential target. The low [+ATR] vowel corresponds with the potential trigger, because they show identity for [+ATR], but it does not correspond with the potential target, to which it is less similar. By terminating the correspondence chain, a low [+ATR] vowel blocks propagation of harmony beyond it. The third configuration, in (30), is for Transparency by Lack of Correspondence (TLC). Here a low [-ATR] vowel intervenes between a potential non-low trigger and target for harmony. Because the potential trigger and low vowel differ in height and [ATR] value, they do not correspond. This enables harmony between non-low vowels to operate across a low [-ATR] vowel. Finally, the fourth configuration, in (31), is height-specific non-harmony. Here, a sequence of low vowels that differ in value for [ATR] do not correspond, with the result that [+ATR] harmony does not operate between them.

　　　In sequences of vowels with different heights, the key differences are that a low [+ATR] vowel blocks harmony because it is identical for [+ATR] with the non-low [+ATR] trigger, while a low [-ATR] vowel is transparent because it does not correspond with flanking non-low vowels. In the following sections I detail the constraint interactions that give rise to the surface correspondence configurations and the resulting vowel agreement patterns.

3.2 Height-parasitic harmony: [+ATR] harmony among non-low vowels

First, I address the core pattern of [+ATR] harmony among non-low vowels. The constraints in (32–34), pertaining to surface correspondence, are relevant for this system.

(32)　CORR-VV[-low]
　　　Let V$_1$ and V$_2$ be [+voc] segments that belong to the same output and are both specified [-low]. If V$_1$ and V$_2$ are not in correspondence with each other, assign a violation.

(33)   IDENT-V$_R$V$_L$[+ATR]
Let V$_R$ and V$_L$ be a pair of segments that are in correspondence with each other in the same output and that are chain-adjacent, where V$_R$ follows V$_L$ in the sequence of output segments. If V$_R$ is [+ATR] and V$_L$ is [-ATR], assign a violation.

(34)   IDENT-V$_L$V$_R$[+ATR]
Let V$_L$ and V$_R$ be a pair of segments that are in correspondence with each other in the same output and that are chain-adjacent, where V$_L$ precedes V$_R$ in the sequence of output segments. If V$_L$ is [+ATR] and V$_R$ is [-ATR], assign a violation.

CORR-VV[-low] will enforce correspondence between non-low vowels within a word, while IDENT-VV[+ATR] will drive [+ATR] harmony between corresponding segments. Directional versions of this constraint are defined in (33–34) (Rose & Walker 2004). IDENT-V$_R$V$_L$[+ATR] promotes regressive [+ATR] harmony and IDENT-V$_L$V$_R$[+ATR] promotes progressive [+ATR] harmony. Since harmony is only regressive in Menominee, IDENT-V$_R$V$_L$[+ATR] will be the IDENT-XX harmony-driver for this system.
        IDENT-IO constraints for [ATR] will also be relevant. These are defined in (35–36) following the schema provided in (26).

(35)   IDENT-IO[+ATR]
Let X be a segment in the input and Y be a correspondent of X in the output. If X is [+ATR] and Y is [-ATR], assign a violation.

(36)   IDENT-IO[-ATR]
Let X be a segment in the input and Y be a correspondent of X in the output. If X is [-ATR] and Y is [+ATR], assign a violation.

        In conformity with the ranking schema in (27), CORR-VV[-low] and IDENT-V$_R$V$_L$[+ATR] will dominate IDENT-IO[-ATR], as illustrated in (37). IDENT-IO[+ATR] will also be ranked over IDENT-IO[-ATR] to guarantee retention of [+ATR] in the trigger vowel. To facilitate demonstration of constraint interaction in this tableau, candidates are reduced to just the two underlined vowels in [aːtəʔnuːhkuwəw] 'he tells him a sacred story'. The first of these two vowels is [-ATR] in the input.

(37)   [aːtəʔnuːhkuwəw] 'he tells him a sacred story'

/… ʊː • u …/	IDENT-IO [+ATR]	CORR-VV [-low]	IDENT-V$_R$V$_L$[+ATR]	IDENT-IO [-ATR]
→ a. uː$_a$ • u$_a$				1
b. ʊː$_a$ • u$_a$			1W	L
c. ʊː$_b$ • u$_a$		1W		L
d. ʊː$_a$ • ʊ$_a$	1W			L

        In (37), candidate (a) is the winner, where the non-low vowels correspond and regressive [+ATR] harmony is enforced between them, at the cost of IDENT-IO[-ATR]. Competing non-harmonizing candidates either have corresponding non-low vowels that violate IDENT-V$_R$V$_L$[+ATR], as in (37b), or their non-low vowels do not correspond, violating CORR-VV[-low], as in (37c). Candidate (d) shows progressive [-ATR] harmony, which violates IDENT-IO[+ATR].
        [+ATR] harmony is regressive only. In contexts where harmony is not exhibited in a sequence of non-low vowels, ambiguity can arise about surface correspondence relations in the output. In one option, the non-harmonizing vowels are in surface correspondence but violate IDENT-VV[αF], as in [V$_{[+ATR]a}$ • V$_{[-ATR]a}$]. In a second option, the non-harmonizing vowels do not correspond, violating CORR-VV, as in

[V_{[+ATR]b} • V_{[-ATR]a}]. Both sequences would be pronounced the same. I will make the simplifying assumption that the first option is optimal. This means that surface correspondence among non-low vowels – owing to CORR-VV[-low] – will be enforced, even at the cost of IDENT-VV for [ATR]. The absence of progressive harmony for [+ATR] will then result from ranking IDENT-IO[-ATR] over IDENT-V$_L$V$_R$[+ATR], as shown in (38). Again, for expositional reasons, candidates are reduced in this tableau to the two underlined vowels, here for the word [nu̱ːkɪ̱ːsɪk] 'Mid Sky' (man's name).

(38)   [nu̱ːkɪ̱ːsɪk] 'Mid Sky' (man's name)

/… uː • ɪː …/	IDENT-IO [+ATR]	CORR-VV [-low]	IDENT- V$_R$V$_L$[+ATR]	IDENT-IO [-ATR]	IDENT- V$_L$V$_R$[+ATR]
→ a. uːₐ • ɪːₐ					1
b. uːₐ • iːₐ				1W	L
c. uːᵦ • ɪːₐ		1W			L

In (38) the winner is candidate (a), where the non-low vowels correspond but do not show progressive [+ATR] harmony, violating IDENT-V$_L$V$_R$[+ATR]. Candidate (b), with progressive [+ATR] harmony is ruled out by IDENT-IO[-ATR], and CORR-VV[-low] rules out (c), where the vowels do not correspond.

The absence of [-ATR] harmony comes about under the ranking of IDENT-IO[+ATR] >> IDENT-IO[-ATR] (supported in (37)). IDENT-VV[-ATR] is also relevant in corresponding pairs containing a [-ATR] vowel. IDENT-VV[-ATR] is dominated by IDENT-IO[+ATR], CORR-VV[-low] and IDENT-IO[-ATR], as shown in (39) for an input where a [+ATR] non-low vowel precedes a [-ATR] non-low vowel (same as in (38)). IDENT-IO[-ATR] eliminates progressive [+ATR] harmony as a solution to satisfy IDENT-VV[-ATR], as in (33d). CORR-VV[-low] rules out (39c), which lacks the assumed surface correspondence between non-low vowels, and IDENT-IO[+ATR] eliminates (39b), where harmony for [-ATR] is witnessed in surface-corresponding vowels. Since unidirectionality is not involved here, bidirectional IDENT-VV[-ATR] is assumed.[9]

(39)   [nu̱ːkɪ̱ːsɪk] 'Mid Sky' (man's name)

/… uː • ɪː …/	IDENT-IO[+ATR]	CORR-VV[-low]	IDENT-IO[-ATR]	IDENT-VV[-ATR]
→ a. uːₐ • ɪːₐ				1
b. ʊːₐ • ɪːₐ	1W			L
c. uːᵦ • ɪːₐ		1W		L
d. uːₐ • iːₐ			1W	L

A Hasse diagram summarizing the constraint rankings established in this section is given in (40). Each ranking is indexed to a supporting winner-loser pair from the above tableaux.

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[9] Alternatively, bidirectional effects could be obtained by ranking two unidirectional constraints in the same tier.

(40)   Ranking summary for height-parasitic [+ATR] harmony among non-low vowels

CORR-VV[-low]   IDENT-IO[+ATR]   IDENT-V_RV_L[+ATR]

                    1   2   3

                        IDENT-IO[-ATR]

                  4   5

        IDENT-VV[-ATR]   IDENT-V_LV_R[+ATR]

1. (37a) ≻ (37c)   2. (37a) ≻ (37d)   3. (37a) ≻ (37b)

    u:ₐ • uₐ ≻ ʊːᵦ • uₐ   uːₐ • uₐ ≻ ʊːₐ • ʊₐ   uːₐ • uₐ ≻ ʊːₐ • uₐ

4. (39a) ≻ (39d)   5. (38a) ≻ (38b)

    uːₐ • ɪːₐ ≻ uːₐ • iːₐ   uːₐ • ɪːₐ ≻ uːₐ • iːₐ

3.3 BBC: Blocking low vowels

Next, I discuss rankings relevant for vowels that block regressive [+ATR] harmony from a non-low vowel. Within the hierarchy in (40), the ranking IDENT-IO[+ATR], IDENT-V_RV_L[+ATR] >> IDENT-IO[-ATR] will enforce regressive [+ATR] harmony in sequences of corresponding vowels that contain a [+ATR] vowel. This means that where harmony is blocked, a non-harmonizing [-ATR] vowel is not in correspondence with a following [+ATR] vowel.

In the BBC account proposed here, [+ATR] low vowels are in surface correspondence with a non-low [+ATR] harmony trigger. However, [+ATR] low vowels are not in correspondence with a preceding non-low vowel, which prevents harmony from propagating beyond them. The BBC configuration from (29) is recapitulated in (41). Under this analysis, blockers of harmony are actually a kind of *icy target* (Jurgec 2011a), where a vowel participates in harmony but "freezes" propagation to targets beyond it.[10] Previous work on icy targets has focused on segments that potentially alternate in harmony but fail to propagate the harmonizing feature (Jurgec 2011a, b). However, in this instance, the icy target bears the harmonizing feature underlyingly and does not violate IO faithfulness. The aim of constraint rankings discussed in this section is to generate a surface correspondence chain like that in (41), leaving it to the previously established ranking to enforce [+ATR] harmony from a [+ATR] vowel to any corresponding vowels that precede it.

(41)   Blocking by Correspondence: Low [+ATR] vowels

Input   Output
/…V1$_{[-low]}$ • V2$_{[+low]}$ • V3$_{[-low]}$…/   […V1$_{[-low]b}$ • V2$_{[+low]a}$ • V3$_{[-low]a}$…]
    [-A]   [+A]   [+A]   [-A]   **[+A]**   **[+A]**
    ɪː   ə   iː   ɪː   ə   iː

Obtaining the BBC configuration involves two additional constraints: CORR-VV[+ATR] and IDENT-VV[low]. CORR-VV[+ATR] drives correspondence between any pair of [+ATR] vowels, as defined in (42). In the context of BBC, this constraint will instigate correspondence between a non-low [+ATR] trigger and low [+ATR] vowel. IDENT-VV[low] functions as a *limiter* of surface correspondence (Bennett 2013, 2015a, b), by penalizing corresponding segments that differ in their value for [low]. This constraint will be ranked so as to prevent a correspondence chain that contains [ə(ː)] adjacent to a non-low [-ATR]

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[10] Low [+ATR] vowels are analyzed as sharing [+ATR] with a non-low trigger, due to the OCP, in the account of Archangeli & Pulleyblank (1994). This feature sharing is also derived in the account of Archangeli & Suzuki (1995), due to best satisfaction of an ALIGN constraint. In this respect, low [+ATR] vowels could be considered an icy target in those analyses.

vowel. For simplicity, in (43) it is defined without a specific value for [low]. As mentioned in section 3.1, it could alternatively be defined as two separate constraints, IDENT-VV[+low] and IDENT-VV[-low]. IDENT-IO[low], in (44), will also be employed to rule out an alternative candidate that alters height.

(42)   CORR-VV[+ATR]
        Let V_1 and V_2 be [+voc] segments that belong to the same output and are both specified [+ATR].
        If V_1 and V_2 are not in correspondence with each other, assign a violation.

(43)   IDENT-VV[low]
        Let V_1 and V_2 be a pair of segments that are in correspondence with each other in the same output and that are chain-adjacent. If V_1 is [αlow] and V_2 is [-αlow], assign a violation.

(44)   IDENT-IO[low]
        Let X be a segment in the input, and Y be a correspondent of X in the output. If X is [αlow] and Y is [-αlow], assign a violation.

The activity of these constraints in deriving the BBC pattern is shown in (45), for the sequence of underlined vowels in [pɪːhtəhkiːʔtaw] 'he sticks his head in'. The aim of the rankings here is to cause vowels that differ in height to correspond only if they are both underlying [+ATR]. The logic is as follows, with discussion of specific candidates below. First, IDENT-IO[+ATR] and IDENT-IO[low] are ranked in the top tier to prevent changes to a [+ATR] specification or height. CORR-VV[+ATR] dominates IDENT-VV[low] to compel a non-low [+ATR] vowel to correspond with [ə(ː)]. IDENT-VV[low] in turn dominates CORR-VV[-low] to otherwise block correspondence between [ə(ː)] and a non-low vowel even if this inhibits correspondence between flanking non-low vowels. The primary constraint interactions of interest for BBC are in the highlighted region, involving the first three candidates. Note that the previously established ranking IDENT-V$_R$V$_L$[+ATR] >> IDENT-IO[-ATR] will rule out candidates where a [+ATR] vowel is preceded by a [-ATR] vowel in the same correspondence chain, so they are not considered here; all candidates shown in (45) obey IDENT-V$_R$V$_L$[+ATR].

(45)   [pɪːhtəhkiːʔtaw] 'he sticks his head in'

/… ɪː • ə • iː …/	IDENT-IO [+ATR]	IDENT-IO [low]	CORR-VV [+ATR]	IDENT-VV [low]	CORR-VV [-low]
→ a. ɪː$_b$ • ə$_a$ • iː$_a$				1	1
b. iː$_a$ • ə$_a$ • iː$_a$				2W	L
c. iː$_a$ • ə$_b$ • iː$_a$			2W	L	L
d. iː$_a$ • i$_a$ • iː$_a$		1W		L	L
e. iː$_a$ • a$_b$ • iː$_a$	1W			L	L

In the winning candidate, in (45a), [+ATR] harmony halts at /ə/ and does not reach the preceding non-low vowel. Here, the two vowels that are underlyingly [+ATR] are in surface correspondence in the output, despite being of different height. This earns a violation of IDENT-VV[low]. Furthermore, the non-low vowels flanking [ə] do not correspond, violating CORR-VV[-low]. Competing candidates in (45b-c) both show [+ATR] harmony that affects the first non-low vowel. The candidate in (45b) forms a correspondence chain that includes all three vowels. This option fails, because it incurs an extra violation of IDENT-VV[low], due to correspondence between the first non-low vowel and [ə]. In (45c), a surface correspondence chain is formed between the two non-low vowels, skipping intervening [ə]. However, excluding [ə] from the surface correspondence chain earns fatal violations of CORR-VV[+ATR]. Finally,
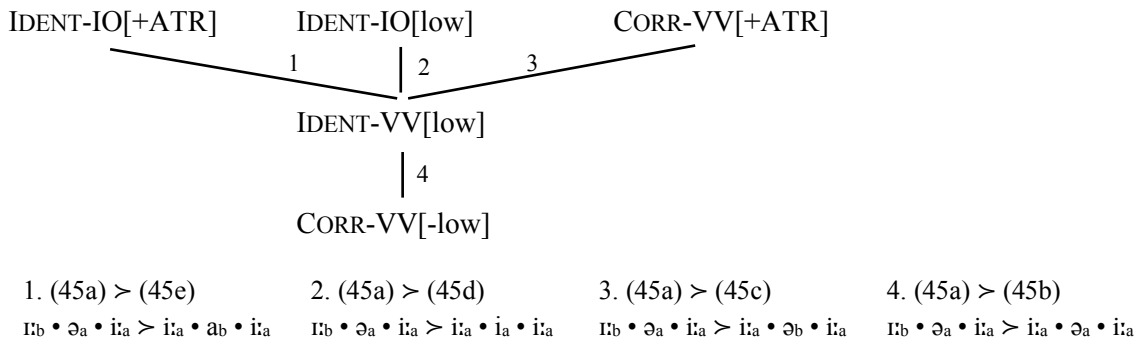
candidates (d-e), which change the specifications of /ə/ to [-low] or [-ATR] are ruled out by IO-faithfulness constraints.

A conceivable alternative output would create two distinct surface correspondence chains that both contain the underlying non-low [+ATR] vowel, as in […iːb • əa • iːa,b…]. While this candidate would incur only a single violation of IDENT-VV[low], it would lose to (45a) by virtue of a violation of CORR-VV[+ATR], because the first two vowels do not correspond. Furthermore, it is doubtful that such a correspondence configuration is even viable. Bennett (2013, 2015a, b) has proposed that surface correspondence relations are transitive. Correspondence of the third vowel with each of the others would thus imply a correspondence relation between the first two vowels so that […iːb • əa • iːa,b…] would actually have the same surface correspondence relations as (45b).

To review, in BBC, /ə/ patterns as a non-alternating icy target in [+ATR] harmony. The reason for this is two-fold. First, surface correspondence among [+ATR] vowels is prioritized over correspondence among [-low] vowels. This favors correspondence between [… ə … iː …] over [… ɪː … iː …]. Second, the surface correspondence limiter, IDENT-VV[low], prevents correspondence between [ə] and a chain-adjacent non-low vowel, except when mandated by both vowels being [+ATR]. As a result, an input sequence /… ɪː • ə …/ will remain as such in the output, without surface correspondence between the vowels, and thus, without [ə] propagating [+ATR] harmony. This configuration, where a vowel blocks harmony because it bears the harmonizing feature and corresponds with a trigger but not a target, parallels that proposed by Rhodes (2008, 2012) for blocking in Khalkha Mongolian round harmony.

The constraint rankings established in this section to obtain the surface correspondence relations needed for BBC are given in (46), together with associated supporting winner/loser pairs.

(46) Ranking summary for BBC: Low [+ATR] vowels

IDENT-IO[+ATR]   IDENT-IO[low]   CORR-VV[+ATR]

                    1 | 2   3

                    IDENT-VV[low]

                         | 4

                    CORR-VV[-low]

1. (45a) ≻ (45e)	2. (45a) ≻ (45d)	3. (45a) ≻ (45c)	4. (45a) ≻ (45b)
ɪːb • əa • iːa ≻ iːa • ab • iːa	ɪːb • əa • iːa ≻ iːa • ia • iːa	ɪːb • əa • iːa ≻ iːa • əb • iːa	ɪːb • əa • iːa ≻ iːa • əa • iːa

3.4 TLC: Transparent low vowels

I turn now to transparent vowels. Low [-ATR] vowels are transparent to [+ATR] harmony among non-low vowels. In ABC, transparent segments do not correspond with potential triggers or targets. This TLC configuration arises when the class of transparent segments lack featural identity with triggers and targets along some dimension, causing them to fall outside the scope of the CORR-VV[αF] constraints that are enforced in the system. The aim of the constraint rankings discussed in this section is to generate a surface correspondence chain like that in (47), where non-low vowels are in surface correspondence to the exclusion of an intervening low [-ATR] vowel.

(47)   Transparency by Lack of Correspondence: Low [-ATR] vowels

Input   Output
/…V1[-low] • V2[+low] • V3[-low]…/   […V1[-low]a • V2[+low]b • V3[-low]a…]
    [-A]   [-A]   [+A]   **[+A]**   [-A]   **[+A]**
     ɪː   a   i   **iː**   a   **i**

Non-low [+ATR] vowels and low [-ATR] vowels differ at least in their values for [low] and [ATR]. They are thus not impacted by CORR-VV[+ATR] and CORR-VV[-low], which are the CORR constraints identified as active in Menominee's [+ATR] harmony.

The desired output violates IDENT-IO[-ATR], as in /ɪː/ → [iː] in (47). It also violates CORR-VV, the constraint that requires correspondence between any [+vocalic] segments, because [a] does not correspond with flanking non-low vowels. The previously established ranking CORR-VV[-low], IDENT-V$_R$V$_L$[+ATR] >> IDENT-IO[-ATR] will drive surface correspondence and harmony between non-low vowels. The transparency of [a(ː)] is achieved by adding IDENT-VV[low] >> CORR-VV, which inhibits surface correspondence between non-low [+ATR] vowels and [a(ː)].

These rankings are illustrated in (48) with the sequence of underlined vowels in [niciːpaːhkim] 'cook (NOM)'. This tableau reflects previously determined IDENT-VV[low] >> CORR-VV[-low] (from (45)).

(48)   [niciːpaːhkim] 'cook (NOM)'

/… ɪː • aː • i …/	IDENT-V$_R$V$_L$ [+ATR]	IDENT-IO [+ATR]	IDENT-VV [low]	CORR-VV [-low]	CORR-VV	IDENT-IO [-ATR]
→ a. iːₐ • aːᵦ • iₐ					2	1
b. iːₐ • əːₐ • iₐ			2W		L	2W
c. ɪːᶜ • aːᵦ • iₐ				1W	3W[11]	L
d. ɪːₐ • aːᵦ • ɪₐ		1W			2	L
e. ɪːₐ • aːₐ • iₐ	1W		2W		L	L
f. ɪːᵦ • aːᵦ • iₐ			1W	1W	2	L

The constraint interactions of primary interest are highlighted in (48), involving the elimination of candidates (b–c). The input contains a low [-ATR] vowel that is followed by a non-low potential trigger for [+ATR] harmony and preceded by a non-low potential target. In the winner, in (48a), the two non-low vowels belong to the same correspondence chain to the exclusion of intervening [aː]. This correspondence chain satisfies CORR-VV[-low], but it violates CORR-VV twice. Harmony affecting the first non-low vowel incurs a violation of IDENT-IO[-ATR]. In the competing candidate in (48b), all vowels are in surface correspondence, satisfying CORR-VV but violating IDENT-VV[low] twice for correspondence between [ə] and each of the non-low vowels. In this form, [+ATR] harmony affects the first two vowels, which incurs two violations of IDENT-IO[-ATR].[12] The remaining candidates in (48) do not show [+ATR] harmony. These are ruled out by constraints that dominate IDENT-IO[-ATR]. In (48c), none of the vowels correspond with each other. The lack of correspondence between the two non-low vowels in this candidate is ruled out

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[11] If CORR-VV were evaluated locally according to the method that Rhodes (2012: 165) proposes, candidate (c) would incur only two violations of this constraint. In that case, the tableau in (48) would provided further support for CORR-VV[-low] >> IDENT-IO[-ATR], a ranking already established in (37).

[12] Either IDENT-VV[low] or IDENT-IO[-ATR] could be ranked above CORR-VV to rule out (48b). However, IDENT-VV[low] dominates IDENT-IO[-ATR] (by transitivity), so IDENT-VV[low] would still dominate CORR-VV under either scenario.

by CORR-VV[-low] >> IDENT-IO[-ATR], a ranking already supported in section 3.2. Though CORR-VV could be ranked over IDENT-IO[-ATR] to eliminate (48c), it is not necessary to posit this additional ranking.

Candidates (48d-f) are ruled out by a violation of IDENT-VV[low] or higher-ranked constraints. Candidate (d) establishes surface correspondence between the two non-low vowels, but it shows progressive [-ATR] harmony, violating IDENT-IO[+ATR]. In (48e), all vowels belong to the same surface correspondence chain, but regressive [+ATR] harmony is not enforced between [i] and its closest preceding correspondent [aː], incurring a violation of IDENT-V$_R$V$_L$[+ATR]. Candidate (f) incurs a violation of IDENT-VV[low] by containing a correspondence chain that includes a low vowel and a non-low vowel.

The TLC configuration in Menominee supports a single additional constraint ranking beyond what has already been established: IDENT-VV[low] >> CORR-VV. Two key rankings relevant for the first three candidates of (48) are shown in (49) with associated winner/loser pairs. The combined effect in the analysis is to mandate surface correspondence between non-low vowels but inhibit it among vowels that differ for [low] and [+ATR].

(49)   Core rankings for TLC: Low [-ATR] vowels

IDENT-VV[low]   CORR-VV[-low]

│ 1   │ 2

CORR-VV   IDENT-IO[-ATR]

1. (48a) ≻ (48b)   2. (48a) ≻ (48c)
iːₐ • aːᵦ • iₐ ≻ iːₐ • əːₐ • iₐ   iːₐ • aːᵦ • iₐ ≻ rː꜀ • aːᵦ • iₐ

3.5 Height-specific non-harmony: No [+ATR] harmony among low vowels

The final component of the [+ATR] harmony pattern is that it does not operate among low vowels. This is handled by ranking IDENT-IO[-ATR] over CORR-VV[+low], which will prevent surface correspondence between [ə(ː)] and a preceding [a(ː)]. A tableau supporting this ranking is given in (50).

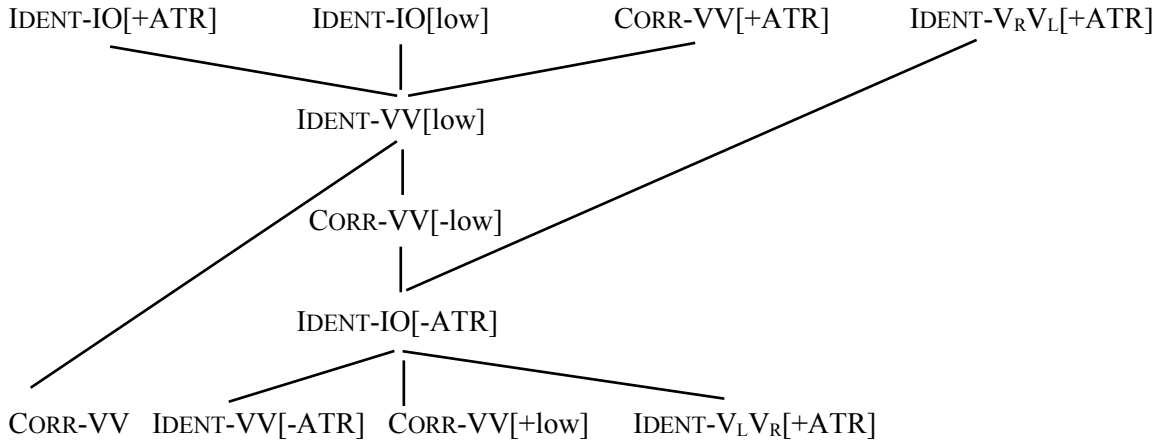(50)   [tuːhkupiạhnə̲w] 'he walks with buttocks spread'

/… a • ə …/	IDENT-IO[-ATR]	CORR-VV[+low]
→ a. aᵦ • əₐ		1
b. əₐ • əₐ	1W	L

Alternative candidates in which /ə/ becomes [a] or the two non-low vowels are in surface correspondence but do not show [+ATR] harmony are ruled out by higher-ranked constraints, IDENT-IO[+ATR] and IDENT-V$_R$V$_L$[+ATR], respectively.

3.6 Summary

A Hasse diagram that combines the rankings discussed in the preceding sections is given in (51).

(51)   Combined ranking for Menominee [+ATR] harmony

IDENT-IO[+ATR]   IDENT-IO[low]   CORR-VV[+ATR]   IDENT-V$_R$V$_L$[+ATR]

IDENT-VV[low]

CORR-VV[-low]

IDENT-IO[-ATR]

CORR-VV   IDENT-VV[-ATR]   CORR-VV[+low]   IDENT-V$_L$V$_R$[+ATR]

To review, the primary claims made in this account are that surface correspondence configurations shape vowel participation in the [+ATR] harmony of Menominee, and these configurations are sensitive to feature identity, including specific feature values. In this pattern, the vowels that alternate in harmony are non-low. This interaction is obtained by CORR-VV[-low], which forms the basis for height-parasitic [+ATR] harmony in ABC. However, [+ATR] harmony does not occur in the low height tier. CORR-VV[+low] is therefore dominated by IDENT-IO[-ATR] to yield non-harmony among low vowels.

Low vowels show different behaviors in harmony, depending on their value for [ATR]. Low [-ATR] vowels do not share featural identity with non-low vowels for any actively enforced CORR constraint in the system ([+ATR], [-low]). They therefore do not correspond with non-low vowels and behave transparent to harmony.

Blocking in Menominee [+ATR] harmony involves the most complex interaction. Low [+ATR] vowels that are flanked by non-low vowels block harmony from reaching a [-ATR] target. This behavior arises because low [+ATR] vowels are in surface correspondence with non-low [+ATR] triggers, due to their identity for [+ATR], but they do not correspond with non-low targets that are underlyingly [-ATR]. The limiter constraint IDENT-VV[low] interacts with other constraints to inhibit alternation-inducing harmony among vowels that differ in height. This causes low [+ATR] vowels to terminate a surface correspondence chain for [+ATR] vowels, in a BBC configuration.

The ranking structure for this system gives rise to the relationships between harmony behavior and featural similarity to triggers outlined in (52), both specific to Menominee and generalized. The feature specifications characterized here refer to underlying representations.[13]

(52)   Underlying specifications: Harmony for [αF] parasitic on [βG]

	Schematic		*Menominee*	
	[αF]	[βG]	[αF]: [+ATR]	[βG]: [-low]
Originating trigger	✓	✓	[+ATR] ✓	[-low] ✓
Alternating target	✗	✓	[-ATR] ✗	[-low] ✓
Icy target	✓	✗	[+ATR] ✓	[+low] ✗
Transparent segment	✗	✗	[-ATR] ✗	[+low] ✗

As sketched in (52), in the ABC model of harmony for [αF] parasitic on [βG] with transparent segments and icy targets, the possible combinations of values for [F] and [G] result in four categories of segment behavior, each with a particular relationship of feature (non-)identity to triggers. Where a check is

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[13] It is also possible for these feature specifications to be not underlying but derived independent of the harmony system.

marked in a table cell, the segment type in question is identical to a trigger for the indicated feature; otherwise an "X" is marked. Originating triggers form one category; these segments are underlyingly [αF] and [βG]. In Menominee, [αF] is [+ATR] and [βG] is [-low]. Alternating targets are identical to triggers along the parasitic dimension [βG], but they differ underlyingly in value for [F].[14] Icy targets and transparent vowels are both [-βG], distinguishing them from triggers and alternating targets along the parasitic dimension. In Menominee, these segments are the class of [+low] vowels. Icy targets are identical to triggers for [αF], while transparent segments differ from triggers in values for both [F] and [G].

4 Alternatives

4.1 Feature identity in harmony

I next consider the role of feature identity in harmony in connection with two alternative approaches. The first replaces CORR constraints with a MAX-XX constraint that does not reference feature identity. The second is an approach to icy targets that is not sensitive to feature identity, for which I discuss a different prediction from the BBC account.

4.1.1 A correspondence driver without feature identity

The structure of the surface correspondence relations among vowels with different behaviors in Menominee harmony has implications for the formalism of constraints that drive correspondence. To differentiate icy targets and transparent vowels within the class of low vowels, the account developed here relies on feature-value specific CORR-XX constraints. This departs from a proposal that CORR constraints be replaced with a MAX formalism without reference to feature identity (McCarthy 2010). In the MAX-XX formalism, all segments in the output are required to be in surface correspondence with each other, and a penalty is assigned to every pair of segments that do not correspond (following specifics elaborated by Shih 2013). IDENT-IO and IDENT-XX constraints limit the effects of MAX-XX (cf. Walker 2015). IDENT-XX punishes surface-corresponding segments that are not featurally identical, and IDENT-IO punishes segments that change their feature values from the input, which is a means of satisfying IDENT-XX among surface-corresponding segments. McCarthy (2010) points out that a difference between the MAX and CORR approaches to surface correspondence is that CORR constraints may be feature-value specific, but MAX-XX does not have this capacity. In other words, through its interactions with IDENT-IO and IDENT-XX constraints, MAX-XX can drive correspondence between segments that agree in [F], but it cannot directly dictate correspondence only between segments that agree in a specific value for [F].

McCarthy's examination of this issue focuses on consonant harmony, with a consonant-centered version of the MAX constraint, MAX-CC. However, the expansion of ABC beyond consonants alone opens up the empirical domain. In this regard, Menominee's parasitic harmony with blocking and transparency offers a new kind of configuration for testing feature-value specific surface correspondence. The behavior of low vowels, which remain faithful, depends on their value for [ATR]: [+ATR] /ə(:)/ blocks harmony as an icy target by corresponding with a trigger, while [-ATR] /a(:)/ is transparent by not corresponding with a trigger. In the feature-value specific analysis, this difference is achieved by the ranking CORR-VV(+ATR) >> IDENT-VV[low] >> CORR-VV ((45) and (48), which enforces harmony between a trigger /i(:)/ and [+ATR] /ə(:)/ but not [-ATR] /a(:)/.

In the MAX-XX approach, surface correspondence is expected to be enforced with equal priority over both values of a feature. Capturing transparent /a(:)/ and icy target /ə(:)/ in the same system presents a challenge, as illustrated in (53). The ranking here is constructed as follows. First, because harmony causes

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[-ATR] vowels to become [+ATR], IDENT-IO[-ATR] is dominated by MAX-XX. IDENT-IO[+ATR] is assumed to be in the top tier and only candidates respecting it are shown. An IDENT-XX constraint that dominates MAX-XX is capable of inhibiting correspondence between transparent /aː/ and trigger /i/. In (53), two possible constraints are considered: IDENT-XX[low] and IDENT-XX[ATR]. IDENT-XX[low] rules out any candidates where a low vowel corresponds with a non-low vowel, enabling harmony to operate across /aː/, as in (53i-a). While this ranking is successful for /aː/, it yields the wrong result for /ə/, which is erroneously also predicted to be transparent. The unwanted selection of candidate (53ii-c) is indicated by "←". The ranking needed to select the desired winner, (53ii-a), requires IDENT-IO[-ATR] >> IDENT-XX[low]. However, this would cause unwanted selection of (53i-d), with blocking by /aː/.[15] IDENT-XX[ATR] does not resolve the problem; it is violated only by candidate (i-e).

(53)   MAX-XX: Problem differentiating behavior among low vowels

Input	Candidate outputs	IDENT-XX [low]	IDENT-XX [ATR]	MAX-XX	IDENT-IO [-ATR]
i. /… ɪː • aː • i …/	→ a. iːₐ • aːᵦ • iₐ			2	1
	b. ɪːᵦ • aːᵦ • iₐ	1W		2	L
	c. iːₐ • əːₐ • iₐ	2W		L	2W
	d. ɪːᵪ • aːᵦ • iₐ			3W	L
	e. ɪːₐ • aːₐ • iₐ	2W	1W	L	L
ii. /… ɪː • ə • iː …/	→ a. ɪːᵦ • əₐ • iːₐ	1		2	
	b. iːₐ • əₐ • iːₐ	2W		L	1W
	← c. iːₐ • əᵦ • iːₐ	L		2	1W

The separation of low vowel behavior into [+ATR] icy targets versus [-ATR] transparent segments is problematic in (53) because MAX-XX does not directly enforce feature-value specific correspondence. McCarthy (2010: 9, footnote 5) notes the possibility of falling back on a feature-value specific constraint of MAX, a modification that Menominee seems to warrant. Along these lines, MAX-XX could be replaced with a constraint schema MAX-XX[αF], which would be violated by any segment specified [αF] that is not in surface correspondence. This would essentially match the CORR-XX[αF] formalism but emphasize a parallel with the function of MAX constraints. Whether another surface correspondence based solution for the Menominee pattern is possible and what complexities it would introduce into the theory remain to be seen. To be sure, the rich set of relationships between harmony behavior and feature identity in Menominee will make it an important case to consider in evaluating any proposals that depart from a feature-value specific version of constraints that enforce surface correspondence.

4.1.2 Feature identity and icy targets

In the analysis proposed here, feature identity plays a role both in conditioning parasitic harmony and blocking by an icy target. This predicts that a segment's role as an icy target could be sensitive to feature identity in its context, a topic that I turn to now.

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[15] McCarthy (2010) adopts IDENT-IO constraints that are relativized to a specified class of sounds defined by [G], expressed in a formalism IDENT-IO[F]/[G]. Non-low vowels alternate in [+ATR] harmony but not low vowels, which is consistent with a ranking IDENT-IO[-ATR]/[+low] >> MAX-XX >> IDENT-IO[-ATR]/[-low]. However, that will not solve the problem in (53), because only candidate (i-c) is violated by IDENT-IO[-ATR]/[+low]. This constraint does not discriminate between (53i-a) and (53i-d), both of which are faithful to /a/.

Parasitic harmony can be restricted to segments that are identical for either value of a binary feature [G], which I will refer to as a *dual-value* system, or it can be restricted to segments that are identical for a specific value of [G]. In Menominee, [+ATR] harmony is parasitic on a specific value: harmony operates among [-low] vowels but not among [+low] vowels.[16] [+ATR] harmony among [+low] vowels is blocked by the ranking IDENT-IO[-ATR] >> CORR-VV[+low] (see (50)). If this ranking were reversed, [+ATR] harmony would operate among vowels that are identical for either value for [low]. An example of a dual-value parasitic system is found in the well-known case of round harmony in the Yowlumne dialect of Yokuts. In Yowlumne, suffix vowels agree in rounding (and backness) with a stem vowel when the trigger and target are identical in height (Newman 1944, Kisseberth 1969, Kenstowicz & Kisseberth 1979).

Dual-value parasitic harmony is relevant to a prediction of the BBC account that a segment could potentially serve as an icy target for harmony from one kind of trigger but as a propagating target from another kind of trigger. For example, in a height-parasitic system of [+ATR] harmony, [ə] could be an icy target for harmony from a [+ATR] non-low vowel. IDENT-VV[low] would prevent it from propagating harmony to a non-low vowel that is underlyingly [-ATR], as in Menominee. However, [ə] could serve as a trigger and propagating target for [+ATR] harmony between low vowels in the same system. The latter is not the case in Menominee, but it is possible under a dual-value parasitic harmony with the opposite ranking of IDENT-IO[-ATR] and CORR-VV[+low] mentioned above. In this hypothetical pattern, the behavior of [ə] in harmony depends on its featural identity with a prospective target. If it has the same value for [low], it will trigger harmony, but if it differs in value for [low], it will not trigger an alternation.

This prediction contrasts with that of a head-based approach to icy targets in Binary Domains Theory, proposed by Jurgec (2011a, b). In Binary Domains Theory, segments to which features are associated function as heads or non-heads for that feature, but only a head can propagate feature spreading. In this approach, an icy target is analyzed as a non-head, which causes it to terminate spreading. This representation is achieved using head-sensitive featural markedness constraints, which prohibit a segment from being a head for [αF] when it is specified [βG]. In the head-based account, the status of a segment as an icy target is context independent, because it is attributed to a property of the segment on its own. This contrasts with the BBC analysis, where the status of a segment as an icy target is related to the feature identity relationship between the segment and a contextual prospective target to which it might propagate harmony.

Further research is needed to assess which of these approaches is better supported empirically. In a related vein, in patterns discussed by Jurgec (2011a, b), icy targets potentially exhibit alternations in harmony. These icy targets differ from the Menominee case, because the target is not necessarily already identical with the trigger for the harmonizing feature. In future work, it would be valuable to examine whether a treatment of alternating icy targets is available in the ABC approach.

4.2 Maximizing the Labor of Constraint Families

I focus next on what kinds of constraints enter into sequencing restrictions associated with vowel harmony. Two alternative approaches to the proposed ABC account are considered: (i) a surface correspondence approach where transparent segments correspond with triggers, and (ii) an analysis of Menominee harmony that employs sequential segmental markedness constraints. An advantage of the ABC account highlighted here is that diverse segment behaviors – harmony, transparency, and blocking – receive a unified explanation in terms of feature identity and correspondence, which aids in reducing the constraint families in Con. Maximal utilization of these constraint sets finds a parallel in Bennett's (2013, 2015a, b) proposal to extend them to dissimilation, and it resonates with a goal of research by Itô & Mester (1994, 1999) to consolidate a variety of segmental sequencing effects under established constraint families in OT.

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[16] This type of feature-value specificity is not necessarily a problem for MAX-XX if IDENT-IO constraints that are relativized to a specific class are adopted, as McCarthy (2010) proposes. The ranking IDENT-IO[-ATR]/[+low], IDENT-XX[ATR] >> MAX-XX >> IDENT-IO[-ATR]/[-low] would drive [-ATR] non-low vowels to alternate in [+ATR] harmony but not [-ATR] low vowels.

4.2.1 Transparency as Balance

Syntagmatic Correspondence Theory (Krämer 2003) offers a surface correspondence account of vowel harmony that is distinct from ABC. Like ABC, harmony in Syntagmatic Correspondence is achieved using IDENT[F] constraints that operate over corresponding segments in an output. A difference is that surface correspondence in ABC is enforced by violable constraints, while in Syntagmatic Correspondence Theory, surface correspondence among segments is assumed. This distinction has implications for the analysis of transparent segments. In ABC, transparent segments do not agree with a potential trigger because a surface correspondence relation does not exist between them. However, in Syntagmatic Correspondence, surface correspondence relations exist over all segments in the output, necessitating a different strategy to prevent transparent segments from undergoing or blocking harmony.

In Syntagmatic Correspondence Theory, transparency is understood in terms of balancing surface disagreement relations between a vowel and its flanking neighbors. This is implemented using BALANCE, a local conjunction of a constraint enforcing surface agreement for [F] between adjacent elements (S-IDENT[F]) with one enforcing disagreement for [F] (*S-IDENT[F]).[17] BALANCE is violated by a vowel that undergoes harmony and blocks further propagation, because it incurs a violation of *S-IDENT[F] for harmonizing with a neighboring vowel and a violation of S-IDENT[F] for not propagating harmony to a neighboring vowel. A transparent vowel obeys BALANCE, because it disagrees with both flanking vowels in its value for [F], and a harmonizing vowel satisfies BALANCE, because it agrees with its flanking vowels.

The BALANCE account of transparency involves adding a constraint that penalizes identity between corresponding segments. This constraint can also be used to capture dissimilation (Krämer 2001, 2003). However, Bennett (2013, 2015a, b) has shown that the constraints involved in Agreement by Correspondence (CORR-XX, IDENT-XX, IDENT-IO) can interact to obtain dissimilation, without requiring an anti-identity constraint. Dissimilation can arise as a means of satisfying CORR-XX[αF] by causing segments to not be identical for [αF]. This scenario enables segments to escape being subject to constraints enforced over surface-corresponding segments, such as IDENT-XX. Assimilation and dissimilation patterns receive a unified treatment using CORR-XX[αF] constraints. Furthermore, in ABC, CORR-XX[αF] is instrumental in characterizing both the classes of segments that participate in harmony and those that are transparent.

The ABC account of transparency thus aids in maximizing the scope of application of the CORR and IDENT constraint families. Nevertheless, transparency in vowel harmony is a rich empirical domain. A comparative study of the typological predictions for transparency made by Syntagmatic Correspondence Theory versus ABC would contribute further understanding on where constraint set economies are possible in a surface correspondence approach.

4.2.2 Sequential markedness

A different approach to harmony in Menominee utilizes sequential segmental/featural markedness constraints to obtain transparent and blocking behavior. In the analysis of Menominee proposed by Archangeli & Suzuki (1995), /ə(ː)/ does not propagate regressive [+ATR] harmony due to the sequential segmental markedness constraint *ATR…LO. This constraint assigns a penalty to a [+ATR] vowel that precedes a [+low] vowel (though details of this constraint's implementation in the account are revised below with a local conjunction). A higher-ranked IDENT-IO constraint will preserve a preceding [+ATR] vowel that was specified as such in the input. A featural alignment constraint functions as the harmony driver.

As to transparency, Archangeli and Suzuki suggest that /a(ː)/ is not a target of harmony because of the constraint ATR/LO, which prohibits a [+ATR] vowel that is [+low] (after Archangeli & Pulleyblank 1994). Again, a higher-ranked IDENT-IO constraint will prevent this constraint from altering features that

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[17] For discussion of local conjunction and the domain in which it is evaluated, see Smolensky (1993, 1997), Baković (2000), Łubowicz (2002, 2005), and Itô & Mester (2003).

are specified in the input, but ATR/LO will dominate the harmony-driving alignment constraint to inhibit [+ATR] harmony from deriving low [+ATR] vowels.

Yet there is a hitch, because *ATR…LO predicts that both /ə(:)/ *and* /a(:)/ will block harmony, rather than /a(:)/ being transparent. Accordingly, the account appeals to a local conjunction of *ATR…LO and ATR/LO to block [+ATR] harmony from /ə(:)/. The local conjunction is interpreted as violated when the same [+low] feature is involved in the violation of both constraints, as when [+ATR] spreads from /ə(:)/ (which violates ATR/LO) to a preceding vowel (violating *ATR…LO). Transparent /a(:)/ will not violate this constraint, because in this context ATR/LO is not violated.

The table in (54) presents a comparison of the approaches to transparent and blocking segments in Menominee in the ABC account versus sequential markedness.

(54)   Comparison of two theoretical treatments

	ABC	Sequential markedness
/ə(:)/ is not a trigger	Lack of feature identity with [-low], [-ATR] targets	Sequential markedness: *ATR…LO
/a(:)/ is not a target	Lack of feature identity with [-low], [+ATR] triggers	Markedness: ATR/LO
/a(:)/ is transparent	Lack of feature identity with [-low], [+ATR] triggers	Local conjunction: *ATR…LO & ATR/LO

As seen in (54), ABC uniformly calls on aspects of feature identity for treating segments that do not alternate in Menominee's [+ATR] harmony, enforced through CORR-XX and IDENT constraints. Correspondence relations and enforcement of identity between correspondents are fundamental concepts in OT (McCarthy & Prince 1995). In the ABC account, sequential segmental markedness constraints and local conjunction are not required. In other work, an approach to vowel harmony has been proposed that employs sequential markedness constraints as the harmony driver (Mahanta 2008, see also Baković 2000, Pulleyblank 2002). This function, too, is potentially subsumed under the role of CORR-XX and IDENT constraints in ABC. These points underscore a strength of the ABC analysis: its core constraint families have a broad reach with prospects to simplify the inventory of constraint types. A parallel is found in the proposal by Itô & Mester (1994, 1999) that segmental sequencing effects in syllables can be subsumed under the umbrella of Alignment constraints, obviating diverse markedness constraints such as ONSET, NOCODA, NODIPHTHONG, *COMPLEX and CODACOND. Collectively, this work emphasizes finding multi-purpose applications for constraints, with concentration of the labor in a limited set of constraint families.

5 Conclusion

The account of parasitic harmony in Menominee proposed here suggests that the intrinsic role of featural identity in ABC is advantageous in the analysis of vowel harmony. The analysis of vowels with different roles in this complex system coheres in employing constraints that govern correspondence relations and identity among correspondents. This approach contributes to a larger theoretical mission where the application of constraints within well-established families is maximized with potential to reduce complexity in Con.

Menominee's complex harmony pattern affords a valuable test for proposals about ABC formalism. It is noteworthy that this account exploits the feature-value specific version of CORR-XX[αF] constraints in capturing the distinct patterning of low vowels as icy targets versus transparent segments. Yet blocking is an empirical area that warrants further attention in the ABC framework. While some research has been brought to predictions about blocking in ABC that are either desirable or unwanted (Hansson 2007, Rhodes 2008, 2012, Sasa 2009, Shih 2013, and the present study), it is important for future work to investigate the theory's predictions about blocking more comprehensively.

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