# Syllable structure and extrametricality: a typological and phonetic study*

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**Abstract**

This paper proposes a functional basis for final consonant extrametricality, the asymmetric status of CVC syllables as stress-attracting in non-final position of a word but stress-rejecting in final position. A typological study of phonemic vowel length pattern in 10 languages with this final vs. non-final stress asymmetry and 30 languages in which CVC attracts stress in final position indicates a robust asymmetry between languages differing in their stress system's treatment of final CVC. Languages that asymmetrically allow stress on non-final but not on final CVC all lack a phonemic vowel length contrast in final position, whereas those lacking the stress asymmetry often have contrastive length in final vowels. It is claimed that the absence of phonemic length in languages that do not stress final CVC facilitates the nearly universal pattern of phonetic final lengthening, which threatens to obscure the perception of phonemic length. The enhanced lengthening of final vowels in languages with final phonemic vowel length reduces the duration ratio of CVC relative to CV, thereby reducing CVC's perceptual prominence and thus its propensity to attract stress in keeping with Lunden's (2006)

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proportional duration theory of weight. A phonetic study of two languages differing in the stress-attracting ability of final CVC offers support for the proposed account. Arabic, which displays consonant extrametricality and largely lacks phonemic vowel length in final position, has substantial final vowel lengthening, whereas Kabardian, which stresses final CVC and contrasts vowel length in final position, lacks substantial final lengthening.

## 1. Introduction

Final syllables resist stress in many languages. For example, in Pintupi (Hansen and Hansen 1969, 1978) and Northern Sámi (Nielsen 1926), stress falls on odd-numbered syllables but not on final syllables. One of the more interesting types of final stress avoidance is found in several languages in which a syllable type that is stressed in non-final position fails to attract stress word-finally. For example, In Cairene Egyptian Arabic (Mitchell 1960, McCarthy 1979, Hayes 1995), a penultimate syllable attracts stress if it is either closed (CVC) or contains a long vowel (CVV) (1a). A final syllable attracts stress, however, only if it contains a long vowel or is closed by a long consonant or cluster (CVCC) (1b). A final CVC syllable is not stressed (1c), even though CVC is stress-attracting in the penult.

(1) Egyptian Arabic stress (examples from Funk 1985)

(a) muˈdarris 'teacher (m.sg.)' (p.49), dʒaˈmiːla 'beautiful (f.sg.)' (p.49)

(b) muˈhimː 'important' (p.110), xaˈbiːr 'specialist' (p.49)

(c) ˈbaːrid 'cold' (p.49), ˈasxan 'hotter' (p.49)

Typically, the asymmetric behavior of CVC as heavy, i.e. stress-attracting, word-internally but not word-finally is handled by treating a word-final consonant as extrametrical (Hayes 1979, 1995). In moraic theory (Hyman 1985, Hayes 1989), this means that CVC is monomoraic, and thus light, in final position, while non-final CVC and final CVCC are bimoraic and heavy (Figure 1).[1] Final syllables containing a long vowel are also bimoraic and heavy, since extrametricality only affects consonants.

[1] The possibility of trimoraic syllables has also been suggested in the literature, e.g. in Estonian (Hayes 1989).

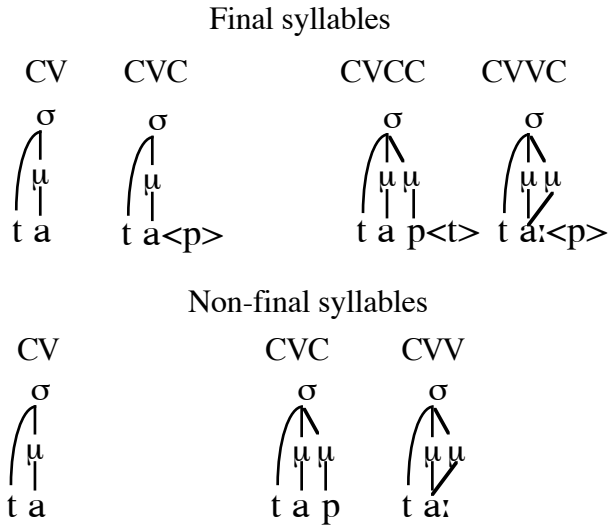


Figure 1. Moraic configurations assuming consonant extrametricality

Another species of extrametricality is found in languages in which all final consonants, even clusters, are metrically ignored. In Klamath (Barker 1964), the heaviest type of syllable in the stress system is CVV(C), which attracts stress over other syllable types (2a). In words with multiple CVV(C) syllables, the rightmost one takes stress (2b). In disyllable words without CVV(C), stress falls on the first syllable (2c). In trisyllabic or longer words with only CV syllables, stress falls on the antepenult (2d). A CVC penult, however, attracts stress from the antepenult (2e) demonstrating its heavy status non-finally. Crucially, though, unlike final CVV(C), final CVC(C) does not attract stress in polysyllabic words: n̪isˈqʼaːk ‘little girl’ vs. ˈɢlegatk ‘dead’, Although this type of consonant transparency is not typically regarded as an instance of extrametricality for theory-internal reasons (Hayes 1995), it differs minimally from the variety of extrametricality exemplified by Arabic in terms of the syllable types that count as heavy in final position.

(2) Klamath stress (examples from Barker 1964:35-8)

(a) ɡabaːˈtambli ‘goes back to shore’, ɡaˈw̪iːnapbabli ‘is going among again’, sakʼamsiˈneːʔ ‘to be lonesome’, n̪isˈqʼaːk ‘little girl’

(b) ɡaːˈmoːla ‘finishes grinding’

(c) ˈlo̰lal ‘to lie’, ˈɢlegatk ‘dead’, ˈgepgi ‘come!’

(d) ˈtʃ’aw̰iga ‘is crazy’

(e) saˈɢapd͡ʒol ‘to play cat’s cradle’, seˈsadwi ‘to sell’

## 2. The phonetic basis for extrametricality

### 2.1. The intonational basis for extrametricality

As part of a broader research program examining phonetic motivations for phonological patterns, phonologists have recently begun to explore the phonetic correlates of extrametricality. For example, building on a hypothesis advanced by Hyman (1977), Gordon (2001) explores the intonational basis for final stress repulsion. He argues that tonal crowding avoidance accounts for the leftward displacement of stress from the final syllable in certain languages. The unmarked intonational tune in most languages consists of a final pitch trough (see Hirst and Di Cristo 1998 and Jun 2005 for surveys of intonation systems), whereas phrasal stress is typically associated with raised pitch. In order to avoid the articulatory and perceptual demands of realizing an excursion from pitch peak to pitch trough on a single syllable, many languages push stress to the left of the final syllable. Stress systems like that of Klamath (Barker 1964), in which stress falls only on final syllables containing a long vowel and not on final CVC or CVCC, can also be explained in intonational terms. Parallel to tone languages which restrict contour tones to long vowels (see Zhang 2002 for typology), languages like Klamath only allow a transition from high to low pitch on syllables with the greatest sonority, those containing a long vowel. Gordon’s account finds support from languages, e.g. Yupik, Chickasaw, Hill Mari, in which final stress avoidance effects are stronger in phrase-final position, where the intonational factors driving extrametricality are most compelling, than phrase-medially, where tonal crowding is less likely to be a factor.

Gordon’s (2001) intonation-based account of extrametricality, however, does not readily extend to languages like Cairene Arabic in which final CVCC but not final CVC is stress attracting, since it is not clear why CVCC should have any advantage over CVC in supporting a pitch transition. Consonants, especially obstruents, do not offer much

assistance in realizing pitch (see Zhang 2002), so there is no apparent explanation for why the entire class of CVCC syllables should be privileged in attracting stress in final position.

### 2.2. The durational basis for extrametricality

Recent work by Lunden (2006) has offered an alternative account of consonant extrametricality couched in durational rather than intonational terms. Her account offers an explanation for the Cairene Arabic type of extrametricality in which final CVCC but not final CVC attracts stress. She argues that the stress attracting ability of CVC in Norwegian, a language like Cairene Arabic with final consonant extrametricality, is predictable from phonetic duration. Results from her phonetic study of Norwegian show that the duration ratio of final CVC to final CV is much smaller than the ratio of non-final CVC to CV, a pattern attributed to the cross-linguistically pervasive phenomenon of final lengthening (Wightman et al. 1992), which reduces the CVC to CV duration ratio in final position. Lunden suggests that there is a threshold duration ratio relative to CV that a syllable must exceed in order to attract stress in a given position. Non-final CVC and final CVCC and CVVC exceed this threshold in keeping with their heavy status, whereas final CVC does not in keeping with its light status. Norwegian arguably lacks final CVV (Lunden 2006).

## 3. The link between syllable structure and extrametricality: a functional account

This paper explores the typological and phonetic basis for consonant extrametricality building on Lunden's duration-based approach. It is shown that the duration patterns claimed to underlie consonant extrametricality are ultimately linked to functional pressures induced by phonemic length contrasts. A comparative survey of languages with consonant extrametricality and those in which final consonants are not extrametrical reveals an interesting correlation between vowel length and weight of CVC. Languages in which final CVC is light are far more likely to lack a phonemic length contrast in word-final vowels than languages in which final CVC is heavy. It is claimed that this

difference in vowel inventory offers a functional explanation for differences in phonetic duration patterns between the two types of languages. Relative to languages with contrastive length in final vowels, in languages without a contrast in vowel length, the cross-linguistically pervasive and phonetically natural phenomenon of final lengthening is free to exert a greater phonetic effect, since there is no threat of final lengthening threatening the perceptibility of a phonemic contrast. The greater final lengthening effect in languages without final phonemic length makes final CV durationally closer to CVC than in languages with a final length contrast and less final lengthening. In addition, a parallel relationship between phonemic length and phonetic duration holding of consonants also potentially impacts the duration of final CVC relative to final CV. A language with a contrast between singleton and geminate consonants in final position is predicted to allow less final lengthening of the singleton consonants since substantial lengthening could obscure the perception of the length contrast in consonants; this constraint on final consonant lengthening would thus reduce the CVC to CV duration ratio in final position. The reduction of the CVC to CV duration ratio both in languages with a contrast in final consonant length and in languages without a contrast in final vowel length is claimed here to be correlated with the light status of final CVC following Lunden's (2006) proportional duration theory of weight. The relationship between phonemic length and phonetic lengthening in final position is depicted schematically in table 1.

Table 1. Relationship between phonemic length and phonetic length of vowels and consonant in final position and the weight of final CVC

| **Segment** | **Phonemic Length** | **Phonetic Length** | **CVC:CV Ratio** | **CVC Weight** |
|---|---|---|---|---|
| Vowels | Yes | Less | Greater | Heavy |
| | No | More | Smaller | Light |
| Consonants | Yes | Less | Smaller | Light |
| | No | More | Greater | Heavy |

The typological link between phonemic vowel length and weight of final CVC found in the present survey is supported by a phonetic experiment conducted on two languages differing in the weight of final CVC: Arabic which treats final CVC as light and Kabardian which treats final CVC as heavy. It is shown that the effects of final vowel lengthening are greater and those of final consonant lengthening smaller in Arabic, which lacks a phonemic length contrast in final vowels but possesses one in final consonants.

## 4. Speech perception and final length

Basic to the account of extrametricality proposed here is the notion that speech perception plays an important role in the organization of phonological systems. Perceptual considerations have long been invoked to account for phonological patterns. For examples, Liljencrants and Lindblom (1972) show that vowel inventories are constructed to maximize the perceptual distinctness of different vowels. Bladon (1986) argues that a number of phonological patterns ranging from dissimilation to the distribution of laryngeal segments are driven by perceptual factors.

Directly germane to the present study, speech perception has also played a prominent role in recent literature exploring the phonetic basis for syllable weight. Gordon (2002a) develops a model of syllable weight in which languages adopt weight distinctions that create maximal perceptual distinction between heavy and light syllables along the phonetic dimension of perceptual energy. Goedemans (1998) shows that the characteristic transparency of syllable onsets in stress systems is related to listener's relative insensitivity to the duration of consonants in onset position.

Lunden (2006) also presents an account of consonant extrametricality grounded in perception. Drawing on the observation that duration plays an important role in the perception of stress cross-linguistically (Fry 1958; see Beckman 1986 and Cutler 2005 for reviews of the literature), Lunden suggests that syllables must be sufficiently long relative to the lightest type of syllable, CV, in order to be treated as heavy in a language. Syllables that fail to exceed a threshold of length proportional to CV in the same position in a word will not attract stress. CVC is considered heavy in non-final syllables in so many languages because it meets the proportional length threshold. In final syllables,

however, CVC in many languages is not long enough relative to CV to be heavy because of the effects of final lengthening on both syllable types. Final lengthening is a nearly universal phonetic phenomenon targeting sounds at the right edge of prosodic domains, where the degree of lengthening is typically correlated with the size of the constituent boundary, i.e. greater lengthening is observed at phrasal boundaries than at word boundaries (Wightman et al. 1992). Given the occurrence of final lengthening, the durational ratio of CVC to CV is much greater in non-final than in final syllables, as Lunden observes, even though the *absolute* duration difference between CVC and CV may be similar in the two positions.

Lunden supports her proportional duration theory of weight with phonetic data from Norwegian, a language that treats CVC as heavy in non-final position but as light in final position, where two coda consonants are required to make a syllable containing a short vowel as heavy. The Norwegian weight system is thus similar to that of Arabic discussed earlier in section 1. Lunden shows that CVC is 80% longer on average than CV in non-final position, but only 27% longer than CV in final position, since both syllable types are targeted by final lengthening. CVXC, where X stands for either the second half of a long vowel or the first consonant in a coda cluster, on the other hand is 74% longer than CV in final position since the added segmental content compensates for the additional length associated with final position. The duration profiles of the rime in CV, CVC, and CVCC in final and non-final position are shown schematically in figure 2. Duration values are calculated as a percentage of the total word duration.

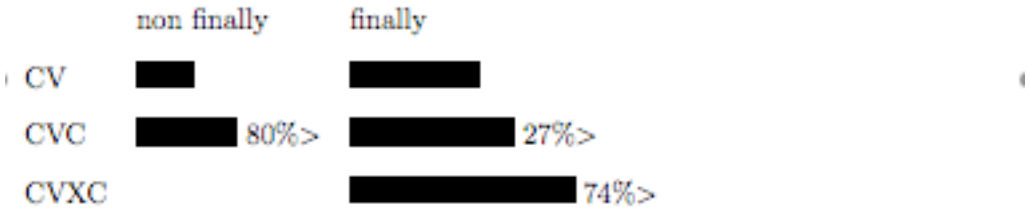


Figure 2. Average rime/word duration proportional increase over same-position CV (from Lunden 2006:76)

Lunden suggests a threshold value of 60% which a syllable type must exceed CV by in order to count as heavy in a given position, though the exact value of this threshold is not

important. What is crucial in her account is that there is some threshold value of proportional length that must be exceeded in order for a syllable to be regarded as heavy in a given position.

Since Lunden's theory appeals to the phonetic effect of final lengthening to account for contextual variation in the weight of CVC, it assumes that final lengthening is present in all languages that asymmetrically treat final CVC as light but non-final CVC as heavy. Although final lengthening is a nearly universal phenomenon, the degree of final lengthening varies considerably from language to language. For example, Delattre (1966) finds a ratio of final-to-non-final syllable duration of 1.17:1 in Spanish but a ratio of 1.78:1 for French. In Creek, Johnson and Martin (2001) find a final:non-final vowel duration ratio of approximately 1.35:1. Gordon and Munro (2007) find the same ratio for Chickasaw. Lee and Seong (1996) observe a ratio of 1.8:1 in Korean. Nagano-Madsen (1993) observes that final vowels in Inuktitut range from 1.5 to 1.79 times longer than non-final vowels.

While many of the observed cross-linguistic differences in degree of final lengthening are plausibly attributed to differences between studies in the type of prosodic boundary examined, it is also true that the extent of phonetic lengthening simply varies from language to language just as any other phonetic parameter, e.g. vowel duration, consonant voice onset time, etc., differs between languages. The question then becomes how much of this cross-linguistic variation is arbitrary versus how much is explained by other properties of the language. It is well known that one characteristic of a language's phonology may impact other properties. For example, vowel-to-vowel coarticulation is less extensive in languages with many contrastive vowel qualities than in languages with fewer vowels (Manuel 1990). In the realm of stress, languages that use fundamental frequency to signal lexical contrasts are less likely to use it as a cue to stress (cf. Everett 1998 on Pirahã, Potisuk et al. 1996 on Thai). Similarly, in languages with phonemic vowel length, e.g. Finnish, phonetic duration is not as available as a marker of stress as in a language where duration does not carry such a high functional load.

Phonological weight also appears to be bound by functional considerations related to phoneme inventory. Gordon (2002a) shows that languages without a phonemic length contrast are far more likely to draw weight distinctions based on vowel quality, e.g.

between vowels of different height, than languages with phonemic length. The reason for this he argues is due to durational differences between the two types of languages: in languages without phonemic vowel length, the inherently longer vowel qualities, lower vowels (Lehiste 1970), are free to lengthen substantially without the potential for obscuring the perception of a length contrast. The greater lengthening of lower vowels creates a greater length differential between vowels of different heights making this difference more likely to be exploited by a weight system seeking to have maximally divergent heavy and light syllables. In languages with phonemic vowel length, on the other hand, lower vowels are constrained in the amount of subphonemic lengthening they may undergo since too much lengthening could potentially interfere with contrastive vowel length. The reduced lengthening effect decreases the likelihood of a stress system exploiting a weight distinction based on vowel height. Ahn (2000) also argues that phonemic length contrasts are relevant for predicting syllable weight patterns. She suggests that CV syllables reject stress because the lengthening associated with stress would potentially jeopardize the perception of phonemic vowel length.

One might also expect final lengthening to be constrained by the functional load of duration in signalling phonemic length contrasts. Languages in which vowel length is phonemic in final position are less free to employ final lengthening than languages in which vowel length is not contrastive. The potentially deleterious effect of final lengthening on the perception of phonemic length likely is one factor (among others such as vowel devoicing and non-modal phonation) contributing to the neutralization of vowel length contrasts in final position (see Barnes 2002 for typology). Presumably, in these languages, the substantial reduction of duration ratios between long and short vowels undermined the perception of phonemic length sufficiently to lead to elimination of the distinction entirely.[2]

If the presence of phonemic length in final vowels plays an important role in conditioning the extent of final lengthening, we would also expect it to affect the weight

[2] Interestingly, the outcome of neutralization can be phonologized on a language-specific basis either as a short vowel, e.g. Kinyarwanda (Myers 2005), or as a long vowel, e.g. Tiberian Hebrew (Prince 1975, McCarthy 1979). On the basis of perception data from Finnish, Myers and Hansen (2007) argue that final shortening plausibly originates from the presence of a devoiced phase in final vowels, which tends to be factored out in listener's perceptions of phonemic length.

of final CVC. In languages with phonemic vowel length word-finally, final phonetic lengthening effects should be smaller thereby leading to proportionally greater CVC-to-CV duration ratios than in languages without phonemic vowel length. In languages without phonemic vowel length in final position, final vowel lengthening is predicted to be greater thereby reducing the CVC-to-CV duration ratio. According to the proportional duration theory of weight, we would thus expect final CVC to be more likely to be treated as light in languages without phonemic vowel length. This prediction can be tested in two ways. First, one can examine the status of final phonemic vowel length in languages that asymmetrically treat CVC as heavy non-finally but light finally. Languages with this type of weight system should be biased against final phonemic vowel length cross-linguistically. In contrast, languages that treat CVC as heavy both finally and non-finally should not display the same bias against contrastive vowel length in final position. Another way to evaluate the proportional duration theory is to look at phonetic duration in languages that asymmetrically treat CVC as light finally but heavy non-finally and compare their duration patterns with those found in languages that treat CVC as heavy word-finally. We would expect to find higher final CVC-to-CV duration ratios in languages that treat CVC as heavy word-finally.

## 5. The present study

The present study employs both a typological component and two individual phonetic case studies to test the proportional duration theory of final weight. For the typological study, a survey of phonemic vowel length in languages with both heavy final CVC and languages with light final CVC was conducted. The individual case study phase consists of a phonetic study of duration patterns of heavy and light syllables in two languages. In one of these languages, Kabardian, CVC is heavy in final position, whereas in the other language, Egyptian Arabic, CVC is light word-finally but heavy non-finally. Egyptian Arabic thus resembles Norwegian, the language examined by Lunden (2006), in its contextually governed weight of CVC. It differs crucially, however, in possessing fewer confounds in the relationship between stress and syllable types. Most crucially, final CVC does not occur on the surface in Norwegian due to the coupling of a restriction

against unstressed final closed syllables in the native vocabulary with a ban on short stressed vowels followed by a single short consonant. This means that it is impossible to tease apart stress and the weight of final closed syllables, since all final closed syllables are both stressed and end in either a geminate or a consonant cluster, i.e. end in CVCC. Thus, there is a virtual absence of unstressed CVC on the surface, meaning that the unstressed final CVC appearing in Lunden's corpus of nonsense words does not conform to typical syllable patterns of Norwegian. The upshot of this is that language-specific limitations on Norwegian phonotactics make it impossible to directly compare the duration of final CVC with that of final CVCC. In contrast, Egyptian Arabic, the object of phonetic study in the present work, lacks this gap, since both CVC, which is unstressed, and CVCC, which is stressed, occur on the surface.

## 6. A cross-linguistic survey of phonemic vowel length and final CVC weight

A total of 40 languages served as the object of study in the cross-linguistic survey of the relationship between final CVC weight and final phonemic vowel and consonant length. The survey consisted of two types of languages: those in which final CVCC and non-final CVC are heavy but final CVC is light and those in which both final CVC and final CVCC (if it occurs) are heavy (collapsed as CVC(C) heavy). The relevant weight criteria were potentially observed for either primary or secondary stress. Languages in the survey were drawn from the Stresstyp database (http://stresstyp.leidenuniv.nl), which includes data on stress from 510 languages of which only a subset possess the requisite properties to be included in the present study. Original source materials were consulted to determine the status of vowel and consonant length in final position. Only a single dialect (assuming traditional, often political rather than linguistic-based, designations of different language varieties as dialects as opposed to separate languages) was included in the case of languages, e.g. Arabic, for which several dialects with the same weight status of final consonants were included in StressTyp. A total of 40 languages were included in the survey of final consonant weight; a list of the languages (in alphabetical order) and their weight and phonemic length patterns appears in table 2. A superscripted [a] indicates languages for which the relevant weight distinction is limited to secondary stress.

Table 2. Languages with final weight distinctions and their phonemic length contrasts

| **Language (Dialect)** | **Source(s)** | **Final heavy σ** | **Final V:** | **Final C:** |
|---|---|---|---|---|
| Amele | Roberts (1987) | CVC(C) | No | No |
| Arabic (Egyptian) | Mitchell (1960), McCarthy (1979) | CVCC | No | Yes |
| Avar | Kodzasov (1999), Alekseev (1997) | CVC(C) | No | No |
| Awadhi | Saksena (1971) | CVC(C) | Yes | No |
| Bagvalal | Kodzasov (1999) | CVC(C) | Yes | No |
| Basque (Hondarribia) | Hualde (1999) | CVC(C) | No | No |
| Bhojpuri | Trammel (1971) | CVC(C) | Yes | Yes |
| Capanahua | Elias-Ulloa (2005) | CVC(C) | Yes | No |
| Danish | Rischel (1982), Basbøll (2005) | CVC(C) | Yes | No |
| Dutch | Trommelen and Zonneveld (1999) | CVCC | No | No |
| English | Hayes (1982) | CVCC | No | No |
| Estonian[a] | Hint (1973) | CVCC | No | Yes |
| German | Jessen (1999) | CVCC | No | No |
| Gooniyandi | McGregor (1990) | CVC(C) | Yes | No |
| Hindi | Kelkar (1968) | CVC(C) | Yes | No |
| Kara | Schlie and Schlie (1993), De Lacy (1997) | CVC(C) | No | No |
| Kilivila | Senft (1986) | CVC(C) | No | No |
| Koya[a] | Tyler (1969) | CVC(C) | Yes | No |
| Kristang | Baxter (1988) | CVC(C) | No | No |
| Mam | England (1983) | CVC(C) | Yes | No |

| | | | | |
|---|---|---|---|---|
| Manam | Lichtenberk (1983) | CVC(C) | No | No |
| Mundari | Cook (1966) | CVC(C) | No | No |
| Ndyuka[a] | Huttar and Huttar (1994) | CVC(C) | Yes | No |
| Norwegian | Lunden (2006), Rice (1999) | CVCC | No | Yes |
| Provençal | Roca (1999) | CVC(C) | No | No |
| Rama | Grinevald (n.d.) cited in Stresstyp | CVC(C) | Yes | No |
| Romanian | Steriade (1984) | CVCC | No | No |
| Romansch (Bergüner) | Kamprath (1987) | CVC(C) | No | No |
| Sentani | Cowan (1966), Elenbaas (1992, 1998) | CVC(C) | No | No |
| Shipibo | Elias-Ulloa (2005) | CVC(C) | Yes | No |
| Sindhi | Khubchandani (1969) | CVC(C) | Yes | No |
| Spanish | Harris (1983) | CVCC | No | No |
| Stoney Dakota | Shaw (1980, 1985) | CVCC | No | No |
| Swedish | Bruce (1999) | CVCC | No | Yes |
| Tiberian Hebrew | (Prince 1975, McCarthy 1979, Dresher 1980, Rappaport 1984, Churchyard 1989, 1999) | CVC(C) | Yes | No |
| Tol | Fleming and Dennis (1982), Holt (1999) | CVC(C) | No | No |
| Unami | Goddard (1979, 1982) | CVC(C) | Yes | No |
| Yana | Sapir and Swadesh (1960) | CVC(C) | Yes | No |
| Yapese[a] | Jensen (1977) | CVC(C) | Yes | No |
| Yaqui | Johnson (1962), Dedrick (1999) | CVC(C) | Yes | No |

The number of languages in which final CVCC is heavy but final CVC is light was far smaller than the number in which both final CVC and final CVCC (if it occurs) are

heavy. A total of 10 languages fell into the former category (CVCC but not CVC heavy): Egyptian Arabic, Dutch, English, Estonian, German, Norwegian, Romanian, Spanish, Stoney Dakota, Swedish.[3] It should be noted that this figure is somewhat inflated due to the inclusion of 4 Germanic languages: 2 West Germanic and 2 North Germanic languages. It is also interesting to observe a geographic skewing in the data: most of the languages (8 of 10) that treat CVC as light are spoken in Europe, whereas very few (4 of 30) languages that treat as heavy are European.

All 10 languages with light final CVC lack a vowel length contrast in word-final position, although, as discussed above, Egyptian Arabic makes a morphological contrast between final CV and final CVV, which is confounded with a difference in stress. It may also be mentioned that certain Arabic dialects appear to have a more robust length contrast in final position, e.g. certain Levantine Arabic varieties (Broselow et al. 1997). It is also interesting to note that 4 of the 10 languages distinguish between singleton and geminate consonants in final position: Egyptian Arabic, Estonian, Norwegian, and Swedish. In Norwegian and Swedish, the situation is complicated somewhat by the compensatory relationship between vowel and consonant length: in final syllables, a short vowel must be followed by a long consonant while a long vowel is obligatorily followed by a short consonant.

There were far more languages, 30 in total, in which CVC (and CVCC) is heavy in final syllables. Among the 30 languages, there was a bias toward possessing phonemic long vowels in final position with 18 having long vowels in this position compared to 12 without them.[4] Only one language (Bhojpuri) could be clearly identified as possessing phonemic consonant length in final position.

As these results show, the distribution of phonemic vowel and consonant length differs substantially between languages that treat final CVC as heavy and those that treat

[3] Ancient Greek (Steriade 1988) also might be regarded as a language in which final CVCC is heavier than final CVC. The Ancient Greek prosodic system, however, is based on pitch accent rather than stress unlike the languages discussed here. Furthermore, unlike the more typical cases of extrametricality, the weight of the final syllable does not bear on the accent bearing ability of the final syllable itself but rather on the accentability of the *penultimate* syllable (see Sauzet 1989 and Golston 1990 for tonal analyses of Ancient Greek).

[4] One of these languages, Tiberian Hebrew, is reported to have only long vowels in final position. It is unclear what predictions the present account would make for such a language since it apparently lacks the syllable type hypothesized to serve as the basis for comparative evaluation of duration.

it as light. In languages with heavy final CVC, there is a skewing in favor of phonemic vowel length and against phonemic consonant length in final position, whereas in languages with light final CVC, phonemic vowel length in final position is absent whereas phonemic consonant length is more common (though still rarer than a lack of phonemic consonant length). Chi-squared tests for vowel length and consonant length were conducted in order to determine whether these distributional differences between languages with different weight criteria are statistically robust. Results indicated a reliable difference between the two language types along the two length parameters (vowel and consonant length); for vowel length, $p=.001$, $\chi^2=10.909$; for consonant length, $p=.0024$, $\chi^2=9.219$. Additional analyses were conducted excluding all but one of the Germanic languages (one analysis including a language with light final CVC and another analysis including a language with heavy final CVC) in order to eliminate the possibility of a genetic bias influencing the results. The statistical results remained significant in the additional analyses.

In summary, a cross-linguistic survey examining the relationship between final consonant weight and final phonemic vowel and consonant length indicates that languages differing in weight of final CVC also tend to differ in their phonemic length contrasts in final position. As predicted, languages that treat final CVCC as heavier than final CVC lack phonemic vowel length contrasts and have an enhanced propensity for phonemic consonant length, though languages with light final CVC and phonemic consonant length in final position still constitute the minority of cases. Conversely, languages with heavy final CVC have a bias toward phonemic vowel length in final position and against consonant length.

## 7. A phonetic study of final CVC weight

In order to explore the hypothesized link between phonemic and phonetic length in final position, two languages with different final weight distinctions were targeted in a phonetic study. In one of these languages, Egyptian Arabic, CVC is heavy non-finally but light finally. Length is contrastive in final consonants but not final vowels. In the

other language, Kabardian, CVC is heavy word-finally. Length is contrastive for final vowels but not final consonants.

7.1. Egyptian Arabic

Stress in Egyptian Arabic falls on a superheavy (CVVC, CVCC) final syllable (3a). If the final syllable is not superheavy, stress falls on a heavy (CVV or CVC) penult (3b). If the penult is light, stress falls on either the penult (3c) or the antepenult (3d), whichever is separated by an even number of syllables (including zero) counting from the nearest preceding heavy syllable or, in a word with all light syllables, by an even number of syllables counting from the beginning of the word.

(3) Egyptian Arabic stress (examples from Funk 1985 and Mitchell 1975)

(a) muˈhimː 'important' (F p.110), xaˈbiːr 'specialist' (F p.49)

(b) ˈbaːrid 'cold' (F p.49), ˈʃurba 'soup' (F p.49), muˈdarris 'teacher (m.sg.)' (F p.49), dʒaˈmiːla 'beautiful (f.sg.)' (F p.49)

(c) ʔadwijaˈtuhu 'his drugs (nom.)' (M p.79)
ˈradʒul 'man' (F p.42), ʃad͡ʒaˈratun 'tree (nom.)' (M p.78)

(d) anˈfusuhum 'themselves (m)' (F p.143), ˈʃadʒara 'tree' (F p.49), ʃad͡ʒaˈratuhu 'his tree (nom.)' (M p.80), ˈnafsuki 'yourself (f)' (F p.143)

Vowel length in absolute word-final position is not contrastive in the native vocabulary with one exception: a morphological contrast in verbal forms between the 3rd person singular masculine object suffix and forms lacking this suffix: e.g. ˈmaska 'she is holding' vs. masˈkaː 'she is holding him' (Birkeland 1952: 36). Crucially, this length difference is confounded with a stress difference as well, so it is unclear whether length or stress is basic (see Birkeland for discussion). Vowel length in word-final position is not contrastive at the lexical level, unlike vowel length in other contexts. Historically, the loss of a productive length contrast in final position was due to a chain shift, whereby final short vowels were lost and final long vowels were shortened (Birkeland 1952).

7.1.1. Methodology

A list of words was compiled such that all occurring syllable types were represented in both stressed word-final and stressed non-final syllables. Non-final target syllables occurred in the first syllable of disyllabic words, whereas final target syllables occurred in monosyllabic words. The selection of monosyllables for measurement of final syllables was necessary since final stressed CV and CVC are restricted to monosyllabic words. Non-final syllables included CV, CVC and CVV, while final syllables consisted of CV, CVC, CVVC and CVCC. CVCC and CVVC do not occur non-finally and final CVV is limited to verbal forms that are longer than one syllable. Final CVV, if included, would thus not have been comparable to other final syllables in terms of overall word length, a factor known to influence the duration of individual segments (Lehiste 1970). Final CV and CVC were closed class lexical items, since open class monosyllabic words in Arabic are subject to a minimal word requirement of CVVC or CVCC. As the results discussed below indicate, although CV and CVC words are subject to considerable lengthening, neither their vowels nor, in the case of CVC, their coda consonant reach the duration of true phonemic long segments. This suggests that the minimality requirement does not apply to closed class lexical items.

Measured syllables all contained the low vowel /a/, while codas consisted of a sonorant (either /n/ or /m/) or, in the case of final CC clusters, a sonorant plus fricative sequence. The list of examined words appears in the appendix. Target words occurred in final position of a semantically bleached carrier phrase *Kalimat* _____ 'The word is _____'. Each word and the surrounding phrase were uttered a total of five times. Four speakers (two female and two male) of a Lower Egyptian Arabic dialect were recorded reading the list. Recordings were made in a sound treated booth using a DAT recorder and a headworn Shure SM10 microphone. Data were subsequently transferred to computer for analysis using Praat (www.praat.org). The onset and offset of the second formant as discerned visually from a spectrogram were adopted as the beginning and end points, respectively, of non-final vowels. Discontinuities in the waveform and

spectrogram were used to mark other segment boundaries. In the case of final vowels, the offset of a clearly visible second formant was taken as the end point of the vowel.

The proportional duration theory of weight predicts that the duration ratio of CVC to CV in non-final position, where CVC is heavy, will exceed the ratio of CVC to CV word-finally, where CVC is light. A substantial final vowel lengthening effect is predicted to account for the proportionally smaller CVC-to-CV duration ratio in final position relative to non-final position. More generally, the duration ratio of all heavy syllable rimes relative to CV should exceed that of all light syllables relative to CV in both final and non-final contexts.

### 7.1.2. Results

Overall results for Arabic validated the examined hypotheses linking duration and weight. The CVC-to-CV duration ratio was greater in non-final position than in final position and the duration ratio of heavy syllables to CV in both positions was greater than the ratio of light syllables to CV. This result was due primarily to a substantial final lengthening effect in final CV syllables. We now consider the results for individual speakers in detail.

Figure 3 shows the duration of the rime in all final syllables for the four speakers in the study.

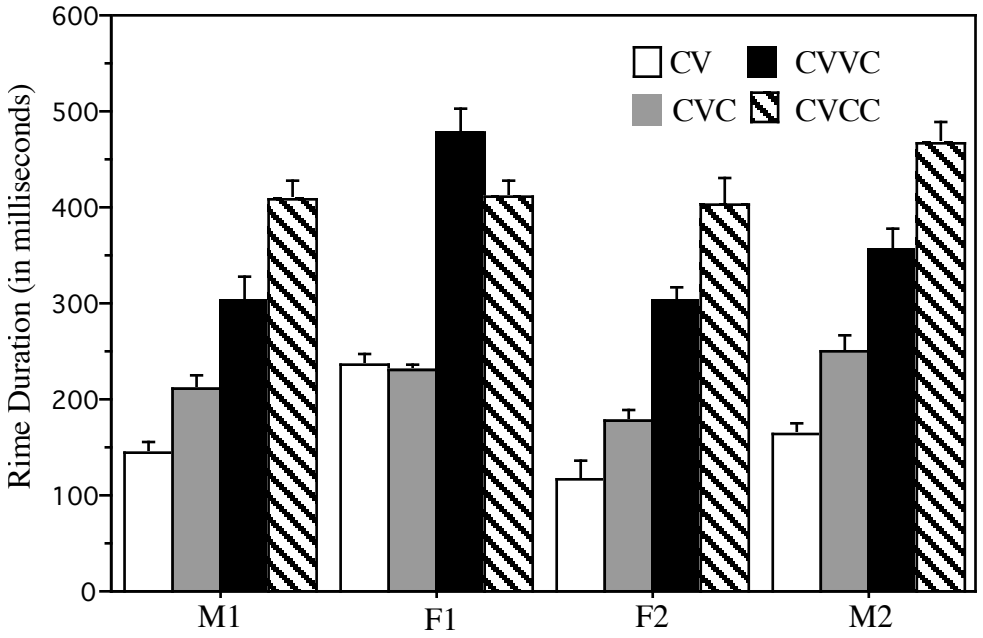


Figure 3. Rime duration in final syllables for four speakers of Egyptian Arabic

As expected, the heavy syllables CVVC and CVCC are both substantially longer than the light syllables CV and CVC for all speakers. A two-factor analysis of variance with speaker and syllable type as independent variables indicates a significant effect of both factors on rime duration: for speaker, $F(3, 63)=100.507$, $p<.0001$; for syllable type, $F(3, 63)=879.156$, $p<.0001$. Furthermore, individual speaker differences produced an interaction between speaker and syllable type: $F(9, 63)=24.366$, $p<.0001$.

Fisher's posthoc tests grouping together data from all speakers indicated that all rime types differed durationally from each other at the $p<.0001$ level. Statistical tests conducted for individual speaker data indicated a largely similar pattern. For all speakers, a one-factor ANOVA taking syllable type as the independent variable indicated a significant effect of syllable type on duration: for speaker M1, $F(3,15)=219.197$, $p<.0001$; for speaker F1, $F(3,16)=320.064$, $p<.0001$; for speaker F2, $F(3,16)=207.102$, $p<.0001$; for speaker M2, $F(3,16)=237.785$, $p<.0001$. Posthoc tests showed that all four rimes occurring in final position differed from each other at the $p<.0001$ level for all speakers with two exceptions. For speaker M2, the difference between CV and CVC was slightly less significant at $p=.0002$. For speaker F1, there was an insignificant difference

between CV and CVC. Interestingly, there was variation between speakers in the duration of the two heavy syllables relative to one another with three speakers having a longer CVCC than CVVC and one speaker (F1) displaying a reversal of this pattern.

Vowel duration in final syllables is plotted in figure 4.

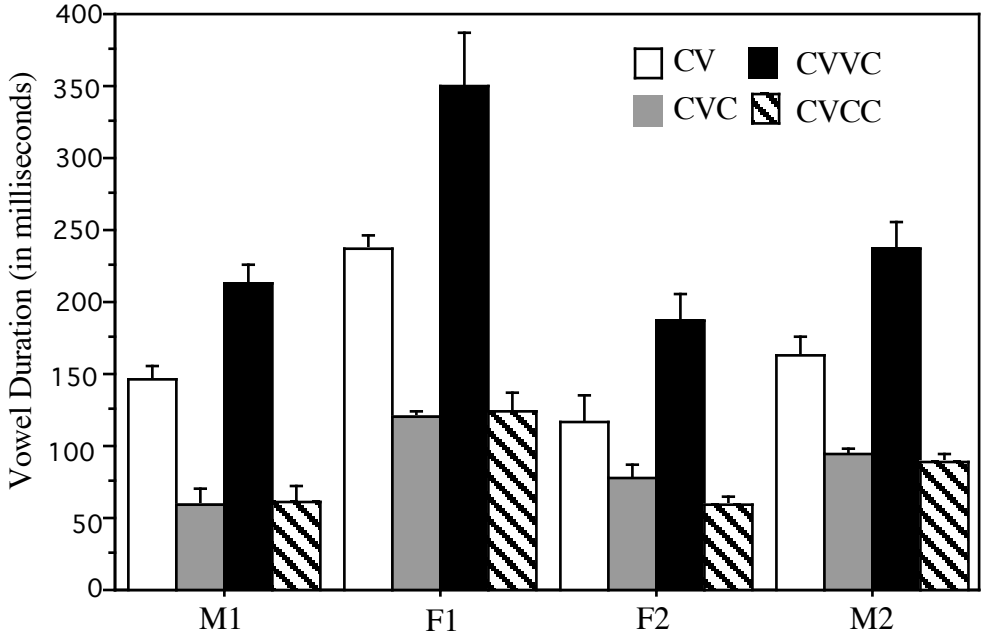


Figure 4. Vowel duration in final syllables for four speakers of Egyptian Arabic

An ANOVA was conducted over the entire data set with speaker and syllable type as independent variables. There was a significant effect of both speaker ($F(3, 63)=174.597$, $p<.0001$) and syllable type ($F(3, 63)=518.130$) on duration. In addition, there was an interaction between the factors: $F(9, 63)=12.825$, $p<.0001$. Posthoc tests indicated a tripartite distinction in vowel duration. The phonemic long vowel in CVVC was longest followed by the lengthened vowel in final CV, followed by the phonemic short vowel in CVC and CVCC, which did not differ in duration from each other. All of the pairwise duration comparisons were significant at the $p<.0001$ level except for the distinction between the vowel in CVC and CVCC, which was not statistically robust. Individual speaker ANOVAs revealed a significant effect of syllable type on vowel duration for all four speakers: for speaker M1, $F(3, 15)=204.600$, $p<.0001$; for speaker F1, $F(3, 16)=148.583$, $p<.0001$; for speaker F2, $F(3, 16)=72.212$, $p<.0001$; for speaker

M2, F (3, 16)=175.435, p<.0001. All four speakers showed the same pairwise differences between syllable types in posthoc tests. All syllables differed from each other in vowel duration at minimally the p<.001 level except for CVC and CVCC, which differed from each other for none of the speakers.

Figure 5 examines the effect of context on the two syllables, CV and CVC, that occur both finally and non-finally. CVC rimes are separated into the vocalic and consonantal portions.

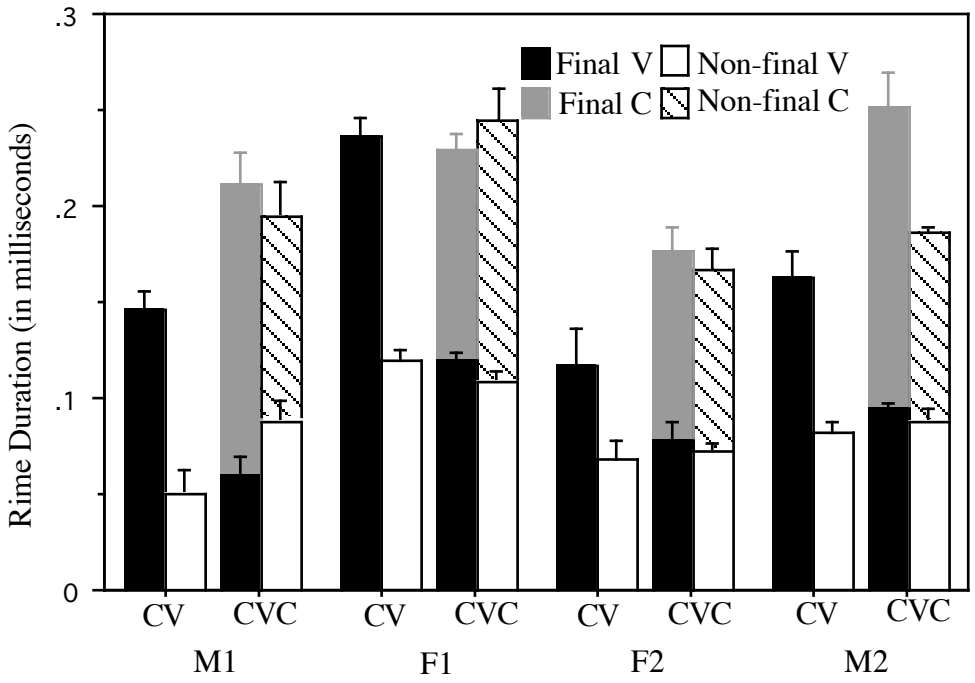


Figure 5. Rime duration (split by vowel and final consonant) of final and non-final CV and CVC for four speakers of Egyptian Arabic

A three-factor ANOVA was conducted with speaker, syllable type, and position serving as independent variables and rime duration as the dependent variable. All three factors exerted a significant effect on duration values: for speaker, F (3, 64)=137.125, p<.0001; for syllable type F (1, 64)=927.083, p<.0001; for position, F (1, 64)=374.780, p<.0001. In addition, all of the two way interactions were significant: speaker and syllable type, F (3, 64)=13.283, p<.0001; speaker and position, F (3, 64)=10.257,

p<.0001; syllable type and position, F (1, 64)=135.081, p<.0001. There was also a three-way interaction between all factors: F (3, 64)=21.089, p<.0001. In individual speaker ANOVAs, all four speakers had a significant effect of position on duration: for speaker M1, (F (1, 16)=110.781, p<.0001); for speaker F1, F (1, 16)=81.535, p<.0001; for speaker F2, F (1, 16)=29.155, p<.0001; for speaker M2, F (1, 16)=203.741, p<.0001. This result was attributed to a substantial lengthening effect on final syllables. In addition, duration was influenced by syllable type for all speakers: for speaker M1, (F (1, 16)=361.496, p<.0001); for speaker F1, (F (1, 16)=100.579, p<.0001); for speaker F2, F (1, 16)=192.517, p<.0001; for speaker M2, F (1, 16)=347.049, p<.0001. This difference was attributed to the greater length of CVC relative to CV. Three of the four speakers (all except speaker M2) also displayed an interaction between position and syllable type: for speaker M1, F (1, 16)=49.485, p<.0001; for speaker F1, (F (1, 16)=124.680, p<.0001; for speaker F2, F (1, 16)=10.079, p=.0059. An asymmetric final lengthening effect present for CV but not CVC was responsible for this interaction. Three of the four speakers displayed this asymmetry. For speaker M1, final CV (146 milliseconds) was nearly three times as long as non-final CV (50 milliseconds), whereas final CVC (211 milliseconds) was only marginally longer than non-final CVC (192 milliseconds). For speaker F1, final CV (237 milliseconds) was nearly twice as long as non-final CV (119 milliseconds), while final CVC (230 milliseconds) and non-final CVC (242 milliseconds) were virtually equivalent in duration. Final CV was also nearly double the length of non-final CV for speaker F2, 117 milliseconds vs. 68 milliseconds, while final and non-final CVC had roughly equivalent durations: 177 milliseconds for final CVC vs. 165 milliseconds for non-final CVC. Only speaker M2 displayed a substantial lengthening effect on both final CV and final CVC. Final CV was nearly twice as long as non-final CV: 163 milliseconds vs. 82 milliseconds. Final CVC was roughly 35% longer than non-final CVC: 251 milliseconds vs. 185 milliseconds.

For the CVC syllables, a two-factor ANOVA with speaker and position as dependent variables were conducted to assess the effect of final position on the vocalic and consonantal phases of the syllable. For the vowel portion, there was a significant effect of speaker (F (3, 32)=66.492,p<.0001) but not position on duration values. There was an interaction between the two factors as well: F (3, 32)=15.651, p<.0001. For codas,

there was an effect of both position ($F(1, 32)=24.326, p<.0001$) and speaker ($F(3, 32)=11.409, p<.0001$) on values and also an interaction between the two factors ($F(3, 32)=18.519, p<.0001$). Posthoc tests indicated a significant overall effect across speakers on coda duration ($p<.0001$) but not vowel duration in CVC. An individual speaker ANOVA for speaker M1 with position as the tested variable indicated a significant effect of position on both vowel ($F(1, 8)=18.643, p=.0026$) and coda ($F(1, 8)=17.392, p=.0031$) duration, though the durational patterns were reversed for the two phases. Non-final vowels were slightly longer than final vowels (88 vs. 60 milliseconds) whereas final consonants were longer than non-final consonants (151 vs. 104 milliseconds). For speaker F1, there was an effect of position on both the vowel ($F(1, 8)=11.707$, $p=.0091$) and the coda consonant ($F(1, 8)=7.345, p=.0267$) in CVC. However, for this speaker, final vowels were marginally longer than non-final vowels (120 vs. 108 milliseconds), while non-final codas were slightly longer than final codas (134 vs. 110 milliseconds). Speaker F2 did not show an effect of position on either the vowel or the coda in CVC. Speaker M2 displayed an effect of position on coda ($F(1, 8)=56.762, p<.0001$) but not vowel duration in CVC. The consonant in final CVC was longer than the one in non-final CVC: 157 vs. 97 milliseconds.

Summarizing the comparison of final vs. non-final position, the most consistent result was the asymmetric lengthening of the rime in final CV but not final CVC for all but one of the speakers. The lack of an overall lengthening effect on final CVC is attributed to either a lack of lengthening of either the vowel or the consonant in final CVC (speaker F2) or the occurrence of shortening in either the vocalic (speaker M1) or consonantal (speaker F1) phase of final CVC, which offsets the slight lengthening of the other portion of the rime. The one speaker who did have a longer overall rime duration for final CVC (speaker M2) displayed a lengthening effect in the consonant but none in the vowel. In any case, for even the two speakers who did lengthen the coda consonant in final CVC, the degree of consonant lengthening was considerably less than that observed for vowels in final CV.

The consistent lengthening of final CV but not final CVC for the majority of speakers is an interesting result since cross-linguistic studies of final lengthening have shown that final consonants are also targeted by final lengthening (Berkovits 1993, Oller

1979). A language-specific property of Arabic, however, likely explains this difference between Arabic and other languages. Arabic contrasts single and geminate consonants in final position, meaning that a substantial increase in length of the final consonant in CVC could endanger the perceptual robustness of the consonant length contrast. Thus, just as we have hypothesized that the degree of final vowel lengthening is constrained by the presence of phonemic vowel length, the degree of final consonant lengthening is plausibly also sensitive to phonemic contrasts in duration. In fact, the combination of phonemic consonant length and the lack of phonemic vowel length plausibly conspire to reduce the duration ratio between final CVC and final CV, thereby reducing the likelihood of CVC being treated as heavy in final position.

We now consider in figure 6 the duration ratios between various syllable types and CV in the equivalent position in both final and non-final contexts. Within the data group for a single speaker, only the leftmost syllable, CVC in final position, is light, while the remaining four syllable types, final CVCC and CVVC, and non-final CVC and CVV, are heavy.

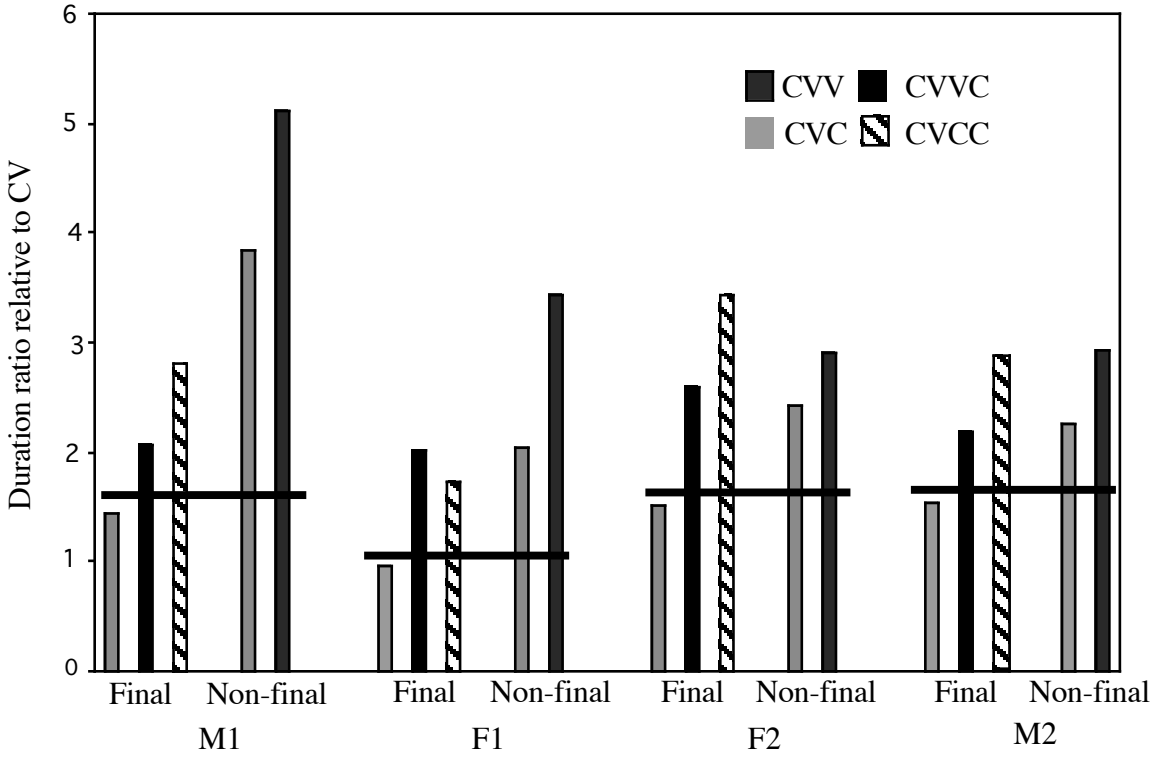


Figure 6. Duration ratio between various rimes and CV in the equivalent context for four speakers of Egyptian Arabic

As predicted by the proportional duration theory of weight, all of the heavy syllables are longer relative to CV in the same context than the light syllable, final CVC. A horizontal line indicates this separation between heavy and light syllables. All of the heavy syllables are at least twice as long as CV, while light final CVC is considerably less than twice as long as final CV.

In summary, the proportional duration theory of weight is supported by the duration patterns characteristic of final and non-final syllables in Egyptian Arabic. Final CV undergoes considerable lengthening which reduces the duration ratio of other syllable types relative to it. The lengthening of final CV creates a substantial asymmetry in the proportional ratio of CVC relative to CV in the same context: CVC is much longer than CV in non-final syllables but only slightly longer than CV in final syllables. The absence of lengthening in final CVC for the majority of speakers further reduces the durational ratio of CVC to CV in final position in accordance with the light status of final CVC. The asymmetric lengthening of final CV but not final CVC has a functional explanation in

terms of contrast maintenance. Final CV is free to lengthen substantially due to the lack of a phonemic length contrast in word-final vowels, whereas final CVC is constrained in the extent to which it may lengthen since lengthening could threaten the perceptual robustness of the phonemic contrast between singleton and geminate consonants in final position.

### 7.2. Kabardian

Kabardian is a Northwest Caucasian language spoken primarily in the Kabardino-Balkar Republic of Russia and in Turkey. Stress in Kabardian (Abitov et al. 1957, Apazhev et al. 1975, Colarusso 1992, 2006) is phonologically predictable, falling on a final heavy syllable, equivalent to CVV, CVC (4a), and otherwise on the penult (4b) (Certain suffixes fall outside of the stress domain but this is not relevant for the present discussion.)

(4) a. sɐˈbən ‘soap’, tɐpˈʃɐg ‘plate’, saːˈbiː ‘baby’, naːˈnuː ‘kid’

b. ˈpaːsɐ ‘early’, ˈməʃɐ ‘bear’, χɐrˈzənɐ ‘good’, ʔɐˈdaːqʼɐ ‘rooster’

The stress attracting ability of final CVC and CVV indicates that both are heavy in final position, in contrast to light CV. Because weight only is relevant in determining the stressability of final syllables, weight does not come into play in non-final syllables. Thus, the crucial data for assessing the proportional duration theory of weight involve syllables in final position.

#### 7.2.1. Methodology

The Kabardian data consisted of words varying in the type of syllable occurring in final position. Focus was on CV and CVC, the two syllables occurring in both final and non-final syllables in both Kabardian and Arabic. In addition, the examined final syllables in Kabardian included CVV, CVCC, and CVVC. CV and CVC were also examined in penultimate position to allow for comparison of the relative effects of final lengthening

on the two syllable types and to allow for comparison with the Arabic results. All target syllables were stressed in order to control for the possibility of stress influencing duration. Words ending in stressed CV were monosyllabic due to the nature of the stress system. To allow for a more direct comparison of CV and CVC, final CVC was also elicited in a monosyllabic word. The other heavy syllable types appeared in disyllabic words, since the long low vowel does not occur in monosyllables. The corpus of examined words appears in the appendix.

Target words were recorded from three native speakers (two female and one male) of Kabardian from Turkey directly onto a computer at a sampling rate of 44.1kHz using a portable handheld microphone in a quiet room. Five tokens of each word were recorded. Duration measurements were taken using Praat (www.praat.org) following the same procedure employed in the analysis of Egyptian Arabic.

### 7.2.2. Results

Overall results indicated a less pervasive final lengthening effect on final CV in Kabardian compared to Egyptian Arabic. Final lengthening was only observed for one of the three Kabardian speakers and the degree of lengthening for this speaker was smaller than that observed in Arabic. The lack of consistent lengthening in final CV in Kabardian is consistent with the heavy status of final CVC in Kabardian. We now consider results for individual speakers in detail.

Figure 7 displays the duration of final rimes in Kabardian for the three speakers providing data.

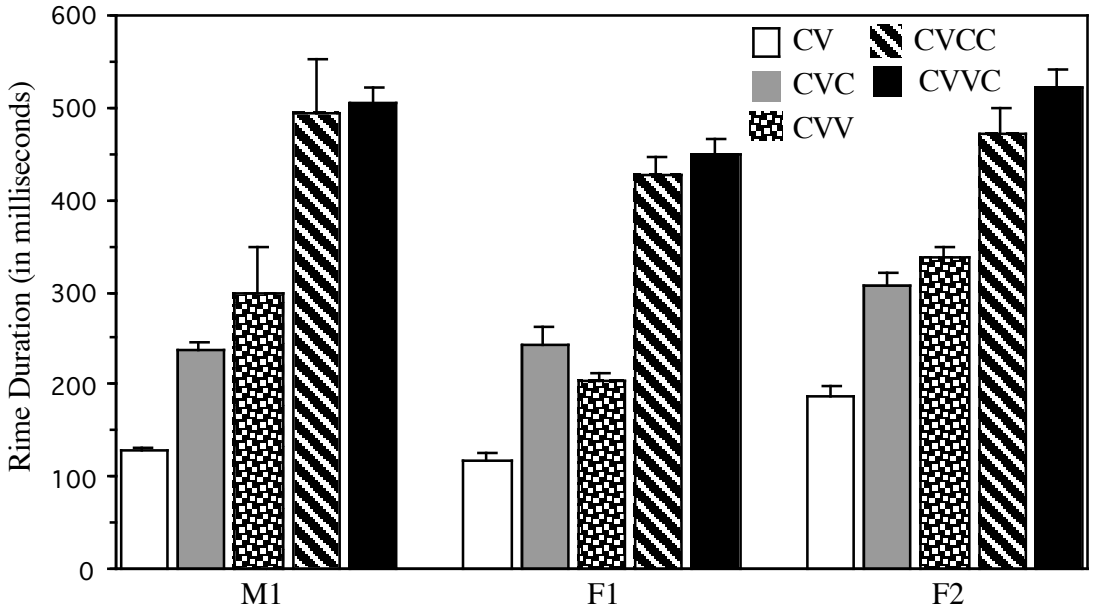


Figure 7. Rime duration in final syllables for three speakers of Kabardian

The heavy syllables CVC, CVV, CVCC, and CVVC are all substantially longer than the light syllable CV. A two-factor analysis of variance with speaker and syllable type as independent variables indicates a significant effect of both factors on rime duration: for speaker, $F(2, 61)=70.609$, $p<.001$; for syllable type, $F(4, 61)=590.645$, $p<.001$. Furthermore, there was an interaction between speaker and syllable type: $F(8, 61)=6.532$, $p<.001$.

Fisher's posthoc tests indicated that all rime types differed durationally from each other, except for CVV and CVC. All of the statistically robust pairwise comparisons were significant at $p<.001$ except for CVVC vs. CVCC ($p=.022$). Statistical tests conducted for individual speaker data indicated a largely similar pattern. For all speakers, a one-factor ANOVA taking syllable type as the independent variable indicated a significant effect of syllable type on duration: for speaker M1, $F(4, 18)=101.666$, $p<.001$; for speaker F1, $F(4, 21)=470.592$, $p<.001$; for speaker F2, $F(4, 22)=319.474$, $p<.001$. Posthoc tests showed that all four rimes occurring in final position differed from each other at the $p<.001$ level for all speakers with a few exceptions. For speaker M1, the difference between CVC and CVV and the difference between CVCC and CVVC were not significant. For speaker F1, CVC and CVV differed at $p=.009$, while CVCC and CVVC

did not differ from each other. For speaker F2, CVC and CVV did not differ from each other, while CVCC and CVVC differed from each other at p=.003.

Figure 8 depicts vowel duration in final syllables for individual speakers.

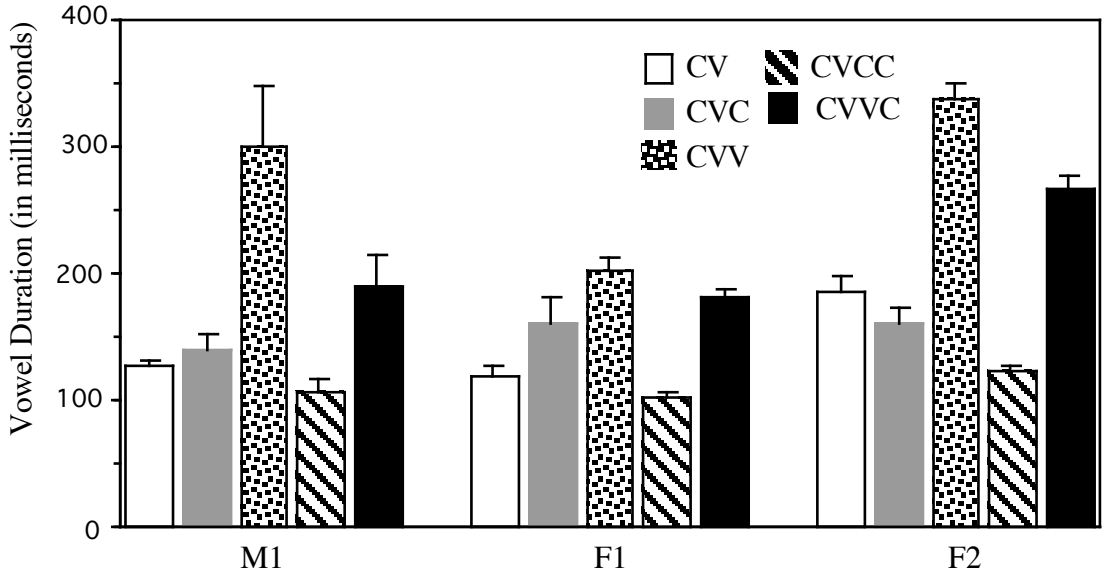


Figure 8. Vowel duration in final syllables for three speakers of Kabardian

An ANOVA was conducted with speaker and syllable type as independent variables and vowel duration as the dependent variable. There was a significant effect of both speaker ($F(2, 10)=105.321$, $p<.001$) and syllable type ($F(4, 61)=264.914$, $p<.001$) on duration. In addition, there was an interaction between the factors: $F(8, 61)=18.447$, $p<.001$. Posthoc tests indicated a four-way distinction in vowel duration. The phonemic long vowel in CVV was longest, followed in turn by the long vowel in CVVC, the short vowels in CV and CVC, and the short vowel in CVCC. All of the pairwise duration comparisons were significant at the $p<.001$ level except for the distinction between the vowel in CV and CVC, which were virtually identical in duration (CV=144 milliseconds vs. CVC=154 milliseconds). Individual speaker ANOVAs also revealed a significant effect of syllable type on vowel duration for all three speakers: for speaker M1, $F(4, 18)=44.091$, $p<.001$; for speaker F1, $F(4, 21)=77.251$, $p<.001$; for speaker F2, F (4,

22)=376.055, p<.001. According to Fisher's posthoc tests, speaker M1 distinguished the vowel in CVV from all other vowels at p<.01. Speaker M1's long vowel in CVVC also differed from other vowels, though differences other than the one between CVVC and CVV were less significant: CVVC vs. CV (p=.022), CVVC vs. CVC (p=.064), CVVC vs. CVCC (p=.001). This speaker did not distinguish the vowel in CV from the vowel in CVC in terms of duration. Speaker F1 displayed a somewhat anomalous pattern in that the vowel in CVC was substantially *longer* than the vowel in CV at p<.001. The vowel in CVCC and the vowel in CV did not differ from each other. CVC was not reliably shorter than the vowel in CVVC for this speaker. The phonemic long vowels in CVVC and CVV also did not differ from each other. Speaker F2 distinguished vowel duration between all five rime types, with the difference being significant at p<.001 in all comparisons except CV vs. CVC, which was less significant: p=.011.

A crucial difference between Egyptian Arabic and Kabardian emerges in the consideration of vowel duration. Unlike Egyptian Arabic, which displayed substantial lengthening of the vowel in final CV relative to the vowel in final CVC, no such consistent effect was found for Kabardian. Only one speaker (F2) displayed longer vowels in final CV compared to final CVC, and the difference was relatively small, especially compared to the difference in duration between phonemic long and short vowels. Another speaker (M1) failed to distinguish the vowels durationally, and yet another speaker (F1) actually had the opposite pattern, whereby vowels were longer in final CVC than in final CV.

The small amount of final vowel lengthening found in Kabardian is apparent in figure 9, which compares the vocalic and consonant portions of final and non-final CV and CVC.

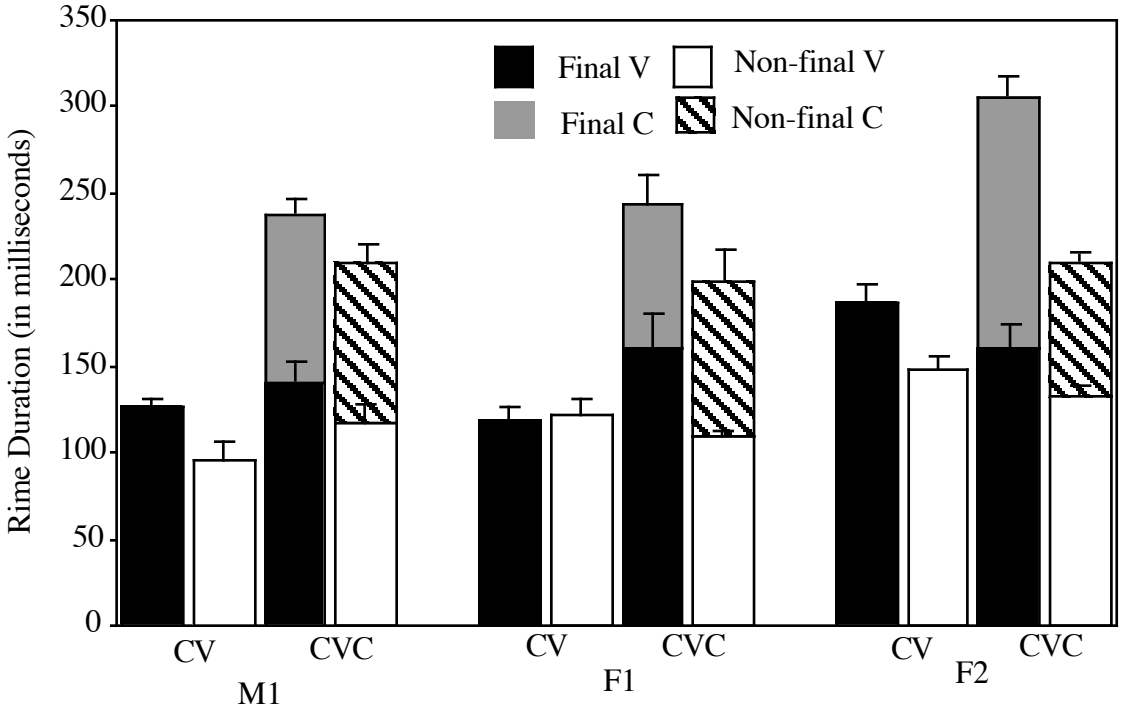


Figure 9. Rime duration (split by vowel and final consonant) in final syllables for three speakers of Kabardian

A three-factor ANOVA was conducted with speaker, syllable type, and position serving as independent variables and rime duration as the dependent variable. All three factors exerted a significant effect on duration values: for speaker, $F(2, 48)=91.739$, $p<.001$; for syllable type $F(1, 48)=1102.875$, $p<.001$; for position, $F(1,48)=164.237$, $p<.001$. In addition, there were several interactions between variables: between syllable type and position, $F(1, 48)=31.890$, $p<.001$, between syllable type and speaker, $F(2, 48)=3.946$, $p=.026$, and between speaker and position, $F(2, 48)=23.844$, $p<.001$. There was also a three-way interaction between all factors: $F(2, 48)=9.921$, $p<.001$. In individual speaker ANOVAs, all three speakers showed a significant effect of position on duration: for speaker M1, $F(1, 15)=31.365$, $p<.001$, for speaker F1, $F(1, 16)=12.468$, $p=.003$; for speaker F2, $F(1, 17)=192.011$, $p<.001$. This result was attributed to a substantial lengthening effect in final syllables. In addition, duration was influenced by syllable type for all speakers: for speaker M1, ($F(1, 15)=461.829$, $p<.001$); for speaker F1, ($F(1, 16)=315.421$, $p<.001$); for speaker F2, $F(1, 17)=391.940$ $p<.001$. This

difference was attributed to the greater length of CVC relative to CV. Two of the three speakers also displayed an interaction between position and syllable type: for speaker F1, ($F(1, 16)=18.523$, $p=.001$; for speaker F2, $F(1, 17)=35.244$ $p<.001$. Asymmetries in the length of final vs. non-final syllables between CV and CVC were responsible for this interaction. For speaker F1, final CVC was longer than non-final CVC (243 milliseconds vs. 199 milliseconds) but final and non-final CV were virtually equivalent in duration (118 milliseconds vs. 122 milliseconds). Speaker F2 displayed a smaller final lengthening effect in CV (186 milliseconds vs. 148 millisecond) as compared to CVC (306 milliseconds vs. 209 milliseconds) syllables. Speaker M1 had similar final lengthening effects in both CV (127 milliseconds vs. 96 milliseconds) and CVC (237 milliseconds vs. 210 milliseconds).

For the CVC syllables, two-factor ANOVAs with speaker and position as dependent variables were conducted to assess the effect of final position on the vocalic and consonantal phases of the syllable. For the vowel portion, there was a significant effect of speaker ($F(2, 24)=5.921$, $p=.008$) and position ($F(1, 24)=61.542$, $p<.001$) on duration values. There was an interaction between the two factors as well: $F(2, 24)=3.882$, $p=.035$. For codas, there was an effect of both position ($F(1, 24)=31.560$, $p<.001$) and speaker ($F(2, 24)=13.608$, $p<.001$) on values and also an interaction between the two factors ($F(2, 24)=34.794$, $p<.001$). There were interesting differences between speakers in the duration patterns found in final CVC that were confirmed in t-tests. Speaker F2 showed a substantial lengthening effect in the final consonant in CVC relative to its non-final counterpart ($t=14.179$, $p<.001$), and a smaller lengthening effect in the vowel ($t=4.838$, $p=.003$). On the other hand, speaker M1 displayed a significant effect of position on vowel duration ($t=3.382$, $p=.01$) but not coda duration. Similarly, for speaker F1, there was also an effect of position on vowel duration ($t=5.366$, $p=.005$) but not coda duration in CVC.

These lengthening patterns differ markedly from Egyptian Arabic in certain ways. First, and most crucially, the lengthening of the vowel in final CV was substantial and robust across speakers in Arabic but smaller and limited to a single speaker of Kabardian. This asymmetry between the two languages is plausibly attributed to differences in phoneme inventory between the two languages. Whereas final vowel length is phonemic

in Kabardian, it is not in Egyptian Arabic. Other observed differences between the two languages are less transparently linked to the distribution of phonological length. Phonetic lengthening of final consonants in CVC is small and inconsistent across speakers in Egyptian Arabic consistent with the contrastive nature of length in final consonants. While the effect of final lengthening on codas in CVC is overall greater in Kabardian, this difference is attributed primarily to a single speaker, even though length is not contrastive in final consonants in Kabardian. A more consistent, though small, lengthening effect is observed instead on the vowel in final CVC in Kabardian. There thus seems to be a preference, at least for certain speakers, for realizing final lengthening on vowels rather than consonants even when the vowel in the final syllable is shielded from the edge of the word by a coda consonant. The variation observed in final consonant length is consistent with cross-linguistic patterns established in section 6 linking phonemic consonant length and the weight of final CVC. Although some languages (4 of 10 in the survey) displaying final consonant extrametricality have contrastive consonant length in final position, the statistical majority (6 of 10) do not, a result that suggests that phonemic consonant duration is a less robust predictor of weight of final CVC than phonemic vowel duration.

### 7.3. Phonetic comparison of Egyptian Arabic and Kabardian

As a final comparison between the two languages, figure 10 shows the duration ratios (averaged across speakers) for heavy (all syllables except final CVC in Arabic) and light syllables (final CVC in Arabic) relative to CV in the same position in the two languages.

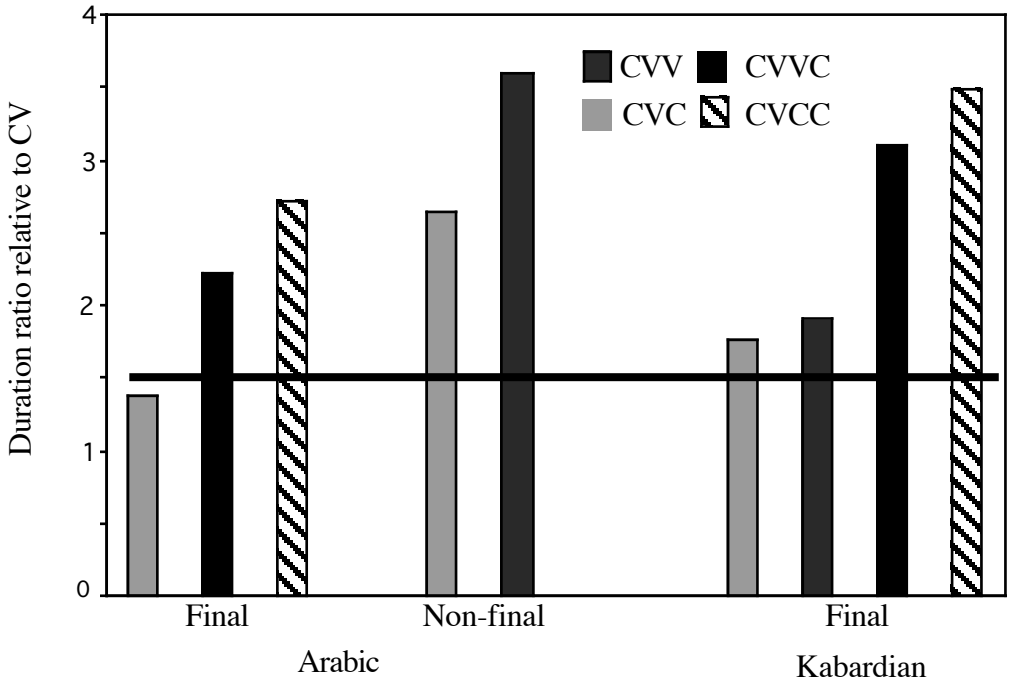


Figure 10. Duration ratio of heavy to light rimes in final syllables in Egyptian Arabic and Kabardian

As the figure shows, a line separating heavy and light syllables can be drawn across data from both languages. This result is consistent with the hypothesis that there is a single threshold ratio holding across syllable rimes that must be exceeded in order for a syllable to be considered heavy. This threshold must fall between 1.37, the ratio of light final CVC relative to final CV in Arabic, and 1.83, the ratio of heavy CVC relative to CV in Kabardian. Interestingly, these data are compatible with Lunden's (2006) hypothesized threshold of 1.6 based on her Norwegian data. Whether the consistency between the current study and Lunden's research is coincidence or not must await further typological evaluation, but it offers plausibility to the hypothesis that there may be a single universal threshold separating heavy and light syllables.

## 8. A diachronic account of consonant extrametricality

The analysis of consonant extrametricality pursued here has assumed that positional asymmetries in the weight of CVC are conditioned by synchronic phonetic factors. It is also a priori possible that there are diachronic explanations for the greater weight of CVCC relative to CVC in final position in some languages. One attractive historical-based approach links the weight asymmetry between CVCC and CVC to vowel apocope (or loss of an entire final rime). Under this account, final CVCC is heavy because there was once a vowel after the cluster, i.e. CVCCV, which meant that the closed syllable was originally in penultimate rather than final position. Assuming that stress patterns became entrenched while this vowel was still present, one could simply assume that stress originally fell on closed penults without any provision for consonant extrametricality. By the time the chronologically later loss of final vowels turned CVCCV to CVCC, the placement of stress on the precluster vowel had already become fossilized. This account finds support from the fact that at least some of the languages, e.g. Estonian, Arabic, English, displaying consonant extrametricality lost material at the right edge of words historically. However, Shaw (1985:9) suggests that there is no diachronic evidence for a vowel ever appearing after final CVCC in Stoney Dakota, which also displays consonant extrametricality.

Turning to languages in which there *is* evidence of vowel loss, it is informative to consider contexts in which deletion applied other than following a consonant cluster. The diachronic account predicts that the synchronic stress pattern would *not* place stress on final CVC that was originally followed by a vowel but came to stand in final position due to apocope, i.e. CVCV > CVC. Detailed evaluation of this prediction for all languages displaying consonant extrametricality falls outside the scope of the present work. However, it is instructive to consider a probative case from Estonian that allows testing of the merits of the diachronic approach to consonant extrametricality.

As background, let us consider the synchronic stress pattern of Estonian, which places primary stress on the initial syllable and secondary stress on odd-numbered syllables after the first one (Hint 1973). This basic pattern is found throughout the Finnic language family and can thus be reconstructed for the proto-language (Laanest 1975).

There are certain deviations from this basic alternating pattern in Estonian (shared in modified form with its linguistic relative Finnish) that are conditioned by weight. One of these weight effects is germane to the present discussion: final syllables are unstressed unless they are heavy, i.e. CVCC in Estonian. All of the final CVCC syllables found synchronically in Estonian were originally followed by a vowel at least through the proto-Finnic period. They would thus have been predictably stressed by the alternating stress pattern regardless of weight if they fell in an odd-numbered syllable. For example, ˈrɑːmaˌtuks ‘book (translative sg.) can be reconstructed as *ˈrɑːmɑˌtuksi. Interestingly, many CVC syllables that are now word-final were originally followed by a vowel as well, e.g. ˈrɑːmɑtul ‘book (adessive sg.) historically *ˈrɑːmɑˌtullɑ, ˈkirjuttɑp ‘write (3sg. present)’ historically *ˈkirjutˌtɑpi. These syllables would also be predicted, incorrectly, to receive stress by the alternating pattern if one were to assume that stress patterns became entrenched before the final vowel was deleted. In order to account for the lack of stress on final CVC that was originally non-final, one would have to assume a subsequent process of stress deletion targeting final CVC but not final CVCC. Although such a process could plausibly have taken place, the asymmetric loss of stress on final CVC but not final CVCC would still require explanation.

The Estonian facts illustrate a more general limitation of a historically-driven account of consonant extrametricality for languages in which there is a left-to-right component in the stress assignment algorithm and in which apocope applied after single consonants and clusters. The presence of an additional vowel following a single consonant increases the number of syllables in a word, thereby potentially predicting different stress patterns for words that not only end synchronically in CVCC but also those that end in CVC, as in Estonian. Egyptian Arabic provides another relevant example of the limitations of the historical approach. Synchronic CVCVCVC words that originally ended in a vowel that was lost as part of a chain shift shortening final long vowels and deleting final short vowels (Birkeland 1952) would be incorrectly expected to have stress on the syllable that is now final but was originally penultimate, i.e. CVCV'CVCV > CVCV'CVC.

In summary, regardless of the role one attributes to historical factors in shaping synchronic stress systems, the proportional duration theory of weight offers a viable account of final weight asymmetries.

## 9. Conclusions

Both typological and phonetic evidence are consistent with a theory of final consonant weight grounded in functional and phonetic considerations. The functional load of duration dictates the magnitude of phonetic final lengthening on a language-specific basis: segments that participate in phonemic length contrasts in final position are constrained in the amount of final lengthening they may undergo. The degree of final phonetic lengthening in turn predicts the phonological weight status of final CVC. If lengthening of final vowels is substantial (as in languages without final phonemic vowel length), the duration ratio between final CVC and final CV is less likely to be sufficiently large for CVC to count as heavy. If, on the other hand, the lengthening of final vowels is smaller (as in languages with final phonemic vowel length), final CVC is long enough relative to final CV to be stress-attracting. The opposite relationship between phonemic length, phonetic length and final CVC weight obtains in the case of consonants though the relationship between phonemic and phonetic duration is less consistent for consonants than for vowels. Reduced phonetic lengthening of final consonants, as in languages like Arabic with final phonemic consonant length, reduces the odds of final CVC attracting stress. Greater phonetic lengthening of final consonants, as in languages like Kabardian without final phonemic consonant length, increases the likelihood of final CVC being heavy.

The model of the phonetics-phonology interface entailed by the proposed account of final consonant extrametricality is depicted schematically in figure 11 (see Gordon 2002a,b, 2004, 2006 for further elaboration of this model).

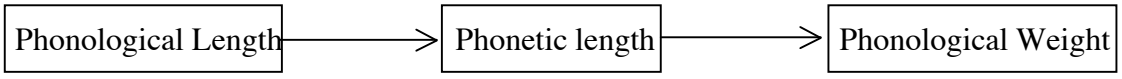


Figure 11. A phonetic-functional model of final syllable weight

A basic phonological property, the distribution of length contrasts, determines the magnitude of subphonemic duration. In turn, phonetic duration conditions another, more complex, phonological property: syllable weight, which is less transparent than phonemic length since it must be inferred from observation of asymmetries between syllables in their ability to attract stress.

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**Appendix**

Arabic corpus used in phonetic experiment

Final syllables

| | |
|---|---|
| fa | 'then' |
| man | 'who' |
| kans | 'sweeping' |
| xaːm | 'raw, unripe' |

Non-final syllables

| | |
|---|---|
| ˈ**sa**na | 'year' |
| ˈ**man**zˤar | 'appearance' |
| ˈ**baː**rid | 'cold' |

Kabardian corpus used in phonetic experiment

Final syllables

| | |
|---|---|
| ʃɐ | 'milk' |
| ʃɐm | 'milk (ergative)' |
| siːˈ**nɐps** | 'my tear' |
| siːˈ**baːʃ** | 'my stick' |
| lɐˈ**ʒaː** | 'work (interrog)' |

Non-final syllables

| | |
|---|---|
| ˈ**ʃɐ**kʲʔɐ | ‘milk (instr)’ |
| ˈ**ʃɐm**kʲʔɐ | ‘milk (instr)(def.)’ |