A Factorial Typology of Codas in the Prosodic Hierarchy

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1 Introduction

Across languages, closed syllables have three basic behavioral patterns. In some languages, codas make syllables heavy and attract stress. These types of codas, known as moraic codas, also contribute to satisfying word minima, allowing word shapes like (C)VC. Nonmoraic codas are exactly the opposite; they have no bearing on syllable weight or stress assignment and do not satisfy word minima. Less common than moraic and nonmoraic codas are final extrasyllabic consonants, which can violate the Sonority Sequencing Principle (SSP, Selkirk 1984).

While a great deal of effort has been put into constructing diagrams of the structure of moraic codas, nonmoraic codas, and extrasyllabicity, there is very little work dedicated to deriving these types of final consonants theoretically. With limited exceptions, the structure of closed syllables is the visual representation of an observation that moraic codas, nonmoraic codas, and extrasyllabic consonants behave differently from each other. Moreover, the standard convention for diagramming the structure of moraic and nonmoraic codas fails to present a meaningful distinction between each type of coda as moraic codas and nonmoraic codas are both dominated by a mora (Hayes 1989). Using these conventions moraic and nonmoraic codas differ only by how many moras the syllable contains.

I propose that the varied behaviors of final consonants are the result of structural dissimilarities dependent on which level of the prosodic hierarchy directly dominates the coda and ultimately argue against Hayes' (1989) structure of closed syllables in favor of the structure put forth by McCarthy & Prince (1986). Furthermore, using an Optimality Theoretic (OT, Prince & Smolensky 1993/2004) approach, I show that extrasyllabic consonants are generated by the same factorial typology that produces moraic codas and nonmoraic codas. This yields a unified account of the differing behaviors of final consonants, which is principled and predicted in a modern theoretical framework.

2 Literature review

The prosodic hierarchy, first introduced by Selkirk (1978, 1980, 1981) and further developed by Nespor & Vogel (1982), is shown below in (1).

(1)
```
ω   – Word
|
φ   – Foot
|
σ   – Syllable
|
μ   – Mora
|
X   – Segment
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* Thanks to Chris Golston, Zachary Metzler, John Simonian, and the attendees of WECOL 2018 for their insights and comments. All errors are my own.

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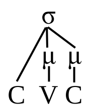
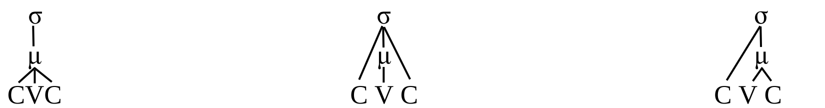
Although there are phrasal levels above words and features below segments, they have been omitted above as they are irrelevant to the discussion at hand. This paper will focus specifically on the portion of the prosodic hierarchy shown in (1).

A number of structures have been proposed for closed syllables, though some are less controversial than others. While the structure of heavy CVC syllables shown in (2) is universally agreed upon, (3) presents conflicting structures that have been posited for light CVC syllables.

(2)



(3)



Hyman (1985) McCarthy & Prince (1986) Hayes (1989)

Hayes' structure of light CVC in (3) is considered standard. When compared to heavy CVC in (2), the only difference is the number of moras in the syllable. Contrary to what their names imply, moraic codas and nonmoraic codas are both dominated by a mora in conventional syllable structure. I return to discuss this issue in greater depth in §3.2.

There is a similar debate about the attachment site of final extrasyllabic consonants; it has been argued that extrasyllabic consonants are attached to either the prosodic word or the foot level of the prosodic hierarchy.

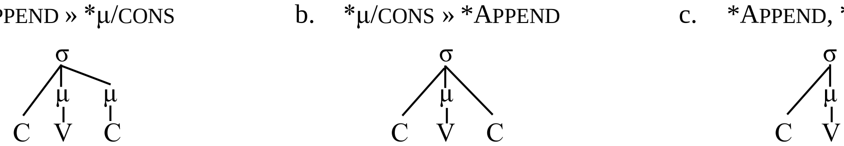
(4)

Hagstrom 1997, Green 2003, Kiparsky 2003 Rubach & Booij 1990

The structures I will argue for in this paper are McCarthy & Prince's (1986) model of light closed syllables and Rubach & Booij's (1990) model of final extrasyllabicity.

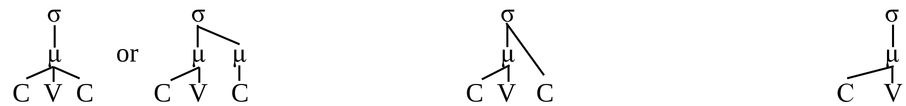
Rosenthal & van der Hulst (1999) propose an OT account for deriving moraic and nonmoraic codas, but this analysis is problematic as it contains internal inconsistencies that predict widely rejected syllable structures. Rosenthal & van der Hulst utilize ad-hoc constraints *μ/CONS (no moraic coda consonants) and *APPEND (no nonmoraic syllable appendix) and claim that *APPEND » *μ/CONS results in the structure in (5a), *μ/CONS » *APPEND yields (5b), and *APPEND, *μ/CONS produces (5c).

(5) a. *APPEND » *μ/CONS b. *μ/CONS » *APPEND c. *APPEND, *μ/CONS



These outputs are selected because onsets were not considered to violate *APPEND, even though onsets are syllable appendices which are not dominated by a mora. If *APPEND is applied consistently, this factorial typology predicts the structures shown in (6a)-(6c).

(6) a. *APPEND » *μ/CONS b. *μ/CONS » *APPEND c. *APPEND, *μ/CONS [1]



This immediately reveals a number of issues with Rosenthal & van der Hulst's analysis. One is that it does not serve the intended purpose of the proposal. It fails to identify a constraint ranking that can only produce bimoraic CVC. (6a) shows that *APPEND » *μ/CONS yields ambiguous results; both of these structures fully satisfy *APPEND and only violate *μ/CONS once. With the same number of violations for each constraint, both structures are considered legal syllable structures. Second, each of the optimal candidates predicted by their factorial typology require that onsets form a constituent with nuclei, a notion which has largely been abandoned by the field. The most troubling example of this is (6b): a structure for light CVC which is absent from the literature, and one for which there is little, if any, evidence. The purpose of this paper is to fill these gaps in the literature.

3 Codas and extrasyllabicity

In this section, I discuss moraic codas, nonmoraic codas, and extrasyllabic consonants and propose that a final consonant's behavior is determined by its relationship to superordinate structures in the prosodic hierarchy. I argue that moraic codas are directly dominated by moras, nonmoraic codas by syllables, and extrasyllabic consonants by prosodic words. Under this analysis the differences in behavior are motivated by structural dissimilarities. I propose an approach that utilizes a set of four constraints, defined below in (7a)-(7d).

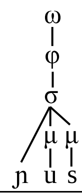
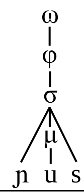
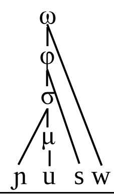
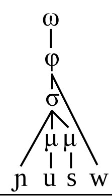
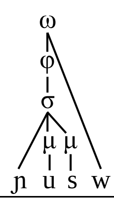
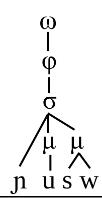
(7) a. WEIGHT BY POSITION (WBP) – Codas must be dominated by a mora (Hayes 1989)
b. SONORITY SEQUENCING PRINCIPLE (SSP) – Onsets must have a rising sonority contour and codas must have a falling sonority contour (Selkirk 1984)
c. WEAKEDGE – the right periphery of PCat should be empty; assign a violation for every level of structure that dominates the rightmost segment (Spaelti 2002)
d. MAX – no deletion (Prince & Smolensky 1993/2004)

A factorial typology of these constraints manipulates the structure of syllables and places restrictions on their contents. The upcoming subsections address the structure of each type of final consonant and the constraint ranking that produces it.

3.1 *Moraic codas* As mentioned before, key attributes of moraic codas are that they contribute to word minimality and attract stress in quantity-sensitive languages. In languages such as Maithili, (C)VC syllables are heavy because the coda is a viable host for its own mora (Jha 1958). Such syllables are bimoraic, which makes them acceptable prosodic words as well. The structure of closed syllables in languages that exhibit these properties is not controversial, but it is important to be able to derive such a structure theoretically. As the defining property of moraic codas is their contribution to syllable weight, there is a strong implication that moraic codas have a direct relationship to the mora level of the prosodic hierarchy. Such a relationship can be produced by high-ranking WBP.

[1] I follow Rosenthal & van der Hulst in considering deletion a viable option only when *APPEND ties *μ/CONS, although MAX should be included in the factorial typology proper as deleting codas would satisfy *μ/CONS in any constraint ranking. The only way to prevent deletion in (5a) and (6a) is if MAX » *μ/CONS while MAX » *APPEND would prevent deletion in (5b) and (6b).

(8) Structure of heavy CVC

ɲusw	WBP	SSP	WEAKEDGE	MAX
a. ☞ 			****	*
b. 	*!		***	*
c. 	*!	*	*	
d. 		*!	**	
e. 		*!	*	
f. 		*!	****	

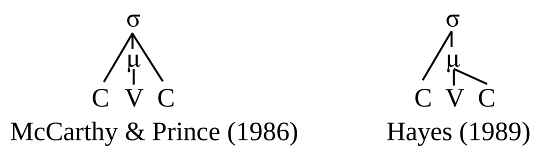
The primary constraints in effect here are WBP and SSP. Candidates (b) and (c) are eliminated for violation of WBP as the coda /s/ is attached to the syllable rather than the mora. In (d) and (e), /w/ does not violate WBP because they are dominated by levels of the prosodic hierarchy above the syllable, and therefore cannot be part of the coda. (d)-(f) violate SSP due the increase in sonority from /s/ to /w/. Despite (a)'s violations of low-ranked WEAKEDGE and MAX, it is the optimal candidate since the other competitors are all eliminated by WBP and SSP.

Note that in (8) syllable structures such as those predicted by Rosenthal & van der Hulst (1999) where onsets and nuclei are dominated by the same mora were not considered in the tableau. This is because none of the constraints regulate the behavior or structure of onsets. While a syllable in which an onset is dominated by a mora may incur the same number of violations as candidates (a)-(f), the notion that syllables are separated into an onset and a rhyme is widely (if not universally) accepted. Structures such as those presented in (6) are not supported by modern theories of syllable structure, whereas (a)-(f) are, and therefore they are omitted from (8) and future tableaux.

While this result does not present a groundbreaking revelation about the theory of syllable structure, it is nonetheless important because it provides a much needed theoretical account of the structure of moraic codas.

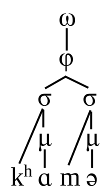
3.2 *Nonmoraic codas* In contrast to moraic codas, nonmoraic codas play no role in a syllable's weight. Unlike the structure of closed syllables with moraic codas, the structure of light closed syllables is a topic of debate. The most commonly used light CVC structures are those proposed by McCarthy & Prince (1986) and Hayes (1989), shown again in (9) for convenience.

(9)



There are two key reasons for which I argue that the structure of light CVC proposed by Hayes (1989) is problematic: the first based is on consistency with principles in phonology and other fields both in and outside linguistics; the second is based on the predictions of the theoretical machinery I propose in this paper. To address the issue of consistency, let us consider the prosodic structure of a word like 'comma.'

(10)

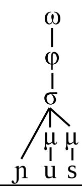
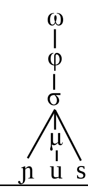
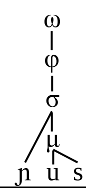
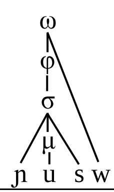
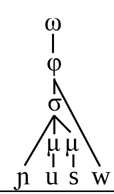
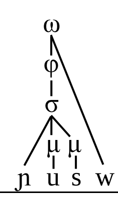


Based on the structure and relationships presented in (10), it is reasonably interpreted and understood that the prosodic word consists of a foot, the foot consists of two syllables, and (momentarily ignoring moras) each syllable consists of two segments. We further implicitly acknowledge that each of the syllables contributes equally to the makeup of the foot and each segment equally contributes to the content of its respective syllable. By the same token, Hayes' structure in (9) implies that in a light closed syllable, the nucleus and coda play an equal role in the syllable's moraic weight. However, because (C)V and (C)VC in languages with nonmoraic codas are both considered monomoraic, it is clear that the nucleus is solely responsible for the moraic content of light syllables. This problem is not present in the structure proposed by McCarthy & Prince (1986) as nonmoraic codas have no relationship with moras.

Furthermore, there is a well-established principle in a number of physical sciences that a system or organism functions in a particular way as a result of its structure. This concept applies to branches of linguistics as well, such as the syntax-semantics interface. The subject of predicates such as 'love' are assigned a thematic role of either agent or experiencer depending on the argument structure of the verb. This in turn determines how a proposition is interpreted semantically. It is no way unreasonable to think that this notion may translate to phonology as well, especially given the resemblance between the hierarchical structure of syntax and that of the prosodic hierarchy; by analogy, the source of different behaviors such as those exhibited by moraic and nonmoraic codas can be attributed to a structural dissimilarity. The structural uniformity of Hayes' (1989) light and heavy CVC syllables counterintuitively produces two distinct patterns, whereas the differing structures for light and heavy CVC syllables proposed by McCarthy & Prince (1986) provide a principled explanation for the contrasts observed between moraic codas and nonmoraic codas.

The second reason for which I argue against light CVC syllables as proposed by Hayes is that they fall short in their ability to satisfy the set of constraints laid out in this paper. Nonmoraic codas observe the SSP much like moraic codas, but they are dominated by fewer levels of structure. To that end, I posit the constraint ranking in (11).

(11) Structure of light CVC

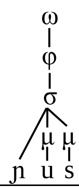
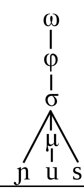
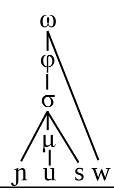
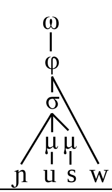
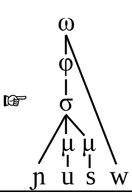
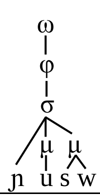
ɲusw	SSP	WEAKEDGE	WBP	MAX
a. 		****!		*
b. ☞ 		***	*	*
c. 		****!		*
d. 	*!	*	*	
e. 	*!	**		
f. 	*!	*		

The constraint ranking in (11) differs from (8) in that it requires minimal structure at the right edge as long it does not result in a violation of SSP. As before, the faithful candidates (d)-(f) violate SSP. The final consonant in (a) and (c) is dominated by four levels of structure, yielding four violations of WEAKEDGE. The coda in (b) is attached to the syllable rather than the mora, receiving one fewer violation of WEAKEDGE. (b) is therefore selected as the optimal candidate.

This constraint ranking produces the desired structural contrast between moraic codas and nonmoraic codas which I have argued for above. This analysis provides an OT account to motivate and support the structure of light CVC proposed by McCarthy & Prince (1986).

3.3 *Extrasyllabicity* Final extrasyllabicity is typically considered an issue unrelated to moraic and nonmoraic codas, though I argue here that it is simply another type of final consonant whose behavior is determined by its structure. As such, I see no reason why it cannot be included in a unified account of final consonant behaviors with moraic codas and nonmoraic codas. Like the structure of nonmoraic codas, there is debate about the attachment site of extrasyllabic consonants, the primary candidates being the foot (Hagstrom 1997, Green 2003, Kiparsky 2003) and the prosodic word (Rubach & Booij 1990). The most salient property of extrasyllabic consonants is their ability to violate the SSP (though see §4 for further discussion of other types of evidence for extrasyllabicity). I propose that this violation of SSP occurs to satisfy WEAKEDGE.

(12) Structure of final extrasyllabicity

ɲusw	WEAKEDGE	MAX	SSP	WBP
a. 	**!**	*		
b. 	**!*	*		*
c. 	*		*	*!
d. 	**!		*	
e. ☞ 	*		*	
f. 	**!**		*	

High-ranked WEAKEDGE requires all outputs to have minimal structure at the right edge of the word while high-ranked MAX ensures that final consonant clusters are not simplified in order to satisfy SSP. These two constraints eliminate (a), (b), (d), and (f). Foot-level attachment of extrasyllabic material as proposed by Hagstrom (1997), Green (2003), and Kiparsky (2003) fails here for a needless violation of WEAKEDGE. The remaining competitors (c) and (e) differ by whether the coda is dominated by a mora. (c) is eliminated for violating of WBP as the coda /s/ is attached to the syllable. (e), where extrasyllabic consonants are dominated by the prosodic word and codas are dominated by a mora, is chosen as the optimal output.

Using this approach, extrasyllabic consonants attached to the foot and word-level attachment with nonmoraic codas are harmonically bounded. These predictions uphold Rubach & Booij's (1990) model of extrasyllabicity and overall support the idea that the varying behaviors of final consonants can be attributed to structural differences. The factorial typology for moraic codas, nonmoraic codas, and final extrasyllabicity is summarized in (13).

(13) Factorial typology

Final Consonant Type	**Ranking**	**Language**
Moraic Codas	WBP » SSP » WEAKEDGE, MAX	Maitihili
Nonmoraic Codas	SSP » WEAKEDGE » WBP, MAX	Malayalam
Extrasyllabic	WEAKEDGE, MAX » SSP, WBP	Russian

As WEAKEDGE interacts with other constraints, it produces three possible attachment sites for final consonants, thus accounting for the three distinct behavioral patterns of final consonants.

4 Typological predictions

The results of this factorial typology have implications for the behavior of codas in languages with final extrasyllabicity. Recall from (12) that candidate (c) is harmonically bounded by (e). The difference between these outputs is whether the coda /s/ is moraic, as in (e), or nonmoraic, as in (c). The selection of (e) over (c) predicts that codas are moraic in languages with final extrasyllabic consonants. However, testing the validity of this prediction has proved challenging. One source of the problem is that there is disagreement about what constitutes evidence for extrasyllabicity. Scheer (2004:417) presents a presumably nonexhaustive list of conditions that are used as arguments for extrasyllabicity:

(14) Situations that give rise to extrasyllabic interpretations
  a. internal Codas react, but final Codas do not
     example: l-vocalisation in French
  b. vowels in internal closed syllables react, but they show no effect in final closed syllables
     example: Icelandic Closed Syllable Shortening
  c. word-initial #RT sequences
     example: Czech *rty* 'lips', *lhát* 'to lie' etc.
  d. heavy word-final clusters
     example: English *sixths* [sɪksθs], German *Herbst* [heχpst] 'autumn'
  e. [s]o-called "trapped" consonants (chapter 1,10 §240)
     example: the [r] in Polish trvać "to last", the [n] in Polish czosnku 'garlic GEN.sg'

Three of the five phenomena laid out by Scheer are violations of SSP (c-e). The other two (a and b) are observations that phonological changes occur in word-medial codas but not word-final codas. A possible rebuttal to Scheer's claim could be that the prosodic edges of syllables and words are fundamentally different; as a result the right edge of the word domain could yield different effects than the right edge of the syllable domain, even when these edges coincide, thus accounting for differences between word-medial and word-final codas. As violation of SSP is the most consistently accepted evidence for extrasyllabicity, I will focus only on these cases. Final extrasyllabicity can be found in English, German, Polish, and Russian.

(15)	English: *strength*	[stɹeɪŋkθ]	
	German: *Herbst*	[heχpst]	'autumn'
	Polish: *zmarł*	[zmarw]	'he died'
	Russian: *tembr*	[tɛmbr]	'timber'

There is clear evidence that codas are moraic in English and German as minimal words can take the shape of CVC in both languages and closed syllables attract stress in German (Alber 1997). Determining the effect that codas have on syllable weight in Polish and Russian is more difficult; stress is lexical in Russian (Gouskova 2010) and Polish stress is assigned on the penultimate nucleus irrespective of syllable weight (Gussmann 2007). The issue is further complicated because minimal words are monomoraic:

(16)	Polish: *gra*	[gra]	'game'
	Russian: *sto*	[sto]	'one hundred'

The conventional methods of evaluating what effect codas have on syllable weight do not indicate whether codas in Polish and Russian are moraic. Because these facts neither support nor refute the predictions made by the factorial typology, further investigation on this topic will be required.

5 Conclusion

I have argued here that the behavior of moraic codas, nonmoraic codas, and final extrasyllabic consonants are the result of dominance relationships in the prosodic hierarchy which are generated by interaction of constraints regulating sonority and structure. The outcomes of the factorial typology I have proposed support the works of McCarthy & Prince (1986) and Rubach & Booij (1990) and predict that codas are moraic in languages with final extrasyllabicity. My proposal provides a unified OT account of final consonant behaviors that is grounded in principles about the relationship between structure and function.

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