

# Reanalyzing final consonant extrametricality: A proportional theory of weight \*

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Many languages, including Norwegian, exhibit CVC weight asymmetry: CVC is usually heavy but behaves as light word-finally. It is proposed that this asymmetry is motivated by facts of phonetic length and human perception. A theory of weight is advanced in which a syllable shape in a given position is only heavy if it, on average, is sufficiently proportionally longer than a (necessarily light) CV in the same position. A syllable will need to be extra-long word-finally in order to be categorized as heavy because a final CV is notably longer than a non-final CV due to final lengthening. Analyzing weight as requiring a minimum proportional increase reflects human perception of differences: the same raw increase has less of a perceptual effect when added to a relatively long stimulus. A production experiment of syllable length in Norwegian shows a parallel minimum proportional increase threshold for heavy syllables across positions. The proportional increase theory of weight provides a phonetically and perceptually motivated explanation for the CVC weight asymmetry, thus replacing final consonant extrametricality, the traditional descriptive mechanism. Issues for moraic theory and possible extensions to other forms of extrametricality are discussed.

## 1 Introduction: The CVC weight asymmetry

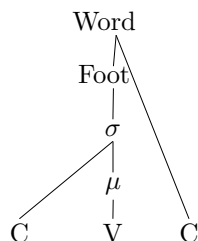
Syllables of the shape CVC present a weight asymmetry in many languages, including Arabic (McCarthy 1979), English (Chomsky and Halle 1968), Estonian (Prince 1980), Greek (Steriade 1980), a dialect of Hindi (Hayes 1981, citing

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Mohanan 1979), Icelandic (Kiparsky 1984), Menomini (Hayes 1995), Norwegian (Kristoffersen 1991), Ponapean (McCarthy and Prince 1986), Romanian (Steriade 1984), Swedish (Riad 1992), and Swiss German (Spaelti 1994). In such languages, syllables of the shape CVC are heavy but word-finally behave as though they are light. Some such languages allow syllables of the shape CVXC in final position, which behave as heavy. This CVC weight asymmetry has traditionally been dealt with, but not explained, by final consonant extrametricality, recast in optimality theory (Prince and Smolensky 1993; henceforth OT) as a consonant appendix in order to satisfy NONFINALITY (as in Rosenthal and van der Hulst 1999). This configuration is shown in (1).

- (1) Word-final consonant extrametricality (satisfies NONFINALITY)







While this approach is able to descriptively account for the CVC weight asymmetry it does not shed light on the reason behind the phenomenon. I propose that the weight asymmetry is motivated by facts of phonetic rime length and human perception. Syllables at prosodic boundaries, including at the word level, are phonetically lengthened (originally noted for intonational-phrase-final syllables by Delattre 1966 and for word-final syllables by Lindblom 1968) and this additional length is argued to account for word-final syllable weight.

I assume that the duration contrast between light and heavy syllables is perceptually important. Given this, I propose that in order for a syllable shape in a given position to be categorized as heavy it must be consistently realized as sufficiently longer than an unstressed CV syllable in the same position. The increase necessary to be sufficiently longer is an empirical question, explored here using the results of a production experiment with Norwegian speakers. I show that it is not the raw increase in duration that sets a heavy syllable apart from a light syllable, rather, it is the proportional increase, and that the minimum proportional increase is consistent across all positions in a word. It is a known fact of perception that if a shorter and a longer duration are increased by the same amount the increase to the shorter duration will be perceptually greater.<sup>1</sup> When the proportional increase of the just noticeable difference (jnd)

<sup>1</sup>The discovery of this aspect of human perception is due to Ernst Heinrich Weber (1795–1878) who performed experiments with the perception of weight and, later, of sight and hearing. He found that the smallest noticeable difference was essentially proportional to the starting unit. For example, the difference between a 100 gram weight and a 110 gram weight was paralleled at a higher level by a 1000 gram weight and a 1100 gram weight, both having a proportional increase of 10%.

is consistent for different starting values, Weber’s Law is said to hold. While it is unclear whether the perception of duration is an absolute case of Weber’s Law, it has been shown to play a significant role in the perception of duration. For example, Henry (1948) found that the jnd decreased slightly as the stimulus duration increased. It is clear from his results, however, that a much larger increase is needed for a longer stimulus than for a shorter one to achieve roughly the same perceptual effect. He found that the jnd for a base stimulus of 47 ms. was 9.5 ms. (a 20.3% increase), whereas for a base stimulus of 277 ms. it was 47.6 ms. (a 17.2% increase). Grondin et al. (2001) found a fairly consistent jnd of approximately 9%, although the duration of stimuli tested were larger, so taken with Henry’s findings for smaller durations may indicate that the threshold does continue to lower as the duration of the stimulus increases (although the experiments’ separation in time and technology may make them incomparable). The perceptual effect of Weber’s Law is shown schematically in (2).

- (2) The same increase does not have the same perceptual effect (Weber’s law)
- a. i.  + x  
 ii. 
- b. i.  + x  
 ii. 

The first and second bars in the pairs in (a) and (b) in (2) are separated by the same raw increase in length (x). However, the two bars in (a) are more perceptually distinct than the two in (b). This is true both looking at the lengths visually and if they were audible durations. The perceived distinction between the two bars in (a) and (b) is different from the actual distinction between them because humans are more sensitive to increases to smaller amounts. Thus, the increase x to the relatively short bar in (a-i) seems greater than the increase x to the relatively long bar in (b-i).

If a minimum proportional increase is required to set a heavy syllable in a particular position apart from a CV syllable in the same position, word-final lengthening means that more length is needed for word-final syllables to be categorized as heavy than is needed for non-final syllables. The additional length present word-finally causes a CVC syllable to have a smaller proportional increase word-finally than it does non-finally. A CVXC syllable, however, has the additional length necessary to create a heavy–light contrast word-finally that is similar to the heavy–light contrast found non-finally.

This proposal differs radically from the solution offered by final consonant extrametricality. Rather than discounting the final consonant, the length provided by the final consonant in a CVXC syllable is crucially needed to parallel the proportional increase of a heavy syllable over a CV found non-finally. I show that this categorization of weight is supported by a comparison of rime

durations in Norwegian.

## 1.1 Weight and stress in Norwegian

Norwegian (like Swedish) requires that stressed syllables be heavy. Long vowels and geminates may only occur under primary stress. The fact that vowel and consonant length is dependent on stress is a result of the historical quantity contrast having been lost, referred to as the quantity shift. Before the quantity shift vowel and consonant length were phonemic. The result of the quantity shift was that a weight requirement was imposed on all syllables: stressed syllables needed to be heavy while unstressed syllables needed to be light. Loan words have since given rise to unstressed heavy syllables. However, syllables in loan words that would surface as stressed and light are augmented so that they surface as heavy.

Primary stress is assigned to the ultima if it is a diphthong or a CVXC, or can be augmented to become a CVXC. Otherwise stress is penultimate, unless the word ends in CV.CV and antepenult is heavy, in which case the antepenult is stressed.<sup>2</sup>

### (3) Placement of primary stress in Norwegian

	ultimate		penultimate	
underlyingly heavy	e.le.fánt	‘elephant’	bru.dúl.je	‘ruckus’
	al.ma.nákk	‘almanac’	di.síp.pel	‘disciple’
augmented	tu.li.pá:n	‘tulip’	lá:ma	‘llama’
	sjas.mí:n	‘jasmine’	ga.má:sje	‘spats’
antepenultimate				
underlyingly heavy	dón.ge.ri	‘denim’		
	brók.ko.li	‘brokkoli’		

Both vowel length and consonant length have independently been argued to be underlying (see Elert 1964, Witting 1977, et al. for underlying vowel length; Eliasson 1978, Riad 1992, Rice 2006, et al. for underlying consonant length).<sup>3</sup>

Speakers are conscious of vowel length but not particularly aware of consonant length, suggesting that vowel length is underlyingly contrastive and gemination occurs only when an otherwise light syllable would surface stressed. However, this analysis has the cost of doubling the phonemic vowel inventory of the language, which is suspicious, given that vowel length is only contrastive in stressed syllables. Eliasson (1978) proposed that phonetically long consonants (in Swedish) can be analyzed as two identical consonants. Following this view,

<sup>2</sup>Loan words, which are abundant and part of the core vocabulary, are used to illustrate the stress pattern, as truly native Norwegian words are limited to the shapes CVX.Cə and CVXC. I am indebted to Gjert Kristoffersen for sharing his database of stress in two syllable and greater loan words, compiled mostly from the A-K listings in a loan word dictionary (Selmer 1966). Most of the words given here and cited elsewhere in the article are taken from his database.

<sup>3</sup>The works cited in this paragraph conflate proposals for Norwegian with those concerned with Swedish, as the representation of length is an issue for both languages.

I assume that geminates, when present, are present underlyingly. Therefore syllables that would otherwise surface as light and stressed are augmented through vowel lengthening. Some independent support for this choice is discussed in §3.3.

The syllable shape inventory is broken down in (4). Because stressed syllables are required to be heavy we can easily identify a syllable shape’s weight by its (in)ability to host stress. The cells of heavy syllable shapes are grayed in the chart below. Medial geminates are represented here and elsewhere with the notation “CVC.:", where a syllable boundary is shown before the length mark (as the second half of the geminate occurs in the following syllable). Syllable shapes that can occur both unstressed and stressed are listed twice.<sup>4</sup>

(4) Possible syllable shapes by position

	occur unstressed			occur stressed			
non finally	CV	CVV	CVC	CVV	CVC	CV:	CVC.:
finally	CV	CVV	CVC	CVV	CV:C	CVC:	CVCC

The CVC weight asymmetry is evident in the final column of unstressed syllable shapes. Apart from diphthongs, syllables in final position must have three segments in the rime in order to bear stress, whereas non-finally any rime with two segments counts as heavy. Note that CV: is not listed as occurring word-finally. The status of a word-final long vowel is discussed in §3.3 where it is suggested that Norwegian has final shortening.

## 2 Rime duration experiment

An experiment was undertaken to investigate the effect of stress, position, and rime shape on rime duration. Native Norwegian speakers were asked to read sentences containing a nonce word of three syllables. Speakers were asked to stress the nonce word on the syllable written in capital letters. The nonce words had a voiceless stop in the three onset positions ([k], [t], [p], respectively) and the vowel [a] in all of the nucleus positions.<sup>5</sup> The rimes of this basic nonce word *katapa* were varied in shape (see (5) below). Only one vowel quality was used in order to control for known variances in the inherent length of different vowels (Lindblom 1968, although Fintoft 1961 failed to find any significant durational differences between [i], [u], and [a] in Norwegian). There were 23 versions of the nonce word. The written stimuli included two copies of each, randomized for each speaker.

<sup>4</sup>Although word-final diphthongs are only listed as stressed, there are a few words in which they occur unstressed (e.g. *éssay*, ‘essay’) despite the assumed stress placement at the right edge if possible. These are taken to be exceptions to the basic stress pattern.

<sup>5</sup>The onset consonants in each position were not varied as a pilot experiment showed no effect of onset place of articulation on the duration of the following rime. The duration experiment in Norwegian by Fintoft 1961 also failed to find an effect of onset consonant place on vowel length.

The stimuli used are shown in (5). Each “basic form” was modified for rime shapes and stress location. Following Norwegian orthography, geminates were written with a double consonant (e.g. KATtapa) whereas long vowels result in the pronunciation of an open stressed syllable (e.g. KAtapa), or, word-finally, a stressed CVC (e.g. kataPAT).

(5)

basic form	antepenult variations	penult variations	ultima variations
katapa	ká:tapa	katá:pa	
	káttapa	katáppa	katapákk
	káptapa	katákpa	
	kántapa	katámpa	
katapan	ká:tapan	katá:pan	katapá:n katapánn katapánk
	káttapat	katáppat	katapátt
	kántapat	katámpat	
katapat		kantá:pat	kantapá:t
		ká:tanpat	kantapá:t

Data was gathered from fourteen subjects, eight female, six male. Subjects were instructed to read the sentences, including the nonce word, as fluently as possible, pronouncing the nonce word with the indicated stress and as if it were a real Norwegian word. They were encouraged to say a sentence over again if they felt that the nonce word had not come out correctly. Subjects were recorded using a headset-mounted microphone, a Sennheiser PC130 (eight subjects) or a KOSS CS100 (6 subjects), connected via a Griffin iMic to a PowerBook G4 (first set of subjects) or a MacBook. Readings were recorded into Praat (Boersma and Weenink 1992–2008).

## 2.1 Classification of data

Because multiple subjects had trouble pronouncing the words with the indicated stress, nonce words were subsequently coded based on how they were actually pronounced, without respect to the written stimuli. This allowed for more data to be used, although it also resulted in a different distribution of syllable types in some cases. (For example, while the printed stimuli contained an almost equal number of stressed antepenults, penults, and ultimas, one subject pronounced 46% with antepenultimate stress, 12% with penultimate, and 42% with ultimate.)

Since a goal was to investigate word-final, as opposed to phrase-final, lengthening, cases in which the nonce word was pronounced as phrase-final were discarded. Although the carrier phrases<sup>6</sup> were structured so that the nonce word

<sup>6</sup>There were several versions of the carrier phrase, as it was changed in the hopes of

was not phrase-final, it was sometimes still pronounced with a fall in intonation or a following pause. For a few subjects, who largely read through the sentences with an intonation that slotted the nonce word into the carrier phrase, this resulted in most of their data being discarded, but most subjects had only a few instances where the nonce word was not clearly phrased with the following part of the carrier phrase. Deciding whether the nonce word was pronounced as phrase-final or not is obviously somewhat subjective. The researcher and an assistant listened to the recordings and came to an agreement on each. Only clearly mis-phrased utterances were discarded (meaning borderline cases were left in). Further data was eliminated due to the pronunciation of the final syllable of the nonce word overlapping with the following syllable of the carrier phrase. For example, some subjects pronounced *Æ ga katapat til henne* without a separate release of the nonce-word final [t], instead combining it with the [t] of the following word. Since the length of the test word could then not be exactly delineated, such pronunciations had to be excluded. Once these exclusions were made, the data set comprised the rimes of 376 words, resulting in 1128 rimes. In addition, four of the subjects were asked to read *katapa*-based nonce words in which the stressed syllable was a diphthong. Diphthongs had not been included in the original stimuli set since vowel quality was kept as a constant. Two diphthongs were put in each position of the basic form *katapa*: [ei] and [aʊ], the latter pronounced [øʊ] by two of the four speakers. The addition of the six diphthongs, each spoken by four people, increased the data set to 399 words, 1197 rimes.<sup>7</sup>

The duration of each rime was then measured, referencing the paired wave form and spectrogram, with intensity displayed in Praat. Vocalic rimes were measured from the beginning of a cyclic wave pattern, (F2 was usually in evidence but light for the first cycle or two). The end of a vowel was determined

encouraging phrasing the nonce word with the following words.

- (i) Carrier phrases
  - a. *Æ ga* \_\_\_\_\_ til henne (6 subjects)  
“I gave \_\_\_\_\_ to her”
  - b. *Æ liger* \_\_\_\_\_ og smør (4 subjects)  
“I like \_\_\_\_\_ and butter”
  - c. *Æ liger* \_\_\_\_\_ med smør (4 subjects)  
“I like \_\_\_\_\_ with butter”

<sup>7</sup>One person skipped one of the diphthong words, resulting in 23, rather than 24, additional words. The final distribution by subject is given in (i).

(i)

subject	sex	# of words	subject	sex	# of words
1	F	28	8	F	35 (+6 w/ diphthongs)
2	F	29 (+6 w/ diphthongs)	9	F	32
3	F	16 (+6 w/ diphthongs)	10	F	39 (+5 w/ diphthongs)
4	M	11	11	F	26
5	F	43	12	M	2
6	M	27	13	M	11
7	M	34	14	M	43

using a combination of the three visual components: a corresponding drop in, or end to, at least two of them taken to denote the end of sound. Voiceless portions of word-final vowels were included, judged both by the wave form and by listening to the utterance. The end of nasal-final rimes were likewise delineated. Stop-final rimes were measured through the release burst. Non-final geminates presented a challenge, since geminate stops have a single release burst. The stop closure was measured, which comprises both a coda and onset consonant. We cannot be certain about the proportion of the closure that is due to the coda, but an estimate was made based on the average closure portions of non-geminate coda-onset stops. For example, there were words in which the first two syllables were *káp.ta...*, and it was found that the coda comprised 52.9% of the closure on average. The closure of a geminate in the same position (*kát.ta...*) was then calculated to be 52.9% of the total. While an estimation, this calculation allows the rimes of medial geminates to be included, with the caveat that the duration of these rimes is somewhat speculative.

### 3 Proportional increase theory of weight

Using the experiment data, I show that syllable weight can be correctly established through comparison of average rime increases over a CV rime in the same position. First, I turn to the results of a statistical model fitted to the data, which shows position in the word to be a significant factor, demonstrating the presence of word-level final lengthening in the language.

#### 3.1 Experiment results with respect to rime duration factors

The measurements of each rime in the data set were coded for subject, position (antepenult, penult, ultima), stress (unstressed, stressed), rime size (number of segments in the rime, long vowels counting as two), and the shape of each word (whether it came from word with one heavy syllable or from a word with two heavy syllables).

While the word a particular rime came from should ideally be a random grouping factor, it cannot be analyzed as such since this would give us only three observations within each grouping, an insufficient amount, especially given the different rime sizes, positions, and stress levels under consideration, for a model. Individual rimes must therefore be treated as independent observations, for sheer practical considerations. In order, however, to investigate if rime duration varies according to the shapes of other rimes in the word, the factor “word shape” was employed.

A repeated measures mixed model linear regression was fit using SPSS. “Subjects” was a random grouping factor, meaning that a separate regression was fit for each subject. The fixed factors were “position”, “stress”, “rime size”, which was nested within “position” and “stress”, as not all rime sizes occur under all levels of position and stress, and “word shape”. All fixed factors except word

shape were found to significantly correlate with rime duration. The interaction of word shape with other factors, however, was significant (except with stress ( $F[1,1167.854]=0.072, p=0.789$ ), which was therefore omitted from the model). The interaction effect of word shape will be discussed further below.

(6) Fixed effects

Factor	df	F statistic	<i>p</i> value
position	2, 1167.728	339.207	<0.001
stress	1, 1167.918	308.921	<0.001
rime size	4, 1169.267	71.381	<0.001
(nested in position * stress)			
word shape	1, 1169.231	0	0.984
position * stress	2, 1169.147	11.012	<0.001
position * wordshape	2, 1168.107	3.854	0.021
rimesize * word shape	1, 1168.441	19.372	<0.001
(nested in position * stress)			
position * stress * wordshape	3, 1168.764	10.3	<0.001

There is significant between-subject variation:  $p=0.014$ , based on a Wald Z score of 2.469. However, A comparison of the estimated variances between subjects of the model with the above fixed effects to the unconditional (random subject factor only) model shows that only 3.9%<sup>8</sup> of the variance between subjects is due to the fixed factors of position, stress, rime size, and word shape, indicating that the subjects were relatively uniform with respect to the influence on rime duration of these factors.

Although the fixed factors were separated as much as possible, there is unavoidable overlap between them. For example, it is not surprising that “position” is significant, with the antepenult and penult differing significantly from the ultima ( $p<0.001$ ) but the two non-final positions not differing significantly from each other ( $p=0.831$ ) since, for example, three-segment rimes can only occur in final position.<sup>9</sup> In order to clearly see the effect of position with respect to establishing the existence of final lengthening, a similar model was fit to only rimes consisting of a single segment. Since CV syllables cannot bear stress and clearly do not vary in rime size, these two factors were omitted from the model.

Looking at the model of CV rime durations, the presence of final lengthening in the language is clearly evident. The effect of “position” was significant ( $F[1, 65.086]=247.302, p<0.001$ ), and, while the antepenult and penult did not differ significantly ( $p=0.977$ ), the ultima did differ significantly from both of the non-final positions ( $p=0.002$  for antepenult,  $p=0.003$  for penult). Thus we can unambiguously see the effect of final lengthening in CV syllables.

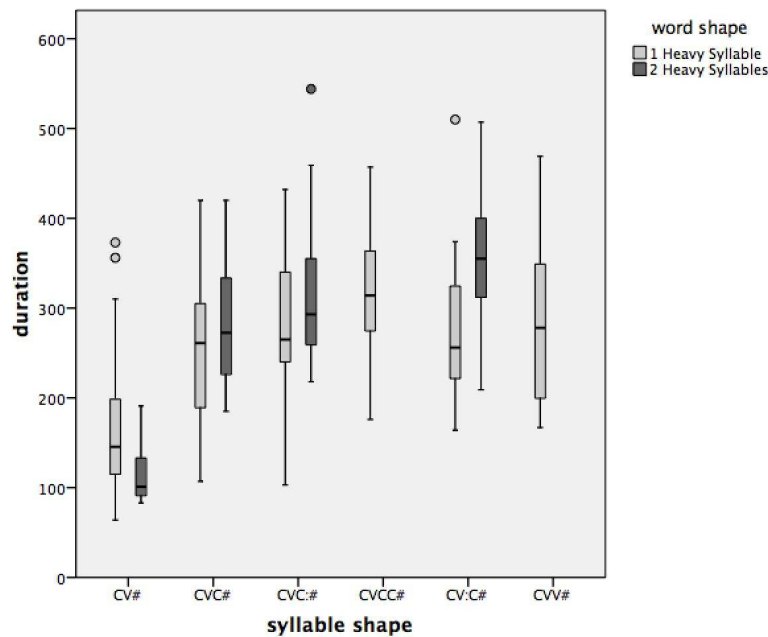
The effect of word shape was also significant ( $F[1, 602.417]=6.118, p=0.014$ ), as was its interaction with position ( $F[2, 602.143]=602.143, p<0.001$ ). While word shape does not affect the length of a non-final CV, it does affect word-final CV syllables. Further, the word-final heavy syllables that were tested

<sup>8</sup>Percentage calculated referencing Norušis (2007), p 214.

<sup>9</sup>The *p* values for factor levels here and elsewhere taken from parameter estimates.

in both word shape levels also show strong evidence of the word shape effect. Looking at the graph of box plots in (7) we can see that the average duration of a CVXC# is longer in a word with another heavy syllable. Each box plot shows the distribution of the duration of a particular syllable shape, broken down further for word shape. Each box plot illustrates the range of the data (with circles representing outliers) the median (horizontal black line), and the distribution of the data into quartiles, where the second and third quartiles, those around the median, are represented by a box, and the first and fourth quartiles are represented by the tails.

(7)



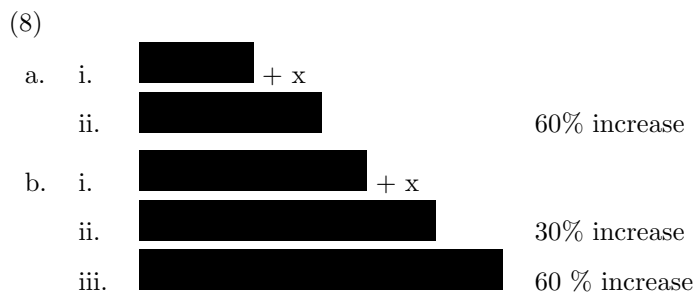
It can be seen from the two CVXC syllable types (CVC: and CV:C) that occurred both in words in which it was the only heavy syllable (words of shape CV.CV.CVXC) and in words with another heavy syllable (one non-final syllable of the shape CVX), that a CVXC is shorter when there are no other heavy syllables in the word. The other notable effect of word shape that is evident from (7) is that CV# is longer when there is only one non-final heavy syllable, and shorter when there are two. This latter difference can be ascribed to the known effect of segment shortening in longer words (Lehiste 1970). The initially-described difference, however, cannot, as CVXC is actually longer in the longer words (those with an additional heavy syllable). I assume that less duration is needed to signal a necessarily-stressed CVXC syllable when there is no other heavy syllable in the word. Likewise, CVXC presumably needs to be longer in a word with another heavy syllable, in order to adequately signal that it is heavy. There is a possibly related finding in Crystal and House (1990) that syllable

duration increases as the proportion of stressed syllables in the run (interpause interval) increases. While the current finding regards syllable weight, rather than stress, the two are related, both in the fact that they often overlap and in that they both typically cause an increase in rime duration. There is some independent evidence, then, that occurring with longer syllables can positively affect the duration of a stressed syllable.

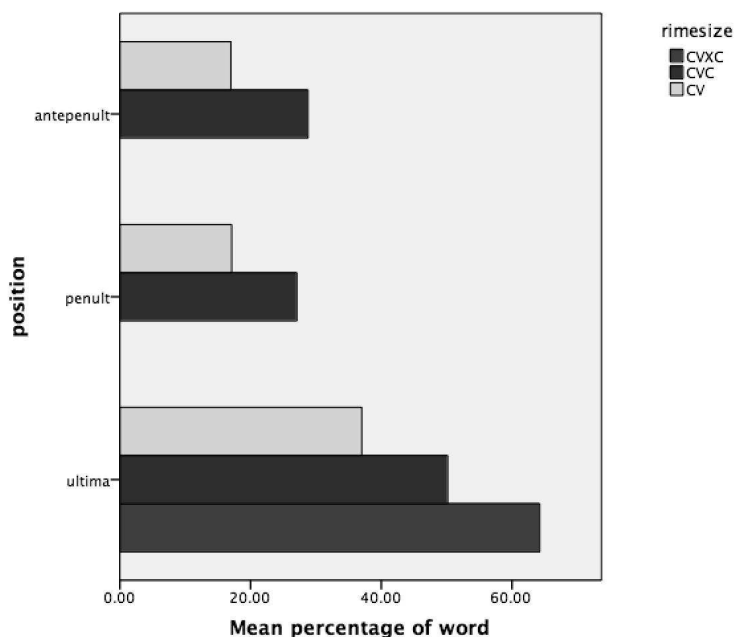
A difficulty with using the raw durations arises because most of the CVXC syllables were the lone heavy syllable in their word, resulting in shorter durations. In the next section I argue for the proportional increase theory of weight, in which a syllable shape is compared to a CV in the same position. Because of the word shape effect found, raw durations do not illustrate it well. In order to control for word shape, as well rate of speech, each syllable rime was divided by the total of the duration of all the rimes in the word. This transformation of the data is discussed further below.

### **3.2 Experiment results with respect to syllable weight**

The experiment results support the proposal that syllable weight is correlated with a minimum increase over a CV syllable in the same position that is consistent across positions. If we visually compare the rime/word percentages in non-final and final position, we see that, proportionally, the difference between V and VC rimes non-finally is paralleled by V and VXC rimes word-finally (diphthongs are argued to group with CVXC syllables word-finally, but are left aside for the moment). The bar graph in (9) compares CV, unstressed CVC, and CVXC syllables across positions. It is preceded by the (modified) general bar graph from §1. Several non-final rime shapes have been omitted in this and some later charts. CVC is used to represent the increase found for heavy syllables non-finally since it is the only heavy shape that can occur unstressed, and thus avoids the confounding durational increase due to stress.



(9) Rime/word percentage by syllable position and size



As was discussed in §1, the same raw increase does not always correspond to the same perceived increase. This is represented generically in (8), where the bars in (a) and the first two bars in (b) are separated by the same raw increase. However, the bars in (a) are more perceptually distinct, both visually, as shown here, and audibly, if heard as sound durations. A very similar pattern is found in (9) with the results from the production experiment with Norwegian speakers. We see that there is a similar raw difference between CV and CVC syllables across positions. However, this similar raw increase does not correspond to a similar perceived increase. Because single-segment rimes are longer in final position than they are non-finally, VC rimes are not perceived to be as durationally distinct in final position as they are non-finally. Rimes with three segments, however, clearly contrast with final single-segment rimes in a way that parallels the CVC contrast with single-segment rimes non-finally.

The basic observation in both (8) and (9) is that a given increase results in a greater perceptual difference at lower/shorter levels and a lesser perceptual difference at higher/longer levels. I suggest that it is this principle of perception that motivates the CVC weight asymmetry. A language is assumed to keep a consistent minimum proportional increase, rather than a minimum raw increase, between CV and a heavy syllable across positions. Although experimental work on the perceptual side remains to be done, this claim fits with what is known of human perception of durations outside of speech.

### 3.2.1 The degree of lengthening found word-finally

Since the argument put forward depends upon the effect of final lengthening, it is worth looking at the effect of final lengthening on different syllable shapes found in this study. Final lengthening is known to chiefly affect the final syllable rime (e.g. Wightman et al. 1992) and to affect segment more strongly the closer it is to the boundary (e.g. Cambier-Langeveld 1997). The degree of the final lengthening effect on different rime shapes, however, is relatively unstudied. The data from the present experiment show that while the raw increase is greater for a larger rime, the proportional increase is smaller. Only data for CV and CVC syllables can be considered since these are the only two rime shapes that occur under the same stress conditions non-finally and word-finally.

(10) Effect of word-final lengthening by syllable shape in ms.<sup>10</sup>

	non-finally	word-finally	raw difference	% difference
CV	74.7	156.41	+82	109%>
CVC	148.32	259.33	+111	75%>

Depending on whether raw increase or magnitude of increase is used, we have a different answer as to whether final lengthening has a greater effect on V or VC rimes. While I have not been able to find work in which the relative effect of final lengthening on different syllable shapes has been explicitly discussed, durational data in Crystal and House 1990 can be used to bear on the question. Their data is taken from the readings of two scripts by six English speakers. They divide the data both by stress level (where primary and secondary stresses are grouped together) and by the presence or absence of a prepausal boundary. The prosodic level of final lengthening is therefore higher than the one being examined as part of the current study so the cases are not fully parallel. Comparisons of the stressed rime durations from these two positions show a greater level of

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<sup>10</sup>Looking at the effect of final lengthening in terms of percentage rimes, the version of the data used generally in this section, we find a similar effect.

(i) Average percentage rimes

	non-finally	word-finally	raw difference	% difference
CV	17.05	37.01	+20	118%>
CVC	27.91	50.16	+22	80%>

both raw increase and of the magnitude of increase: +113ms/87% for V rimes, +83ms/42% for VC rimes.<sup>11</sup> The data in Crystal and House show a surprisingly minimal increase for unstressed V rimes, however: +19ms./27% for V rimes, compared to +53ms./44% for unstressed VC rimes. Although all of the rimes considered in (10) are unstressed, they clearly pattern with the stressed data in Crystal and House with respect to the effect of final lengthening. Pending further work on the relative effect of final lengthening on different syllable shapes I will assume that what was found in this study is compatible with typical relative final lengthening effects.

### 3.2.2 Details of experiment data

The raw and proportional increases of the syllable shapes of particular interest are shown in the tables below. In (11), a comparison of the raw increases is made. Measurements of syllables in the antepenult and penult have been combined since we see an important difference between non-final and word-final positions but not within the non-final positions.

(11) Average rime/word percentages

	non-finally		word-finally
CV	17%		37%
CVC	28%	+11%	50%
CVXC			64%
			+27%

A CVC syllable is approximately 11–13 percent more of the word than a CV syllable, regardless of the position of a syllable. A CVXC syllable represents a much greater increase. A comparison of the proportional increases over the average CV in the same position is made in (12). Each rime-as-percentage-of-word (henceforth “percentage rime”) was divided by the average rime/word percentage for a CV rime in the same position.

(12) Avg. rime/word percentages proportional increase over same-position CV

	non-finally		word-finally
CV			
CVC		64%>	36%>
CVXC			74%>

Non-finally, we see that a heavy (unstressed) syllable is, on average, 64% greater than a non-final CV syllable. Non-final CVC syllables are heavy, so an 64% increase is sufficient to be perceived as substantially greater than a non-final light syllable. Word-finally, syllable sizes fall into a pattern we can now

<sup>11</sup>Rimes that come from a syllable with an onset show an even greater difference: +142ms/108%> for V rimes, +85ms/44%> for VC rimes. Since only entire syllable durations and vowel durations are given, the latter VC measurements were estimated from a bar graph.

interpret. A word-final CVC is only 36% greater than a final CV on average. This falls notably short of the 64% increase we see for a CVC in non-final position. Therefore, while a non-final CVC is substantially greater than a CV in the same position, a final CVC is not. Consequently, CVC naturally patterns as heavy non-finally but as light word-finally, based on the rime’s average proportional increase over a CV in the same position. A final CVXC, on the other hand, is 74% greater than a final CV on average. This is similar to the 64% average increase for a heavy syllable we see non-finally.

The table in (13) gives the average increase over a same-position CV, expanded from (12) to include diphthongs. The CV syllables themselves of course have an average of a 0% increase. Where there is both unstressed and stressed data from a syllable shape the increase of the stressed rimes is given in parentheses.

(13) Avg. rime/word increases over same-position CV by rime

		antepenult	penult	ultima
size	CV	(baseline)	(baseline)	(baseline)
	CVC (CVC)	69% (120%)	58% (149%)	36%
	CVXC	–	–	74%
	CVV	133%	156%	80%

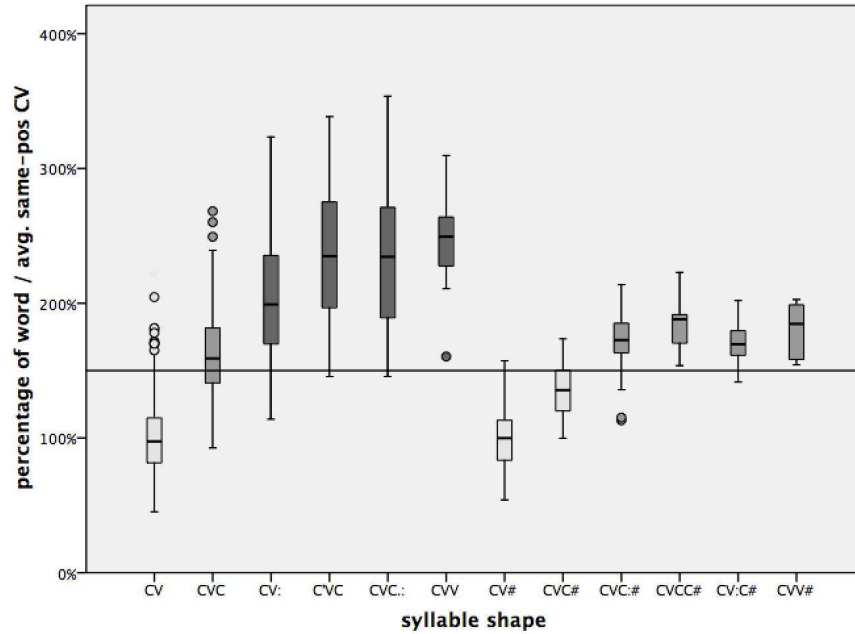
What is striking about (13) is that word-finally, it is in CVXC and CVV rimes that we see a similar increase to what is found non-finally in unstressed CVC rimes. This correlates with the fact that while CVC counts as heavy non-finally, it counts as light word-finally, while rimes with three syllables or with diphthongs count as heavy. Final CVXC syllables are necessarily stressed, and while their average proportional increase is a bit greater than that of an unstressed heavy syllable non-finally, it is less than the average increase of stressed syllables non-finally. This point will be discussed further below.

The distribution of increases for all rimes is shown in the chart of box plots in (14). The grayed boxplots belong to syllable shapes that are categorized as heavy, darker gray indicating syllable shapes that are subject to additional phonetic lengthening under stress. A line has been drawn at the 50% increase mark. Notice that the distribution of light syllable shapes (shown in white) falls almost entirely below it, and the distribution of heavy syllable shapes falls almost entirely above it.<sup>12</sup>

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<sup>12</sup>The same proportional increase distribution can be calculated based on a rime’s raw duration. Each rime’s duration was divided by the average rime duration of a CV in the same position for that subject. As discussed at the end of §3.1, at least some stressed syllables are shorter in words in which they are the only heavy syllable. Including CVXC rimes, as well as CV: rimes, which showed a similar effect, only from word shapes having more than one heavy syllable, we can see the same proportional increase distribution. Note that for the proportional increase of raw rimes, individual speaker’s CV averages were used in order to control for rate of speech. (The overall average was used in calculating the increase of percentage rimes since taking each rime as a percentage of the word also controls for rate of speech).

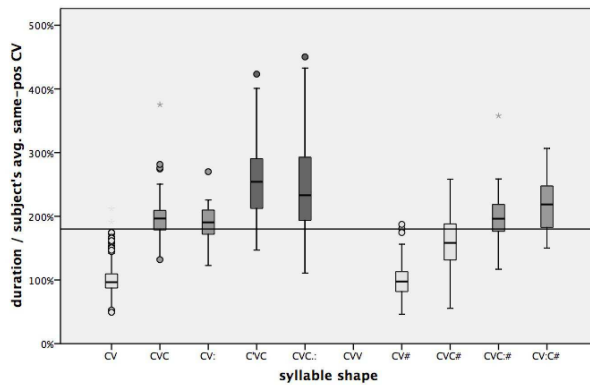
(14)



Here again the parallel proportional increase of heavy syllables over a CV syllable in the same position is clear. Although word-final syllables are a much bigger percentage of their word than non-final syllables are (see (11) above), we see that when compared to the average CV syllable in the same position that word-final syllable rimes behave remarkably similarly to non-final rimes.

One notable difference between non-final and final heavy syllables is that there is a much smaller range for percentage-of-word increase word-finally. This is unsurprising since a CVXC is already quite long due to rime size and final

(i)



lengthening.<sup>13</sup> While there is a heavy syllable shape non-finally that can exist unstressed (CVC), all heavy syllable shapes word-finally are stressed.<sup>14</sup> The increase of the word-final heavy syllables, while greater than the non-final unstressed CVC (collectively 74% greater compared to 64% greater) is still closer to the unstressed non-final CVC than the non-final stressed syllables (with an collective increase of 123%). Nootboom (1997) notes that Klatt (1976) found that there is not much durational increase due to stress word-finally and states that it seems “[final] lengthening has exhausted the ‘stretchability’ of the syllable” (p 663).

The proposed theory of weight has been shown to be motivated by production data from Norwegian. While it seems likely that the CVC asymmetry holds in many other languages for the same reason, this has yet to be borne out by phonetic evidence. Of particular interest would be phonetic data from a language in which CVC is heavy in all positions, as we should then see final CVC syllables rising to a similar proportional increase as found for heavy syllables non-finally.<sup>15</sup> The fact that the usual case seems to be that weight-by-position languages exhibit CVC weight asymmetry (or final syllable extrametricality, rendering the question of final weight moot) leads to the working hypothesis that we should find final CVC syllables falling short of the proportional increase found in heavy syllables non-finally, as was found in Norwegian. While it will be interesting to see if research on other languages that exhibit the CVC weight asymmetry find a similar proportional increase threshold, the expectation is more narrow: that within a language, the increase threshold is the same across all positions of the word.

### 3.2.3 Current proposal in the context of Gordon 1999

In a wide-ranging study of phonetic correlates to syllable weight divisions Gordon (1999) found that languages will draw the line between light and heavy syllables at the largest perceptual energy difference, where “perceptual energy” is a function of rime intensity and duration. Given this finding, we can assume that Norwegian and other weight-by-position languages have the largest perceptual energy difference between CV and CVX. This seems to be consistent

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<sup>13</sup>A smaller increase range word-finally is also found if the raw durations are compared to the average CV duration in that position (see footnote 12): in the antepenultimate position there is a range of 374 percentage points (all syllable shapes), in the penultimate position the range is 386, and in the final position the range is only 312. This cap on the range of ultimate rimes is emphasized when the percentage rimes are used.

<sup>14</sup>The absence of unstressed CVC: and CV:C is explained by the general prohibition against long vowels and geminates outside of the domain of primary stress in the language. There are in fact a few words that have an unstressed CVCC#, such as *ádvēt* (‘advent’) and *hárpiks* (‘sap’). While this study did not include any unstressed CVCC syllables, this would be an interesting and potentially important point to follow up in a future study since being able to compare the proportional increase of an unstressed CVXC to other word-final syllables would assist in teasing apart the effects of rime size versus stress word-finally.

<sup>15</sup>A language brought to my attention by Brett Hyde, Wergaia (Hercus 1986) counts word-final CVC as heavy but seems to be sensitive to syllable weight only in final position.

with the findings here as well, although these were based on duration only.<sup>16</sup> The claim made here is that there is evidence for a consistent weight criterion within a language that is couched in the perceptual reality of Weber’s Law. It is not clear whether the criterion in Gordon’s work would make the right prediction of weight if applied specifically to the word-final position in Norwegian or not. The percentage-of-word increase was found to be about equal between final CV and CVC (36%) and between final CVC and CVXC (38%). Looking at the distribution of the increases in (14) it can be seen that word-final CVC falls between that of CV and CVXC syllables. (Looking at the distribution of the increase in raw duration (illustrated in footnote 12) we find a similar placement of final CVC syllables.) The proposal of a minimum proportional increase, applied to all positions in the word, is consistent with these findings, and can correctly predict that a final CVC acts as light since it fails to reach the threshold increase.

### 3.3 The categorization of syllable weight

Weight is assumed to be assigned to a particular syllable shape in a particular position based on that syllable shape’s average proportional increase over a CV syllable in the same position. It has been found that heavy syllables both non-finally and word-finally are typically at least 50% greater than the average CV syllable in the same position.<sup>17</sup> This consistent criterion for syllable weight is markedly different from the traditional account that assumed a uniform CVC syllable weight in conjunction with the possibility of final consonant extrametricality.

The average increase in each syllable shape is given in (15). All of the increases for syllables that count as heavy are in gray (light and dark).

(15) Avg. proportional increases by shape, position, and stress

	non-final		final
	$\acute{\sigma}$	$\acute{\sigma}$	
CV		–	–
CV:		102%	NA
CVC	64%	133%	36%
CVC.:		132%	NA
CVV		146%	80%
CVC:	NA		73%
CVCC	NA		84%
CV:C	NA		70%

There are four stressed syllable shapes non-finally and word-finally. While all heavy syllables word-finally show a similar increase, non-finally we see CV: falling

<sup>16</sup>Measurements that factored in syllable intensity were examined and found not to notably vary the distribution from what is seen by considering only the duration. The decision was made to use the duration-only measurements in the interest of simplicity.

<sup>17</sup>The 50% minimum increase refers to the increase for percentage-rimes. The raw durational increase seems to be around 80%, as can be seen in the chart of box plots in footnote 12.

short of stressed CVC, geminates, and diphthongs (CVC, CVC:, CVV). (This is true, too, in the duration-increase chart in footnote 12, where in fact long vowels have about the same increase as unstressed CVC syllables.) I would like to raise two possible hypotheses for the contrast in proportional increase among non-final syllables. One is that, in addition to the proportional increase over CV in order to meet the weight requirement, stressed syllables are required to contrast with unstressed syllables of the same shape. Thus, a CV: has a lower proportional increase because it contrasts with a CV, but a CVC contrasts with a CVC, a syllable shape that is already heavy, and so additional length would be required in order to make the stress levels contrast. The alternative hypothesis is that phonetic lengthening under stress applies only to syllables that were “underlyingly heavy” and this phonetic lengthening is not crucial in the sense that it is in the first hypothesis.

A way to differentiate these theories is look at the proportional increase of CV: syllables in known words. The data reflected in (15) comes from pronunciations of novel words and so long vowels are assumed to arise when a syllable would otherwise surface as light and stressed, but known words would be subject to lexicon optimization (Prince and Smolensky 1993), meaning that any long vowels in the surface form would be stored underlyingly. A study of this kind has not been undertaken but a mini-pilot was done in which a native speaker read sentences that each had a real Norwegian noun in a controlled position (neither phrase-final nor sentence-final). It was found that a non-final [í:] was 132% greater than [i] in the same position and a non-final [á:] was 146% greater than [ã] in the same position.<sup>18</sup> These numbers seem to pattern with those reported for stressed CVC syllables in (15), rather than with stressed CV: syllables. If we believe that the difference lies in whether or not the long vowel was underlyingly present then the second hypothesis put forward is supported. While further research is needed, I will assume that phonetic lengthening under stress is not crucially necessary to distinguish stressed syllables. The fact that non-final CVC: syllables (those closed with a geminate), but not CV: syllables, have a proportional increase similar to non-geminate CVC syllables supports the position taken in §1.1 that geminates are present underlyingly and that vowel lengthening is the default method of syllable augmentation.

A final long vowel in an open syllable is listed as non-occurring, however, we do find some final stressed CV syllables in some monosyllabic words (e.g. *fã* ‘get’, *by* ‘city’) and in some French and Greek loan words (e.g. *kopí* ‘copy’, *obó* ‘oboe’). Although these are usually transcribed as long vowels, I suggest that it is not clear whether final stressed CV syllables have a long or short vowel because it is difficult to perceive vowel length contrasts word-finally. I have not undertaken a perception study of final vowel length with Norwegian speakers, but in informally asking native speakers, who are normally conscious of vowel length, I have found that they were in fact unsure whether final stressed vowels (as in *fã* and *obo*) were long or short. This is consistent with the fact that many

<sup>18</sup>The words that measured [i] were *tulipán*, *dómino*, and *albino*, said twice each. Measurements of [ã] were taken from *papáya*, *páprika*, and *ánanas*, said twice each.

languages with phonemic vowel length neutralize it in final position because final lengthening, as well as the tendency to partially devoice word-final segments, make a contrast difficult to perceive (Myers and Hansen 2007). If there is no perceived vowel length difference word-finally it explains why we do not find final stressed vowels patterning as heavy: additional word-final vowel length is not parsed as a phonologically long vowel. So while a final stressed CV(:) may well surpass the proportional increase threshold, a durationally long word-final vowel is too blurred by final lengthening and possibly by final devoicing to be perceived as distinct from a final CV. A final CVV does not fall victim to this perceptual problem because the change in vowel quality signals its phonological content. Assuming final shortening, we should treat a final stressed CV as a violation of the prohibition against stressed light syllables in Norwegian.

From the viewpoint of OT, there is no reason to think that a speaker considers candidates that reflect the incorrect weight for a syllable. The categorization of syllable weight, based on the proportional increase threshold, is taken to be encoded on GEN.

This proposed weight criterion determines the weight of a particular syllable shape for the rime, percolated to the syllable, as a whole. This is a departure from the standard assumption that moras are prosodic entities linked to independent segments. The proportional increase theory of weight relies on rime duration (which is linked to the rime’s segmental content), rather than purely on the phonological make-up of the rime. Word-finally, the presence of a final consonant must differentiate a CV from a CVC. However, it is argued that it is the relative proportional increase of the rime that is crucial for its weight classification, a proposal which is supported by the parallel minimum proportional increase for heavy syllables found across positions. The consequences of the proposed theory of weight for moraic theory are discussed in the following section. I argue that the view of segmentally-associated moras is problematic and outline a syllable structure that is consistent with the proposed theory of weight and is independently motivated.

## 4 Consequences for moraic theory

The proposed weight criterion takes moras to be associated at the level of the syllable, rather at the level of the segment. Where CVC weight asymmetry is a problem for standard moraic theory (Hyman 1985, McCarthy and Prince 1986, Hayes 1989), the proposed weight criterion accounts for the asymmetry. Taking moras to be units of syllable weight retains the core claims of moraic theory, outlined in (16).

(16) Classical moraic theory (originated in classical Latin and Greek metrics)

1. **Binarity:** There is a binary distinction between light and heavy syllables.
2. **Quantity sensitivity:** Prosodic processes are sensitive to syllable weight, not to segments.

3. **Moraic equivalence:** Syllables of different shapes but belonging to the same weight class pattern together.

Accepting the proposed weight criterion means rejecting the additional claims made by standard moraic theory.

- (17) Standard moraic theory (Hyman 1985, McCarthy and Prince 1986, Hayes 1989)

1. **Moraic status:** Weight-bearing segments are associated with a mora.
2. **Moraic distinction:** Segment length is encoded by moraic association.

Rejecting segmentally-associated moras affects both the claims in (17), as if the first claim does not hold then there can be no distinction made between segments on the basis of whether or not they are associated with a mora. I consider these claims in turn.

Taking moras to be associated with individual segments does not always lead to the correct prediction of syllable weight. The CVC weight asymmetry is a case in point. While segmentally-associated moras have been taken to be a unit of tone association (e.g. Hyman 1985), Zhang (2002, 2004) has demonstrated that tone association does not match up to the mora count of a syllable, even in languages in which tones had been thought to associate with individual moras. He shows, for example, that contour tones are allowed on syllable shapes word final syllables that are not able to bear contour tones non-finally. This cannot be due to additional moras in final position and so must be due to the additional length in final position due to final lengthening which enables more tones to occur on the syllable. Zhang therefore argues that tones are sensitive to the phonetic duration of a syllable and that the mora is not an appropriate unit for tone association. Given this finding, we are not able to assume that moras are associated directly to segments without significant repairs and exceptions to the system.

The classic argument for segmentally-associated moras is due to Hayes (1989), who shows that X slot theory (Clements and Keyser 1983, Levin 1985) fails to correctly predict compensatory lengthening. Under the analysis presented by Hayes, when a coda consonant associated with a mora deletes, the preceding vowel will associate to the mora that was left behind. Thus lengthening is motivated by mora preservation and explains why we do not find lengthening in response to onset deletion. Given the proposed weight criterion that assigns weight to syllables, it is possible to view processes of compensatory lengthening as faithfulness to syllabic weight. A vowel may lengthen in the face of coda deletion in order to preserve the weight of the syllable as a whole, rather than to preserve a particular mora. (Also see Kavitskaya 2002 for phonetic accounts of compensatory lengthening that cast doubt on an auto-segmental analysis of weight.)

The assumption under standard moraic theory that geminates are consonants with an underlying mora, as shown in (18), is also independently problematic.

(18) A geminate in moraic theory

$$\begin{array}{c} \mu \\ | \\ C \end{array}$$

Under this assumption, which I will refer to as the geminate-weight hypothesis, length is a consequence of weight.<sup>19</sup> A moraic consonant is not necessarily long, however, and will only be realized as a geminate if the following syllable requires an onset.

There are multiple reasons to think that geminates should be represented with underlyingly length. First, their representation in standard moraic theory relegates phonological length to a reflex of their moraic status and the constraint ONSET (which requires syllables to be consonant-initial). This denies geminates inherent length, although duration is the primary perceptual distinction between geminates and singleton consonants (Lahiri and Hankamer 1988, Hankamer et al. 1989, Abramson 1999). Secondly, the representation of initial and final geminates is problematic for standard moraic theory, since even if the segment is weight-contributing there is nothing to force consonantal length (gemination).<sup>20</sup> Finally, it is problematic that the geminate-weight hypothesis predicts that syllables with geminates must be heavy. Vago (1992) and Ringen and Vago (2002) discuss cases where geminates pattern with consonant clusters rather than with (other) moraic segments with respect to quantity sensitive processes. Selkirk (1990) and Tranel (1991) express skepticism of the geminate-weight hypothesis prediction that all geminate codas are weight-contributing, especially in languages where CVC is light. Although Davis (1994), for example, presents two languages, Hindi and Korean, in which CVC syllables are light but syllables closed by geminates are heavy, Curtis (2003) shows that these data are subject to reanalysis. Curtis, after an extensive study of geminates and language systems that have geminates, concludes that geminates must be represented with inherent length.

The geminate-weight hypothesis is consistent with the principle of lexical minimality, a tenet of underspecification theory (Stanley 1967, Chomsky and Halle 1968, Archangeli 1988, et al.).<sup>21</sup> Lexical minimality assumes that only the minimum phonological information necessary to distinguish words is present underlyingly. Other features are predictable and so do not need to be specified

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<sup>19</sup>Ham (2001) found that coda geminates are longer than onset geminates. This is taken by Cohn (2003) as phonetic evidence for the mora as a segmental unit of weight. However, it may also be attributed to a difference between the phonetic realization of segments that contribute to syllable weight and those that do not.

<sup>20</sup>The geminate-weight hypothesis also fails to predict some medial geminates. For example, there is no reason for gemination in Italian *febbre* ('fever'), since [b] is not forced to geminate to satisfy ONSET. The geminate-weight hypothesis predicts that we should find syllabification contrasts like hypothetical *feb.re* and *fe.bre*, based on whether or not [b] is moraic. It is well-known that languages do not contrast syllabification and so this prediction is not borne out. (Thanks to Armin Mester for pointing out this problem for the geminate-weight hypothesis.)

<sup>21</sup>I thank Armin Mester for pointing out the connection between the geminate-weight hypothesis and underspecification theory.

underlyingly, although they are present in the surface form (principle of full specification). Thus, geminates are minimally specified as mora-bearing, and their length is assumed to be derivable. However, underspecification has lost its power within OT as there are no phonological conditions on inputs (the principle of richness of the base entails that the grammar must be able to deal with fully specified inputs). Smolensky (1993) shows many processes that had previously been analyzed with reference to underspecification can be reanalyzed within OT with markedness constraints playing the crucial role. Inkelas (1994) and Artstein (1998) show that, given the structure of OT, an output cannot be more marked than its input. It can be as marked, where markedness in the input is preserved due to faithfulness constraints, or it can be less marked, due to markedness constraints. This means that underspecification is usually not useful since it can only be assumed for alternations of unmarked structure. Given the representation of a geminate as an underlyingly mora-bearing consonant, the constraint ONSET is relied on to force phonological length on the surface. However, if the markedness constraint against long segments/geminates is ranked above ONSET, the predicted lengthening will not occur. This is shown in (19). (The constraint MAXLINK $\mu$  (Morén 1999) requires that underlying segmental links to moras must be preserved.) The notation in candidate (c) represents consonantal length, split across two syllables.

(19)

	/CVC $\mu$ V/	MAXLINK $\mu$	*GEMINATE/*LONG	ONSET
☞ a.	CVC $\mu$ .V			*!
b.	CV.CV	*!		
c.	CVC $\mu$ .:V		*	

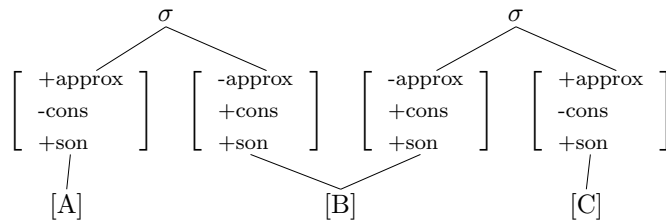
Under this ranking, the cross-linguistically dispreferred form, candidate (a), is in fact optimal. This is a problem, since an intervocalic consonant is always syllabified as an onset, not a coda. In fact, one of Hyman's (1985) motivations for moraic structure was to prevent such a form from being predicted. We see from (19), however, that an intervocalic moraic consonant is not always forced to geminate in OT.

Segments themselves already denote singleton length, and two identical segments in a row will result in a phonologically long segment. The assumption that segments have inherent (singleton) length must be assumed under standard moraic theory as weightless consonants, such as onsets, must have (singleton) length. A onset cluster, as a sequence of two weightless segments, will be longer than a single onset consonant. If there were two adjacent identical segments such a sequence would be realized (with no further assumptions) as a long vowel or a geminate.

A segment's features are assumed to be headed by a root node which contains the major class features (Schein and Steriade 1986, McCarthy 1988). It is usually assumed that adjacent identical segments are marked, and that adjacent segments with the same value of a feature will share that feature. I therefore borrow from Selkirk (1990) the idea that adjacent identical root nodes may oc-

cur, and, when they share all other features, represent a long vowel or geminate. This idea has seen a recent revival in the literature (see, for example, Ringen and Vago 2002 and Curtis 2003). My proposal differs from Selkirk’s because I do not also assume a moraic tier. This is shown in (20) for a sonorant geminate, but represents the assumed structure of phonological length generally. Capital letters represent all features below the root node.

(20) Compositional representation of length



The representation of length illustrated above is consistent with the standard assumptions that, first, a sequence of two segments is longer than a single segment, and secondly, that adjacent identical features are shared. The root nodes are not assumed to have any prosodic status. On the (standardly necessary, but generally unspoken) assumption that every segment, headed by a root node, contributes length, the compositional representation of length allows us to capture long vowels and geminates.

It was shown in (19) that the geminate-weight hypothesis incorrectly predicts that an intervocalic moraic consonant may surface as only a coda. The proposed representational theory of length instead predicts that such a candidate will never surface, as it can be seen in (21) to be harmonically bounded. Generic ‘C’ and ‘V’ are used to represent consonantal and vocalic root nodes. Further features, where relevant, are again represented by capital letters.

(21) CVC.C parsing harmonically bounded

	/C V C C V/		MAX	*GEMINATE/*LONG	ONSET
	[A] [A]				
a.	CVC.V		*		*!
b.	CV.CV		*		
c.	C V C C V	[A]		*	

Because candidate (a) incurs more violations than the other candidates it will never surface, regardless of the constraint ranking, a desirable theoretical result.

I have shown that the additional tenets of standard moraic theory are problematic and that the insights moraic theory seeks to capture may be captured, in some cases more successfully, by taking moras to be associated with syllables rather than with segments.

## 5 NonFinality revisited

The proportional increase theory of weight has been shown to account for the CVC weight asymmetry. The fact that some languages treat CVC as light word-finally and CVXC as heavy in this position is explained by the need for additional length to set a heavy syllable apart from a light one in the domain of word-final lengthening. This recasts the CVC weight asymmetry entirely, and means that NONFINALITY is ill-suited to motivate it because it misses the interplay of duration and weight that causes the asymmetry. Final-consonant extrametricality is only one kind of NONFINALITY effect, however. I discuss some shortcomings of NONFINALITY and propose that the effects of NONFINALITY can be at least understood as, if not reanalyzed as, perceptual consequences of final lengthening.

### 5.1 Issues with NonFinality

The constraint NONFINALITY was formulated by Prince and Smolensky (1993, p. 52) so that OT could account for phenomena previously analyzed by extrametricality. Rather than mandating material be set off from (lower) prosodic structure, as extrametricality did, NONFINALITY requires that the head foot not be word-final. Prince and Smolensky's definition is given in (22).

(22) NONFINALITY: No head of PrWd [prosodic word] is final in PrWd

Languages previously analyzed with final syllable or final foot extrametricality are recast in OT as cases where stress minimality violates RIGHTMOST (which requires the head foot to be aligned to the right edge of the prosodic word) in order to satisfy higher-ranked NONFINALITY. Cases of final-consonant extrametricality also satisfy NONFINALITY at the cost of violating RIGHTMOST but require the additional stipulation that the language allows a final consonant appendix. By setting the final consonant prosodically off from the final syllable, stress is able to fall closer to the right edge of the word (on the final syllable) while still not being final (as there is a further consonant appendix).

While this descriptively motivates stress falling as rightward as possible without being word-final, it does not explain the value of this stress pattern. A possible explanation for NONFINALITY is that it avoids stress clash at the phrasal level (Karvonen 2005). However, final stress in polysyllabic words also results in alternating stress. NONFINALITY will only prevent words of at least three syllables from clashing with a preceding or following stress.<sup>22</sup> Given that shorter words are generally common, clash avoidance is a suspect motivation for NONFINALITY effects. Further, stress clash avoidance cannot be a motivation for final consonant extrametricality since a final superheavy syllable is pronounced as a single syllable and so clash with a following stress will still occur.

The OT analysis of final consonant extrametricality is particularly troubling because we must assume that all languages traditionally analyzed with final

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<sup>22</sup>I want to thank Jaye Padgett for drawing this to my attention.

consonant extrametricality in fact allow a final appendix. This is suspicious if the weight asymmetry is the only evidence that a language allows an appendix. Further, if the idea behind final consonant extrametricality in OT is to allow stress to fall on the final syllable while buffering the stressed syllable from the right edge of the word, then we would expect to find languages that also allowed the second part of long vowels or diphthongs to be extrametrical. The lack of clear cases employing final-mora extrametricality, therefore is unexpected. Further, to my knowledge, final-vowel extrametricality, a logical possibility, has never been proposed to exist.

Gordon (2000) gives a case in which an extrametricality/NONFINALITY account fails. Languages like Chickasaw and Klamath allow CV:C, but not CVCC, to be stressed word finally, despite the fact that syllables closed with a consonant are treated as heavy in non-final position. This is a finer distinction than final consonant extrametricality or NONFINALITY is able to make.

The proposed theory of the CVC weight asymmetry does not have these problems because vowels are generally longer than consonants. Therefore a language with consistent CVC weight across positions and a CVV weight asymmetry is predicted not to exist. It is also not surprising to see final diphthongs (or long vowels) patterning as heavy word-finally when CVC fails to do so. It is also compatible with a language classifying final CV:C as heavy but CVCC as light, assuming the former rime to be longer than the latter, and with the prediction that while the increase of CV:C over a final CV will parallel that of CVC over CV non-finally, the increase of CVCC will fail to do so.

Hayes (1995) identifies three kinds of extrametricality: final consonant, final syllable, and final foot. Only prosodic constituents may be extrametrical (leaving the absence of final-vowel and final-mora extrametricality, as addressed above, unexplained). Further, while the right edge is taken to be the unmarked edge, extrametricality in theory is possible on either the left or right periphery but in practice proposed almost exclusively for the right.

While final lengthening affects the rime of the final syllable, initial lengthening has been found to usually affect only the initial consonant in CV-initial words (e.g. Oller 1973). Thus the current proposal predicts that extrametricality effects should be confined to the right edge.

I have shown that the CVC weight asymmetry can be explained without an appeal to NONFINALITY. Further, it can be predicted to occur (or not) in a language, given the relative proportional increases of the rimes, whereas no independent prediction for NONFINALITY is known. I suggest that taking final lengthening into account motivates the other effects of NONFINALITY as well.

### 5.1.1 Final syllable extrametricality

There are several reasons why the final position is not a perceptually good place for stress. If an increase in phonetic duration is an important cue for stress in a language (Fry 1955, 1958), placing the stressed syllable in a position that is already subject to phonetic lengthening will make it hard for speakers to perceive the increase due to stress. The fact that final syllables are subject to word-final

devoicing also suggests that length is not well perceived in final position (Myers and Hansen 2007). Thus final stress avoidance is due to the final syllable being a poor place to perceive stress, rather than due to an avoidance of final stress per se. This account makes the prediction that languages in which phonetic duration is not a strong perceptual correlate of stress would be less likely to avoid placing stress on the final syllable. A crucial distinction must be made between phonetic length due to final lengthening and phonological length due to segmental content. While the latter is known to attract stress, I propose that causes of segmental lengthening (final lengthening, stress) do not fare well when they converge.

It is possible that final stress is avoided for different reasons in different languages. In Norwegian, where the requirement that stressed syllables be heavy makes it clear that duration is a major correlate of stress, we find the requirement of extra length word-finally to maintain a consistent light-heavy distinction. Gordon (2000) proposes that final stress is avoided in Chickasaw and Klamath on all but CV:C syllables because a long vowel is needed to host the contour tone resulting from the high pitch associated with stress falling on the same syllable as the low tone due to a prosodic phrase boundary. This theory of final stress avoidance proposes that a phrase-final issue is generalized to all word-final syllables. Thus languages may have one or more reasons to avoid or limit final stress.

### 5.1.2 Final foot extrametricality

Consideration of word-final lengthening may also motivate final foot extrametricality. Palestinian Arabic is analyzed with final foot extrametricality by Hayes 1995, as shown in (23).

- (23) Stress on CV.CV.CV-final words in Palestinian Arabic (Hayes 1995, p. 127)
- a. (C<sup>́</sup>V.CV).<(CV.CV)>
  - b. (CVC).(C<sup>́</sup>V.CV).CV
  - c. (CV.CV).(C<sup>́</sup>V.CV).CV

If the stress were on the final syllable in (23-a), it would violate NONFINALITY, as the head foot is final in the prosodic word. The avoidance of stress on the final foot can also be motivated by considering the effect of final lengthening. While I do not have data from Palestinian Arabic, Ahn (2000) conducted studies in Jordanian Arabic, which shows a clear effect of final lengthening.

- (24) Average vowel duration in Jordanian Arabic (Ahn 2000:118)

	Antepenult	Penult	Final
Stressed CV:	127 ms.	137 ms.	173 ms.
Unstressed CVC	46 ms.	51 ms.	73 ms.
Unstressed CV	57 ms.	65 ms.	81 ms.

Given final lengthening, a final (C<sup>́</sup>V.CV) is a bad trochee. While a true (LH) trochee violates WEIGHT-TO-STRESS “If heavy then stressed” (Prince 1990) a final CV is only phonetically long. A COINCIDE constraint (following the format of Zoll 1996) is proposed in (25) that references phonetic length in a general way. Given left-to-right footing, (25) makes the correct predication that stress is pre-antepenultimate in CV.CV.CV.CV words.

- (25) CONCIIDE(PROMINENCE, FOOTHEAD): Any prominence (weight, duration, pitch) must coincide with the head of the foot.

However, the penult is a common place for stress in trochaic languages (e.g. Cavineña, Djingili, Piro, Warao (Hayes 1995)), suggesting it is not as bad as a true (LH) trochee. In these cases, we can assume the ranking RIGHTMOST  $\gg$  CONCIIDE(PROMINENCE, FOOTHEAD). Alternatively, we might find that word-level final-lengthening is minimal in such languages, or that duration is not a strong cue to stress, resulting in the non-violation of CONCIIDE(PROMINENCE, FOOTHEAD) by a final trochee.

### 5.1.3 Language strategies

I have suggested perceptual motivations for the NONFINALITY effects at the segment, syllable, and foot levels. A syllable shape that is heavy non-finally may fall short of the minimum proportional increase over a CV when in word-final position, as has been shown for Norwegian. In order to maintain a weight contrast in word-final position, then, such a language must allow a bigger syllable rime word-finally. Although there are exceptions (e.g. Hindi, Estonian), it is common for languages exhibiting the CVC weight asymmetry to only allow CVXC syllables word-finally. This is explained if we assume that it is a marked rime size, generally disallowed, but permitted in final position in order to maintain a weight contrast. Word-level final lengthening will make it more difficult to perceive final stress in a language in which duration is a major cue to stress. Such a language may chose to eschew final stress altogether, the situation analyzed classically as final syllable extrametricality. Languages may also avoid a final disyllabic trochee since final lengthening splits the prominence of the foot.

## 6 Conclusion

The proportional increase theory of weight has been proposed as a weight-determining criterion and shown to correctly predict syllable weight in Norwegian. The weight of a given syllable shape in a particular position is determined based on the relationship between of the syllable’s rime and that of a CV syllable in the same position. If the proportional increase of a syllable does not regularly reach the minimum increase threshold then the syllable is categorized as light. This weight-determining algorithm accounts naturally for the CVC weight asymmetry. A non-final CVC was shown to surpass the proportional increase threshold, whereas a final CVC fell notably short of it. This difference is due to the fact

that a final CV is markedly longer due to final lengthening. Therefore, additional length is needed in order for a rime's duration to contrast sufficiently with that of a final CV.

The proposed theory of weight has been argued to be superior to the approach taken within standard moraic theory, which assumes segmentally-associated moras and final consonant extrametricality. The proposed weight criterion is perceptually motivated and does not need to single out the final position. While the effectiveness of the proportional increase theory of weight needs to be investigated for other languages traditionally analyzed with final consonant extrametricality, the results shown for Norwegian are very promising.

It is a consequence of the proportional increase theory of weight that moras must be taken to be properties of syllables, rather than of individual segments. While this is not at odds with the tenets and insights of classical moraic theory, it is inconsistent with standard moraic theory since there is no longer a moraic tier. I have argued that there are problems with taking moras to be associated with segments, especially with respect to the geminate-weight hypothesis, and that the proposed view of moras is compatible with phonological theory.

Taking into account that a word-final syllable will be subject to final lengthening allows us to perceptually motivate the avoidance of stress on final syllables and feet. The influence of final lengthening on perception explains why stress assignment behaves differently in word-final position, thus motivating the surface facts that extrametricality and NONFINALITY have been formulated to describe.

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