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Vocalic segments and the phonetic basis of weight in Norwegian

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Abstract. This paper revisits and expands on previous analyses of Norwegian syllable weight (Lunden 2006, 2013) and different rime shapes' ability to draw stress. A production study was run to examine the durationally-based weight categorization of all possible Norwegian rime shapes in non-final and word-final positions. Specific attention is given to the behavior of word-final long vowels in open syllables, which may occur in the language but are relatively uncommon. Evidence regarding different rime shapes' ability to draw stress is shown through the results of a perception study which probed listeners' preference for penultimate versus final stress with different rime shape combinations, including those which would result in a word-final long vowel if stressed. These preferences are compared to the results of a Maximum Entropy Model (Goldwater et al. 2003) of Norwegian stress assignment based on a corpus of loan words. We conclude that final long vowels are in fact phonologically heavy, and while they are relatively rare in the lexicon of Norwegian, native speakers tolerate them surprisingly well.

Keywords. stress; Norwegian; MaxEnt; syllable weight

1. Introduction. Norwegian shows a typical, binary weight distinction where coda consonants contribute weight. Syllables bearing primary stress must be heavy. Both long vowels and geminates occur, but only in primary-stressed syllables. Following Lunden (2006) and Rice (2006), we assume geminate consonants, when they occur, are present underlyingly (e.g. [hák.kə] 'pickaxe'), and that long vowels result when a syllable that receives primary stress would otherwise be light (e.g. [há:.kə] 'chin'). All rime shapes bigger than a single short vowel are heavy in non-final positions, but VC rimes behave as light word-finally, as evident from the fact that they require long vowels if stressed ([tʉ.li.pá:n] 'tulip,' *[tu.li.pán]). A final CVCC syllable may bear primary stress without undergoing vowel lengthening (e.g. [ɛ.li.fánt] 'elephant').

Hogoboom (Lunden 2006) argues that stress is assigned to the rightmost syllable that is or can be made heavy. This metric requires that a long vowel in a final open syllable (V:#) be light. However, such long vowels do occur, stressed, in a minority of loan words (e.g. [kɑ.fé:] 'coffee', [de.bú:] 'debut').

This paper investigates the weight status of long vowels in final open syllables. Either (i) they are heavy and the analysis that the rightmost syllable is stressed if possible must be revisited or (ii) they are light and are an exception to the general requirement in Norwegian that a primary-stressed syllable must be heavy. The fact that they can bear primary stress would indicate that they are heavy; but, if they were, we might expect that stress would be placed on a final CV syllable more frequency than it is. We investigate the weight of these rimes by first looking at the phonetic evidence from relative duration in §2, then turning to evidence from listener preferences

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for stress placement in nonce words in §3, and finally by modeling the likelihood of stress placements for words of different shapes in the lexicon in §4.

2. Production study. Previous work on Norwegian weight by Hogoboom (Lunden 2006, 2013) established a link between the weight of a syllable's rime and its average proportional increase over a short vowel in the same position of the word.[1] That is, she proposes that there is a direct connection between rime duration and weight, and, moreover, while the criterion for being heavy is consistent for all positions in a word, the key component is a comparison in duration with a short vowel in the same position. Because a word-final short vowel is inherently longer due to final lengthening, meeting the proportional increase threshold word-finally requires substantially more raw duration than required non-finally to meet the same threshold.

Hogoboom's previous work (Lunden 2013) examined the common rime shapes found in Norwegian, plus diphthongs. Long vowels in final open syllables were not tested. The measurements came from speakers' productions of three-syllable nonce words, read in carrier phrases. Nonce words were printed with capital letters to indicate target stress, although the data included rime durations from all fluently-pronounced words, coded for the pronounced stress. We want to ask whether a long vowel in a final open syllable would meet the proportional increase threshold; that is, is there evidence, beyond the fact that long vowels can occur under stress in this position, that a long vowel in a final open syllable is heavy?

We ran a production study with 12 native Norwegian speakers (aged 43–80, mean age=59; 3 female, 9 male) who were recruited online. They recorded themselves reading question/answer pairs that included 40 target words. These were real, two-syllable Norwegian words which were chosen to exhibit all possible rime shapes in non-final and word-final position. Loan words were used because native Norwegian words have very limited rime shapes (Kristoffersen 2000). The rime shapes and words they came in are given in the appendix. We attempted to have at least three instances of each rime shape in each position, however, certain syllable shapes have only a handful of examples in the lexicon. For instance, we were only able to find one word, *essay* which had an unstressed word-final diphthong. Other words turned out not to be well-known enough for the stress to be consistent (e.g. *boikott* 'boycott,', *kautel* 'caution'). See the appendix for a complete word list.

Target words were randomized into 20 question/answer pairs, and the target rime was measured in both pronunciations of the word. An example question/answer pair is shown in (1).

(1) Sample question/answer

Q Hvilken _ undersøkte søsteren din
which _ investigated sister yours
"Which _ did your sister investigate?

A Min søster undersøkte en _ som løp inn i buskene
my sister investigated a _ that ran in bushes-the
"My sister investigated a _ that ran into the bushes"

One speaker paused after every target word and another often paused but always had phrase-final intonation on the target word and so both participants were excluded. Target rimes were delineated starting from the onset of the vowel based on the waveform in conjunction with the

[1] This weight criterion has also been found to hold in English (Lunden 2011), Egyptian Arabic, and Karbardian (Gordon et al. 2010).

spectrogram to the end of the articulation of the rime, up until the release of a word-final stop, if present. Rime durations were extracted using a Praat (Boersma & Weenink 2022) script (Lennes 2003). For each speaker, the average short full vowel in each of the two positions (initial, final) was calculated. Each rime duration was then calculated as a proportion of that speaker's average short full vowel in the same position. During the exploratory phase, it was found that word-final schwas were notably shorter than other word-final vowels and so these were excluded from the short vowel average.[2] The proportional increases for each rime shape are shown in figure 1.

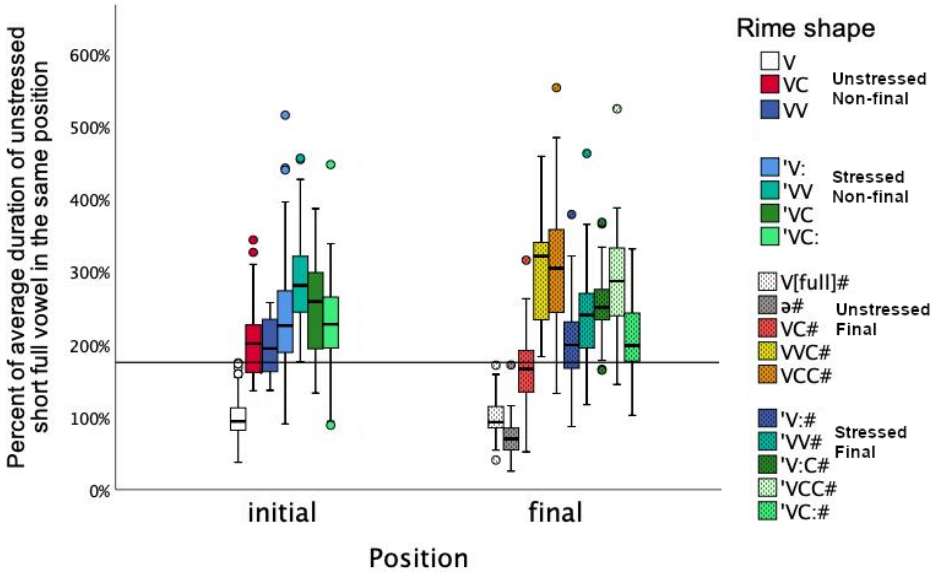

Figure 1. Proportional increase of rime shapes over a short, full vowel in the same position of the word

There was a clear threshold, shown by the horizontal line at 170% duration, at which all known heavy and light syllable shapes were above or below depending on their weight status.

We continue to see the different categorization of unstressed VC rimes that was found in previous work with nonce words. In non-final position, nearly 75% of these rimes are above the rough cut for the proportional increase threshold, whereas word-finally more than 50% are below it. We also see a much lower distribution of the bottom 25% of final VC rimes. The fact that the proportional increase of an average final VC rime is lower than that of an average non-final VC rime is in line with the fact that VC behaves as a heavy rime does non-finally (i.e. can be stressed without augmentation) and as a light rime does word-finally (i.e. cannot bear stress without augmentation).

All non-final rime shapes, other than a short vowel, meet the proportional increase threshold, and indeed, all pattern as heavy in the language. Word-finally, we see that all but short vowels in open syllables and VC rimes are regularly above the threshold, which also reflects the heavy/light split accurately.

Looking specifically at our particular rime shape of interest, we see that final long vowels clearly pattern with heavy syllables. Thus, we can conclude that final long vowels are in-

[2] Lunden (2018) also found notably final schwas to be notably shorter than final full vowels.

deed heavy. This would appear to make it difficult to maintain Hogoboom's previously proposed stress-assignment metric that primary stress is placed on the rightmost syllable that is or can be made heavy. Given that a final long vowel is heavy, every word's final syllable could be made heavy. Either the proposed stress assignment algorithm is incorrect, or it can be maintained but there must be another factor in play that accounts for the relative scarcity of stressed final long vowels in open syllables.

In order to probe whether Norwegian speakers have a preference for stressing the final over the penult we now turn to a perception study which is set up to look at preferred stress placement before turning to a comparison between that study's results and the patterns in the lexicon.

3. Perception study. In order to test Norwegian speakers' preference for penultimate versus final stress placement given different rime shapes, a perception study was run in which listeners chose one of two spoken stress placements on a nonce word as more Norwegian-like.

Five word shapes were used, where three were set up to see how a final /CVC/ fares against various penultimate syllable shapes that might "lure" the stress to the left. Another had /CV/ syllables in both positions, to compare listeners' preferences for the more commonly-found penultimate stress on such words or the less commonly-found final stress. Two word shapes included diphthongs: one with a diphthong in the final position and one with it in the penult (and a final /CVC/). It is hard to determine the stress-drawing behavior of diphthongs in Norwegian as relatively few actual Norwegian words with a word-final diphthong are polysyllabic.

Twenty-eight native Norwegian speakers (aged 26–68, mean age=40.5; 17 female, 11 male), separate from those who participated in the production study above, took part in an online perception study.

Five types of three-syllable nonce words were constructed, with 10 of each type. Each nonce word was pronounced twice by a native Norwegian speaker (female, aged 43): once with stress on the penultimate syllable and once with stress on the final syllable. The words were read in carrier phrases and then extracted. The five types are shown in 1, along with their syllable shapes under each stress.

	nonce word shape	with penult stressed	with final stressed
Type 1	CV.CV.CVV	CV.**CV:**.CVV	CV.CV.**CVV**
Type 2	CV.CVV.CVC	CV.**CVV**.CVC	CV.CVV.**CV:C**
Type 3	CV.CVC.CVC	CV.**CVC**.CVC	CV.CVC.**CV:C**
Type 4	CV.CV.CVC	CV.**CV:**.CVC	CV.CV.**CV:C**
Type 5	CV.CV.CV	CV.**CV:**.CV	CV.CV.**CV:**

Table 1. Stimuli word shapes

The study was run through Ibex Farm (Drummond 2014), where for each of the 50 items, the two productions were played in random order and participants were asked which would be a better pronunciation if it were a real Norwegian word, and they selected one of two buttons which were labeled "the first" and "the second" (labels and instructions were in Norwegian). The results are shown in table 2 below.

Listeners were much more accepting than anticipated of stress patterns that do not have good matches in the lexicon. For example, while penultimate stress was somewhat preferred for Type 5 (/CV.CV.CV/) final stress was chosen 44% of the time, despite the fact that this does

		penult stress	final stress
Type 1	CV.CV.CVV	35%	65%
Type 2	CV.CVV.CVC	58%	42%
Type 3	CV.CVC.CVC	50%	50%
Type 4	CV.CV.CVC	45%	55%
Type 5	CV.CV.CV	56%	44%

Table 2. Stress preference by word shape

not match the pattern in the lexicon. In our sample of the lexicon, discussed in §4, there are 84 /((C)V).CV.CV/ words, and only 4 of them (0.05%) have final stress, while 62 (74%) have penultimate (and the remaining have antepenultimate). This seems to be in large part due to the fact that listeners strongly preferred whichever stress placement they heard first. While this was true to some degree in all cases, the difference was extreme in Type 5: the final syllable stress was only chosen 23% of the time when penultimate stress was heard first, but it was chosen 62% of the time when it was heard first.

We see that final stress was most strongly preferred when there was a word-final diphthong (Type 1). Penultimate stress was most strongly preferred when there was a penultimate diphthong (Type 2), or the final syllable was /CV/ (Type 5). Clearly, there is a preference to stress diphthongs in either of the two final positions. We see that stress preferences are essentially split down the middle when the final syllable shape is underlyingly /CVC/ and the penult is not a diphthong. If rightmost stress were favored in general in Norwegian, we would expect a preference for final stress in both of these cases. On the other hand, if stressing an underlyingly heavy syllable were a driving force (as it seems to be given the diphthong results), we would then expect the preference for penultimate stress to be stronger in Type 3 than in Type 4, as the penult in the former is underlyingly heavy. Instead we see the both word shapes eliciting a similar lack of preference for either penultimate or final stress. Finally, while there is some preference for penultimate stress in . . . CV.CV# words (Type 5), it is not nearly as strong as the patterns in the lexicon would lead us to expect. We explicitly compare these results to the patterns in the lexicon in the following section.

A binary logistic GLiM was run, with *response* as the dependent variable and factor *type*, blocked by subject. Despite a relatively high level of acceptance for both stress pronunciations for all five word shapes, *type* was statistically significant ($p < 0.001$), indicating that the different penultimate and final syllable shapes lead to different stress patterns.

Types 3 and 4, which both have a /CVC/ final syllable, are not significantly different ($p = .209$, pairwise comparison). They were, however, both different from Type 2 ($p = 0.039$, $p < 0.001$, respectively), which also had a final /CVC/ but had a diphthong in the penult and was therefore more likely to be preferred with penultimate stress. Types 2 and 5 showed the same preference for penultimate stress ($p = 0.719$).

4. MaxEnt analysis. To compare the results of the perception study to the patterns in the lexicon of Norwegian, we conducted a MaxEnt analysis (Goldwater et al. 2003) of the data. The tolerance for different outcomes despite stress preferences based on syllable shape found in the perception study makes MaxEnt an appropriate phonological model. To train the model, we used

a corpus of 675 Norwegian words from a loanword dictionary (Selmer 1966)[3]. Each occurring syllable shape and its theoretically possible stresses were coded for constraint violations from the following set.

(2) a. RIGHTMOST– Stress is on the final syllable
b. NONFINALITY– The final syllable is not stressed
c. *AUGMENT– No vowel lengthening
d. *V:#– No final long vowels
e. *STRESSHIATUS– No stress on either syllable that is part of a vowel hiatus

We included both RIGHTMOST and NONFINALITY, which penalize non-final stress and final stress respectively, since we do see evidence of both a pull for final stress and a push away from it. *AUGMENT takes into account the faithfulness cost of lengthening a vowel, which is taken to necessarily happen anytime an underlyingly-light syllable bears stress.[4] The constraint *V:# reflects the dispreference for stress falling on a final open syllable. Finally, *STRESSHIATUS was included because Hogoboom's analysis (Lunden 2006) noted a pattern where both the penult and the final syllables were eshewed for stress when in a hiatus configuration; stress tends to fall on the antepenult instead in these cases (e.g. [fó:.li.e] 'foil').

We did not include constraints that must be undominated in Norwegian, and therefore did not consider candidates that violated them. Undominated constraints include STRESS-TO-WEIGHT (if a syllable is stressed, it must be heavy), COINCIDE(GEMINATE, PRIMARY STRESS) (a geminate may only occur if licensed by affiliation with a stressed syllable), or COINCIDE(LONG VOWEL, PRIMARY STRESS) (a long vowel may only occur if licensed by affiliation with a stressed syllable).

(3) Constraint weights for the data from the lexicon

*V:#	No final long vowels	3.34
*STRESSHIATUS	No stress on a syllable in hiatus	1.64
NONFINALITY	No final stress	1.33
RIGHTMOST	The final syllable is stressed	1.33
*AUGMENT	Do not lengthen the vowel	1.23

We see that the constraint against final long vowels is the most strongly weighted. The proposal for stress avoidance in syllables under hiatus finds support from the reasonably strong weighting of *STRESSHIATUS. We again see the tension between penultimate and final stress in the equally weight NONFINALITY and RIGHTMOST constraints.

Other constraints were initially included but then taken out because they received weights of 0. For example, we saw in the perception study that diphthongs strongly draw stress and so initially included a constraint STRESSVV (a diphthong must bear primary stress) but it had no weight.

We then compared the predictions of our model to the results of the perception data from §3. This was done by adding in the five different underlying word shapes used in the perception study (given in 1) without frequency data to allow the model to predict the likelihood between the two candidate possibilities (penultimate and final stress) for each of these five shapes. We then

[3] Thank you to Gjert Kristoffersen for sharing this list of A-K words compiled from Selmer 1966

[4] This is written to be transparent but may be more technically encoded as DEPμ.

compared the resulting probabilities of final stress against the stress preferences shown by the participants of the perception study.

As can be seen in table 3 below, the prediction of how often word shapes of Types 2 and 3 would be found with final stress was a very close match to the results from the perception study. Types 1 and 4 were predicted to have a much higher percentage of final stress than listeners in the perception study chose as the most Norwegian-like pronunciation. Type 5 was predicted to have fewer instances of final stress than were selected by perception study participants.

Type		predicted	selected by participants
1	CV.CV.CVV	94	65
2	CV.CVV.CVC	55	42
3	CV.CVC.CVC	55	50
4	CV.CV.CVC	81	55
5	CV.CV.CV	13	44

Table 3. Model prediction for final stress occurrences and perception study results

Shown as a scatterplot in figure 2, we can see a reasonable correlation between the predicted likelihood of final stress and how frequently the final stress option was chosen by participants.

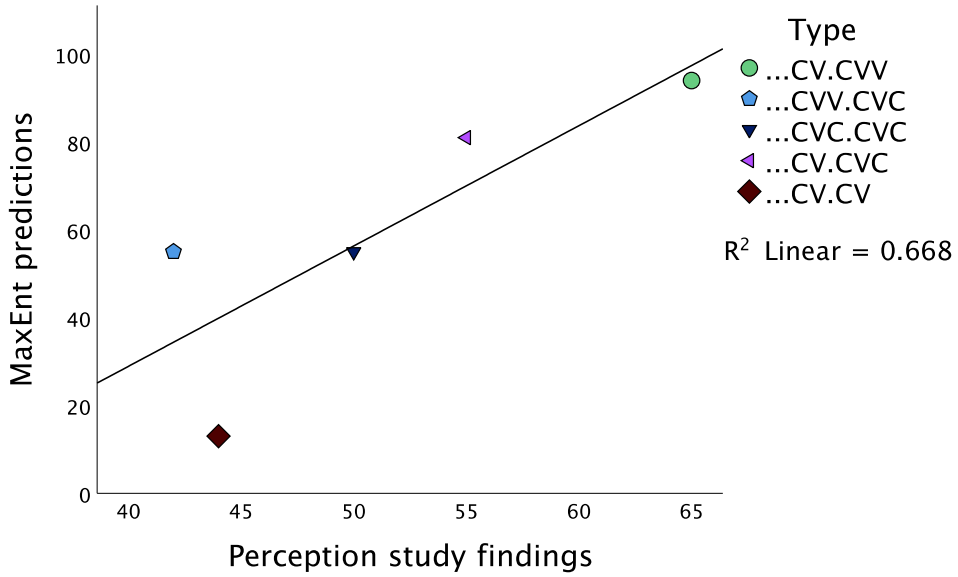

Figure 2. Likelihood of final stress: Experiment/Model correlation

5. Conclusion. Given the results of the production study in §2 we have found that final long vowels in open syllables phonetically pattern with other heavy rime shapes. This finding, coupled with the expectation that stressed syllables must be heavy in Norwegian, leads to the clear conclusion that a word-final long vowel is heavy.

Given that a final long vowel in an open syllable is in fact heavy, we might expect to find word-final stress in V-final words more frequency than we do in the lexicon. We see them in

0.05% of disyllablic or trisyllabic words with all underlyingly short vowels in open syllables, and our MaxEnt model predicts that 13% of trisyllabic words should get final stress. Both of these numbers indicate that final stress in such cases is highly dispreferred, as does the high constraint weighting our MaxEnt model gave our "no final long vowels" constraint. On the other hand, 44% of such words were chosen to sound more Norwegian-like with final stress in the perception study. This indicates a surprising mismatch between the lexicon and speakers' judgements. The perception study findings may indicate that it is a perfectly acceptable pattern for listeners' phonological grammars, albeit underrepresented in the lexicon of the language. We suspect, however, that there was some interference from the perception study task itself. The fact that listeners were biased toward whichever pronunciation they heard first, and that they chose final stress after hearing it second only 23% of the time, supports this suspicion.

While further work is needed to clarify the best analysis of stress placement in Norwegian, we suggest that the preference for rightmost stress could be maintained in an analysis in which additional factors affecting final long vowels were considered. Many languages with contrastive vowel length neutralize this length word-finally. Myers and Hanson (2007) motivate this common process of final shortening by showing that phrase-final devoicing interferes with the perception of vowel length. While vowel length is not contrastive in Norwegian, the dispreference for final long vowels could still hold for the same reasons. Hogoboom and Lorber (2023) additionally propose that the final lengthening inherent in a word-final syllable makes them a poor choice perceptually for length-inducing phonological processes, as the duration due to vowel length may be perceptually compromised by the duration due to final lengthening.

Thus, we conclude that while word-final long vowels are avoided in Norwegian, this dispreference is not because they violate the requirement that a primary-stressed syllable must be heavy. Rather, there may be a more general perceptual issues with accurately perceiving a long vowel in this position.

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Appendix

rime shape	stress status	word	gloss	word	gloss
V	unstressed	debut	debut	kamel	camel
		buffé	buffet	tomat	tomato
		filet	fillet	postei	mail
		gemakk	convenience	kafé	café
		fabrikk	factory	abrupt	abrupt
		atom	atom		
V:	stressed	bison	bison	kabel	cable
		chili	chili	boraks	borax
		ego	ego	biceps	biceps
VC	unstressed	absint	absinthe	konvoi	convoy
		harnisk	armor	kornett	cornet
		falsett	falsetto	bonsai	bonsai
		advent	advent	versailles	versailles
VC	stressed	kultus	cult	harpiks	resin
		ketsjup	ketchup	asfalt	asphalt
		album	album		
VC:	stressed	ekko	echo	bille	beetle
		hallik	pimp	rally	rally
		gallup	poll	kannik	canon
VV	unstressed	kainitt	kainite	boikott	boycott
		kaiman	caiman	kautel	caution
VV	stressed	auto	auto	løype	track
		pause	break	eisbein	ice bone (dish)
		reise	travel/journey	haubits	howitzer (artillery)

Table 4. Words used for non-final rime shapes in production study

rime shape	stress status	word	gloss	word	gloss
V	unstressed	chili	chili	auto	auto
		ego	ego	pause	break
		ekko	echo	reise	travel/journey
		bille	beetle	løype	track
		rally	rally		
V:	stressed	debut	debut	filet	fillet
		buffé	buffet	kafé	café
VV	unstressed	essay	essay		
VV	stressed	postei	mail	bonsai	bonsai
		marseille	marseille	versailles	Versailles
		konvoi	convoy		
VC	unstressed	bison	bison	album	album
		kabel	cable	hallik	pimp
		marseille	Marseille	gallup	poll
		kultus	cult	kannik	canon
		ketsjup	ketchup	kautel	caution
V:C	stressed	atom	atom	tomat	tomato
		kamel	camel	kaiman	caiman
VC:	stressed	gemakk	convenience	kornett	cornet
		fabrikk	factory	kainitt	kainite
		falsett	falsetto	boikott	boycott
VCC	unstressed	harpiks	resin	biceps	biceps
		boraks	borax	haubits	howitzer (artillery)
		asfalt	asphalt		
VCC	stressed	abrupt	abrupt	harnisk	armor
		absint	absinthe	advent	advent
VVC	unstressed	eisbein	ice bone (dish)		

Table 5. Words used for word-final rime shapes in production study