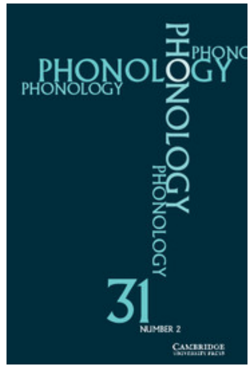


Syllable weight: convergence of phonology and phonetics

Ellen Broselow, Su-I Chen and Marie Huffman

Phonology / Volume 14 / Issue 01 / May 1997, pp 47 - 82
DOI: null, Published online: 19 November 2002

Phonology **14** (1997) 47–82. Printed in the United Kingdom

*Syllable weight: convergence of phonology and phonetics**

Ellen Broselow
Su-I Chen
Marie Huffman
State University of New York at Stony Brook

1 Introduction

In some languages, syllable weight depends exclusively on vowel length, while in others, coda consonants add weight to syllables. In this paper we assume that syllable weight is reflected in moraic structure, and that weight-bearing coda consonants are the exclusive dependents of a mora, while weightless consonants share a mora with the preceding vowel. We consider whether the durations of vowels and coda consonants reflect the distinction between a segment which occupies its own mora and a segment that shares a mora. We examine three patterns of coda weight, reflected in stress assignment: in Hindi, codas always contribute to syllable weight; in Malayalam, coda consonants are always weightless; and in Levantine Arabic, coda weight is contextually determined, with word-internal codas contributing to syllable weight following a short vowel, but weightless following a long vowel. These phonological patterns translate into different moraic representations of CVC and CVVC syllables across the different languages. We examine the durations of vowels and coda consonants in CV, CVC, CVV and CVVC syllables in Hindi, Malayalam and Levantine Arabic, and find that in all three languages, segments that we represent as mora-sharing are significantly shorter than segments that we represent as occupying an independent mora. The striking differences in durational patterns across the three languages correlate with the different moraic representations proposed on the basis of phonological patterning.

Having motivated different patterns of moraic representation, and having shown the correlation between moraic representation and segment duration, we then consider the grammars associated with these patterns. We propose a set of constraints on moraic and syllabic structure that define four possible patterns for the realisation of input CV, CVV, CVC and CVVC: the Hindi pattern, with all codas heading a mora; the Malayalam pattern, with all codas sharing a vocalic mora; the Levantine

Arabic pattern, with an independently moraic coda in CVC syllables but with the coda sharing a mora in CVVC syllables; and a fourth pattern, exemplified by Egyptian Arabic, in which a long vowel is shortened in a closed syllable, realising lexical CVVC as CVC. (We restrict our focus to the contrast between CV, CVV, CVC and CVVC, due to the relative scarcity of CVCC examples and to the difficulty of measuring individual consonant durations in clusters.) We propose that the four surface patterns produced by the various possible constraint rankings represent all and only the attested patterns of syllable-weight opposition found in natural language.

We begin by examining the facts of stress in the two languages with uniform coda weight, Hindi and Malayalam. In §2 we present moraic representations for these two languages and examine their durational patterns. In §3 we turn to Levantine Arabic, in which coda weight varies according to vowel length, and again show the correspondence between moraic representation and rhyme segment duration. We contrast the Levantine facts with those of Egyptian Arabic, which uses a strategy of mora loss, rather than mora sharing, to avoid the realisation of lexical CVVC as trimoraic. §4 summarises the cross-linguistic correspondence between phonological representation and phonetic duration. We turn in §5 to the set of constraints and the rankings necessary to account for the different patterns of moraic association. We consider both the patterns that our constraint set will generate and those patterns that are predicted to be impossible.

2 Uniform coda weight: Hindi and Malayalam

2.1 Weight-bearing codas: Hindi

Hindi stress has been the subject of a number of studies, among them Kelkar (1968), Ohala (1986), Gupta (1987), Pandey (1989), Shukla (1990), Prince & Smolensky (1993) and Hayes (1995). As Ohala (1986) documents, there is a great deal of inter- and intra-speaker variation in Hindi stress, as well as conflicting effects of word-level and phrasal stress, where three degrees of syllable weight must be recognised: light (CV), heavy (CVV or CVC) and superheavy (CVVC or CVCC). (We adopt the general assumption that onsets are irrelevant to syllable weight, but follow common practice in including a C onset in shorthand reference to syllable types.) In the dialect described by Kelkar (1968), these three syllable types form a hierarchy of prominence, with stress falling on the heaviest syllable within a word. When a word contains more than one contender for heaviest syllable, the rightmost non-final candidate is stressed. The forms in (1a–c) show a superheavy syllable attracting stress in various positions, while (1d–e) show stress on the rightmost non-final superheavy syllable (data from Hayes 1995, which relies on Kelkar 1968):

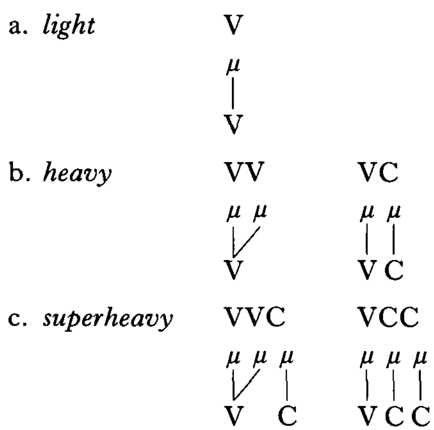
(1) a. ʃóox.ǰa.baa.nii 'talkative'
b. réez.gaa.rii 'small change'
c. mu.sal.máan 'Muslim'
d. áas.mãã.ǰaah 'highly placed'
e. aas.máan.ǰaah 'highly placed' (alternative pronunciation)

In the absence of a superheavy syllable, the heaviest syllable attracts stress. In case of a tie, stress falls on the rightmost non-final heavy syllable:

(2) a. kaa.rií.ga.rii 'craftsmanship'
b. roo.záa.naa 'daily'
c. ru.pi.áa 'rupee'
d. ki.d^hár 'which way'

The preference for stressing the heaviest syllable in a word is described by Prince & Smolensky (1993) as an effect of the high ranking of a constraint PEAKPROMINENCE, which favours assignment of prominence to the heaviest syllable in a stress domain. (A lower-ranked constraint, NON-FINALITY, forbids assignment of peak prominence to a final syllable. The effects of this constraint become visible only when a tie for heaviest syllable prevents the satisfaction of PEAKPROMINENCE.) We assume, following Hyman (1985), Hayes (1989) and others, that syllable weight is a reflection of moraic structure. The following structures represent the three degrees of Hindi weight in terms of mora count.

(3) *Hindi syllable rhyme structures*



In most dialects of Hindi, then, each coda consonant has its own mora, resulting in a three-way contrast among monomoraic, bimoraic and trimoraic syllables. We now contrast the Hindi facts with a language in which coda consonants are weightless.

2.2 Weightless codas: Malayalam

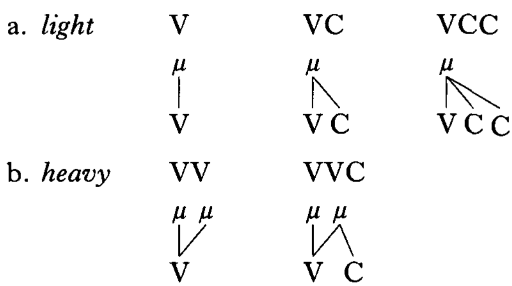
Malayalam stress is also sensitive to syllable weight, but in this language, weight is solely dependent on vowel length. According to Mohanan (1986: 112): 'If the first syllable of a word has a short vowel and the second syllable has a long one, the primary stress falls on the second syllable; otherwise the primary stress falls on the first syllable. Secondary stress falls on all the remaining long vowels.' (4c, e, f) show the failure of initial V and VC rhymes to attract stress when followed by a long vowel:

(4) a. ká.rʲa.ʈi 'bear'
b. káa.rʲa.ɳam 'reason'
c. ka.rʲáa.rə 'agreement'
d. páʈ.ʈa.ɳam 'town'
e. paʈ.ʈáaɭam 'army'
f. aŋ.gáa.rʲa.sàat̪.mìi.ka.rʲa.ɳam 'carbon assimilation'

Hayes (1995) analyses the Malayalam stress pattern as the construction of moraic trochees from the left edge of the word. Syllable weight is determined entirely by vowel length. An initial sequence of light syllable followed by heavy syllable cannot be grouped into a moraic trochee, since this would result in an ill-formed foot: the head, on the left, would be lighter than the complement, on the right. Thus the initial syllable is skipped, and the second (heavy) syllable constitutes a foot head. A ban on degenerate (monomoraic) feet prevents the initial syllable in this case from being footed on its own, leaving it unstressed.

Malayalam differs from Hindi in that syllables containing long vowels do not pattern with CVC syllables, while CVV and CVVC pattern identically. Thus, whereas Hindi stress motivates three degrees of syllable weight, Malayalam exhibits only a two-way contrast, reflected in the following representations:[1]

(5) *Malayalam syllable rhyme structures*



The different moraic structures shown in (3) and (5) account for the patterning of syllable types in the stress systems of Hindi and Malayalam.

If mora structure is reflected in segment duration, as proposed by Maddieson & Ladefoged (1993), Hubbard (1994, 1995), Broselow *et al.* (1995), among others, these structures predict different timing patterns in Hindi and Malayalam syllable rhymes.

2.3 Predicted duration patterns

Assuming a relationship between moraic structure and duration, the proposed structures in (3) and (5) make clear predictions about the relative durations of vowels and consonants in different kinds of rhymes in Hindi and Malayalam. These predictions are summarised in formulaic terms below. Taking Hindi vowels first, since coda consonants in Hindi have their own moras, the presence of a coda consonant does not affect the moraic content of the vowel. Thus, vowels should have comparable durations in open and closed syllables (e.g. VV = VVC), while vowel length contrasts are maintained (all VV > all V).

(6) *Predicted vowel duration patterns for Hindi*

$\mu\mu$ $\mu\mu$ μ μ
VV = VVC > V = VC

In contrast, the Malayalam rhyme structures in (5) predict four degrees of phonetic vowel length, with phonemically long vowels longer than phonemically short vowels, and vowels in closed syllables shorter than comparable vowels in open syllables.

(7) *Predicted vowel duration patterns for Malayalam*

$\mu\mu$ μ + shared μ μ shared μ
VV > VVC > V > VC

As for consonants, the languages are similar in that the moraic structure of a coda consonant is identical in both VC and VVC rhymes. In Hindi, a coda consonant always has its own mora, while in Malayalam, a coda consonant always shares a mora with the preceding vowel. So for each language, coda consonants following long and short vowels should have similar durations:

(8) *Predicted consonant duration patterns*

Hindi:	μ		μ
	VVC	=	**VC**
Malayalam:	shared μ		shared μ
	VVC		**VC**

The next sections present phonetic evidence bearing on these predictions.

2.4 Results

The general methodology for recording subjects and measuring segment durations was common to all languages studied. A word-list was constructed for each language containing minimally contrastive forms illustrating the syllable structure differences of interest. In all cases, the target syllable was non-word-final. To facilitate cross-linguistic comparisons, low non-front vowels were used in all the syllables of interest. A frame sentence was also constructed for each language, to minimise prosodic differences between experimental items such as list intonation. Subjects were presented with the word-list and frame sentence written in English, and were asked to say each word in the frame sentence, translating the entire sentence into their language. (The presentation of test items in English was designed to avoid the influence of orthography and, in the Arabic case, to encourage the use of the colloquial (spoken) variety rather than Modern Standard Arabic, which is the form normally written. Subjects were directed to speak as they would in an informal conversation with a friend, and experimenters monitored carefully to ensure that the appropriate colloquial forms were used.) To facilitate the task, the experimental items were grouped into blocks in the word-list. The last item in each block was a filler, not used in the analysis. Each subject produced three repetitions of each item. Recordings were made in a sound-treated room, and were then digitised and analysed using Kay Elemetrics' CSL speech analysis package. Segmentation was based on wide-band spectrograms and followed standard practice in identifying the consonant:vowel boundaries and vowel:consonant boundaries as the moment of sharp change in sound amplitude in the lower formants. In most cases, the consonants were non-continuants, often stops, which had readily identifiable closure onset and offset points. The consonants measured for Hindi include [p t s l], for Malayalam [t̪ t n̪ l] and for Levantine Arabic [b]. In all three languages, the syllable of interest was stressed. See Appendix B for a list of all test words.

2.4.1 *Hindi duration.* Two native speakers of Hindi (both female, age mid-twenties, from Uttar Pradesh) were recorded producing contrastive sets of words such as those shown in (9).[2] For each speaker there were four such sets, repeated three times, producing twelve tokens of each syllable type. In each token, the syllable containing the crucial segments was stressed.[3]

(9) *Sample Hindi word-set*
    a. k**a**.ʈaa 'was cut (PERF)'
    b. k**aʈ**.naa 'to be cut'
    c. k**aa**.ʈaa 'cut (PERF)'
    d. k**aaʈ**.naa 'to cut'

    Frame sentence:
    /ab me __ ʃabd kehne vali hũũ/ 'The word I am saying now is __.'

Means and standard deviations for the vowels and consonants of interest are given in Table I. There it may be seen that long vowels are at least twice as long as short vowels, and vowels with the same phonemic length have essentially identical durations in open and closed syllables. In addition, coda consonants have about the same length, regardless of whether they follow long or short vowels. The segments which were measured appear in bold face in Table I.

	VV	**VV**C	**V**	**V**C
speaker 1	143·5 (20·8)	142·5 (20·4)	66·1 (15·7)	66·0 (11·2)
speaker 2	152·6 (14·7)	158·4 (12·5)	80·4 (12·4)	77·4 (8·0)
		VV**C**		V**C**
speaker 1		109·3 (26·1)		115·6 (23·2)
speaker 2		105·5 (17·9)		98·8 (16·8)

[Table I. Mean vowel and coda durations (in ms) for four syllable types in Hindi. Standard deviations are given in parentheses.]

Statistical analysis of each speaker's duration data confirmed that the predictions schematised in §2.3 were borne out. Analysis of variance confirmed the relations predicted for specific segment-duration comparisons. The results are summarised in (10), using data for Speaker 1. The probability values for Speaker 2 were comparable, with no significant differences between like vowels in open *vs.* closed syllables, no difference in coda consonants following vowels of different phonemic lengths, and a highly significant difference ($p < \cdot 0001$) between long and short vowels.[4] More detailed results of these statistical tests are given in Appendix C. The duration patterns are illustrated graphically for one set of contrastive words with data from Speaker 2 in Fig. 1, which appears in §4.

(10) *Statistical results for Hindi Speaker 1*

Vowel duration: $\overset{\mu\mu}{\mathbf{VV}} \;=\; \overset{\mu\mu}{\mathbf{VV}\mathrm{C}} \;>\; \overset{\mu}{\mathbf{V}} \;=\; \overset{\mu}{\mathbf{V}\mathrm{C}}$

$p = \cdot 91 \qquad p < \cdot 0001 \qquad p = \cdot 98$

Consonant duration: $\overset{\mu}{\mathrm{VV}\mathbf{C}} \;=\; \overset{\mu}{\mathrm{V}\mathbf{C}}$

$p = \cdot 54$

In summary, then, we find no significant shortening of vowels in closed syllables and no significant difference in the durations of coda consonants after long *vs.* short vowels. Both of these patterns support the proposal that in Hindi, coda consonants do not share a mora with the preceding vowel.

2.4.2 *Malayalam duration.* Three native speakers of Malayalam, all from Kerala (all female, age 35, 35 and 69) read a word-list contrasting words with the four syllable types of interest. An example word-set is given in (11). For each speaker there were at least three tokens of each syllable type, and for most there were six or nine tokens. Each syllable containing the measured segments was stressed.

(11) *Sample Malayalam word-set*

a. **pa**.t̪i 'husband'
b. **paa**.t̪i 'half'
c. **pat**.ram 'leaf, newspaper'
d. **paat**.ram 'vessel'
e. **kal**.pa.na 'imagine, order' (for some speakers *kalppana*)
f. **kaal**.paa.t̪am 'foot'

Frame sentence :
/ñaan ippooɭ parayun̪n̪at̪u __ en̪n̪a vaakkaaɳu/ 'The word I am saying now is __'.

Table II summarises the duration data for the three speakers. There we see that vowels in closed syllables are always shorter than comparable vowels in open syllables. This vowel shortening, combined with the phonemic distinction in vowel length, produces four degrees of phonetic vowel length, for each speaker. As for the consonants, coda consonants have very similar durations following long and short vowels.

	VV	VVC	V	VC
speaker 1	216·8 (13·6)	166·3 (18·1)	96·2 (11·3)	77·0 (3·9)
speaker 2	236·9 (31·2)	178·0 (29·3)	119·6 (11·2)	79·5 (18·3)
speaker 3	366·6 (22·0)	282·2 (37·7)	166·9 (12·6)	99·7 (19·1)
		VVC		**VC**
speaker 1		71·0 (2·7)		67·0 (12·3)
speaker 2		37·5 (5·0)		39·1 (1·5)
speaker 3		84·5 (2·7)		85·9 (3·3)

[Table II. Mean vowel and coda durations (in ms) for four syllable types in Malayalam. Standard deviations are given in parentheses.]

Analysis of variance confirmed the significance of the patterns shown in Table II. The results are summarised in (12), with specific probability values for Speaker 1; other speakers had similar values, with all vowel duration differences significant to at least the ·01 level of significance, and no significant difference in coda consonant durations. More detailed results of statistical tests are given in Appendix C. These duration patterns are illustrated graphically in Fig. 1 (in §4), with data from Speaker 1.

(12) *Statistical results for Malayalam Speaker 1*

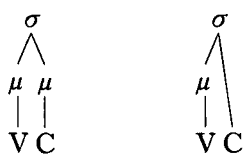
Vowel duration:	$\mu\mu$ **VV**	>	μ + shared μ **VVC**	>	μ **V**	>	shared μ **VC**
		p = ·0001		p = ·0001		p = ·003	

Consonant duration:	shared μ VVC	=	shared μ VC
		p = ·677	

In summary, in Malayalam we observe phonetic shortening of both long and short vowels in closed syllables. There is no significant difference in duration of coda consonants after long *vs.* short vowels. These patterns are consistent with moraic representations in which a coda consonant shares a mora with a preceding long or short vowel, and contrast with the Hindi patterns in which the presence of a coda consonant appears to have no effect on the length of a preceding vowel.

We should note that these patterns also favour a mora-sharing representation of a weightless coda, as opposed to an alternative representation in which weightless consonants attach directly to the syllable node (as in, for example, McCarthy & Prince 1986, Davis 1994). Given this representation, Hindi and Malayalam CVC syllable rhymes would have the following structures:

(13) a. *Hindi* b. *Malayalam*



It is difficult to find phonological arguments to distinguish representations like (13b) from the mora-sharing representation in (5). But our phonetic data do provide an argument. Given the mora-sharing representation of Malayalam closed syllables, closed syllable shortening is a direct reflection of moraic structure: a segment in a shared mora will be shorter than a corresponding segment that is fully moraic. But given the structures in (13), the shortening of vowels in closed syllables in Malayalam but not in Hindi has no obvious explanation: why should only non-moraic codas shorten a preceding vowel? We will therefore continue to assume that weightless coda consonants share a preceding vocalic mora, and turn to additional facts that are consistent with this hypothesis.

3 Variable coda weight

A third pattern of syllable weight opposition is exemplified by Levantine Arabic, a cover term for (mainly) urban dialects of Syria, Lebanon, Jordan and historical Palestine (though the relevant patterns discussed here are manifested in other dialects, including Iraqi). These are all dialects in which CVVC syllables are tolerated in non-final position (as opposed to dialects such as Egyptian and Makkan in which CVVC is not tolerated except word-finally: Broselow 1992, Farwaneh 1992, Abu-Mansour 1995). We argue that in Levantine Arabic, coda consonants may be either weight-bearing or weightless, depending on context: codas that follow a short vowel occupy their own mora, while codas following a long vowel share the preceding vocalic mora.

In the stress patterns of Levantine Arabic, both syllable weight and syllable position are crucial in determining the position of stress (see Kenstowicz & Abdul-Karim 1980, Kenstowicz 1983, Hayes 1995, among others). Stress falls on one of the last three syllables of the word, and final syllables are stressed only if they are CVVC, CVCC or CVV, as in (14a–c):[5]

(14) *Syrian Arabic* (Cowell 1964)

a.	ki.táab	'book'
b.	ma.fárr	'he did not escape'
c.	da.ras.túu	'you (PL) studied it (MASC)'
d.	ká.tab	'he wrote'
e.	da.rás.tu	'you (PL) studied'

In the absence of a CVV/CVVC/CVCC final syllable, stress falls on the penultimate syllable when it is CVC, CVV or CVVC, as in (15a–c). If neither the final nor the penultimate syllable is stressed, stress falls on the antepenult, as in (15d–f):

(15) *Syrian Arabic* (Cowell 1964)

a.	da.ras.túu.ha	'you (PL) studied it (FEM)'
b.	da.rás.hon	'he studied them'
c.	ma.náam.hon	'he did not dream them'
d.	mád.ra.se	'school'
e.	dá.ra.su	'they studied'
f.	má.sa.lan	'example'

As in Hindi, we see three classes of syllables differing in their ability to attract stress. However, the Levantine stress pattern does not imply three degrees of syllable weight. The fundamental generalisation is that in each position – word-final *vs.* penultimate – two classes of syllables are distinguished:

(16) *Stress-attracting syllables*

a. in word-final position:
   CVV, CVVC, CVCC (*vs.* CVC, CV)

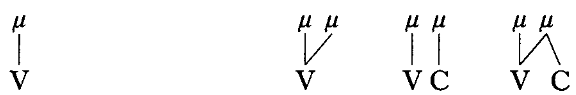
b. in penultimate position:
   CVV, CVVC, CVC, CVCC (if possible) (*vs.* CV)

The insight that underlies most analyses of Arabic stress is that a word-final consonant is irrelevant for the purposes of stress assignment (McCarthy 1979, Hayes 1981), rendering word-final CVC equivalent to CV. The irrelevance of the final consonant is in earlier accounts expressed in terms of extrametricality, but in an optimality-theoretic framework could be enforced by a constraint forbidding final consonants to head a mora. Thus, word-final CVC patterns with CV, because the constraint against final C moras prevents final C from adding weight to a syllable. This constraint has no effect on non-final CVC, which then patterns with CVV. Word-final CVVC and CVCC count as heavier than CVC not because they are trimoraic, but because – despite the weightlessness of their final consonant – they have sufficient non-final material to count as bimoraic.

Thus, Arabic stress provides no motivation for a three-way distinction in syllable weight. We will therefore argue that Levantine Arabic syllables are either monomoraic or bimoraic. The representation of non-final syllables is as follows (we omit CVCC, which is quite restricted in its occurrence, as discussed below):

(17) *Levantine Arabic syllable rhyme structures: non-final position*

a. *light* V   b. *heavy* VV   VC   VVC



Levantine Arabic is, in this account, a hybrid. Coda consonants bear weight in (non-final) CVC syllables, as in Hindi. But in CVVC syllables, coda consonants are weightless, sharing a mora with the preceding vowel, as in Malayalam.

An additional argument for the bimoraic analysis of Levantine CVVC syllables comes from the asymmetry between CVVC and CVCC. If CVVC is trimoraic, Levantine must allow trimoraic syllables. However, many of the dialects which allow CVVC syllables prohibit CVCC syllables or severely restrict the types of possible coda clusters they may contain (Broselow 1992, Farwaneh 1992). Given the assumption that CVVC syllables are bimoraic, we can account for the CVVC/CVCC asymmetry by assuming that trimoraic syllables are in fact prohibited in these dialects: CVVC is tolerated because a bimoraic analysis of CVVC is available, but constraints on moraic structure prohibit a bimoraic analysis of CVCC sequences (see Broselow *et al.* 1995 for arguments that constraints on the minimal sonority of head moras prevent assignment of the first consonant to the mora dominating the head vowel, and that constraints enforcing particular sonority profiles on non-head moras prevent the assignment of both coda consonants to a single mora in these cases).

3.1 Predicted duration patterns

Given the structures shown in (17), we would predict somewhat different durational patterns for Levantine Arabic than are found in Hindi and Malayalam. Because the coda consonant shares its mora with a preceding vowel only when that vowel is long, we expect to see only long vowels shortening in closed syllables. Short vowels should have essentially the same length in both open and closed syllables. Furthermore, since we have a contrast between coda consonants that occupy their own moras (after short vowels) and coda consonants that share a vocalic mora (after long vowels), we expect to see a difference in the length of coda consonants in CVVC *vs*. CVC syllables. Our predictions are summarised in (18):

(18) *Predicted duration patterns for Levantine Arabic*

Vowel duration:	$\mu\mu$		μ + shared μ		μ		μ
	VV	>	**VVC**	>	**V**	=	**VC**

Consonant duration:	shared μ		μ
	VVC	<	**VC**

3.2 Results

A speaker of Jordanian Arabic (male, age 36, from Zerka) was recorded reading a word-list contrasting the four syllable types of interest. Example words are given in (19). Each syllable containing the measured segments was stressed; note that, contrary to the general pattern of stress in Arabic, stress falls on the light penultimate in (19a), because in this form, *in-* is a proclitic, which cannot be stressed in this dialect. The speaker produced at least nine tokens of each syllable type.[6]

(19) *Sample Arabic word-set*

a. ʔin.n**a**.bi 'the prophet'
b. ʕi.n**ab**.hum 'their grape'
c. ki.t**aa**.bi 'my book'
d. ki.t**aab**.hum 'their book'

Frame sentence :[7]
/w baʕdeen ʃuft(i) __ / 'And then I saw a __.'

Table III summarises segment duration patterns for the Jordanian speaker, and provides comparable data for speakers of two other Levantine dialects – Syrian (male, age 30, from Damascus) and Lebanese (male, age 18, from Beirut), also discussed in Broselow *et al.* (1995).[8] In the table it may be seen that the duration predictions given in (18) are confirmed. That is, long vowels are shorter in closed syllables than in open syllables (about 10 to 30 milliseconds shorter), while short vowels have very similar durations, regardless of the presence of a following coda consonant. Furthermore, coda consonants following long vowels are about 15 to 35 milliseconds shorter than coda consonants following short vowels.

	VV	**VVC**	**V**	**VC**
Jordanian	161·0 (9·9)	131·6 (5·5)	80·2 (9·0)	79·9 (6·6)
Syrian	123·9 (5·7)	112·2 (5·7)	68·0 (1·9)	65·0 (4·7)
Lebanese	114·2 (7·8)	97·8 (6·3)	65·2 (6·4)	67·4 (8·4)
		VVC		**VC**
Jordanian		67·6 (9·4)		88·4 (10·3)
Syrian		80·9 (19·8)		114·4 (8·0)
Lebanese		66·9 (11·2)		81·2 (8·3)

[Table III. Mean vowel and coda durations (in ms) for four syllable types in Levantine Arabic. Standard deviations are given in parentheses.]

Analysis of variance confirmed that the specific vowel and consonant duration patterns outlined in Table III were statistically significant. The statistical results are summarised in (20), with specific probability values for the Jordanian speaker. Specific probabilities for the Syrian and Lebanese speakers were similar, with vowel duration differences significant to at least the ·0005 level, coda consonant durations different to at least the ·007 level and no significant difference between phonemically short vowels in open *vs.* closed syllables. More detailed results of statistical tests are given in Appendix C, and Jordanian data is represented graphically in Fig. 1.

(20) *Statistical results for Jordanian*

Vowel	$\mu\mu$		μ + shared μ		μ		μ
duration:	**VV**	>	**VVC**	>	**V**	=	**VC**
		$p < \cdot 00001$		$p < \cdot 00001$		$p = \cdot 94$	

Consonant duration:	shared μ		μ
	VV**C**	<	V**C**
		$p < \cdot 0002$	

In summary, then, in Levantine Arabic we find significant shortening of long (but not short) vowels in closed syllables and significant shortening of coda consonants after long vowels, relative to coda consonant duration after short vowels. These patterns accord well with the representations proposed in (17).

At this point we must consider the possibility that the difference in coda duration following long and short vowels has nothing to do with moraic structure, but rather results from a general phonetic effect of long vowels on following consonants regardless of syllable membership. If this is the case, then we would expect onset consonants to be shorter after long vowels than after short vowels (as is apparently the case in Sinhalese; Letterman 1994). There is no such effect in Arabic, as shown by the following data:

(21) *Mean onset C duration* (msec)

	VV.C	V.C
Jordanian	51·6	54·5
Syrian	66·7	62·7
Lebanese	78·0	81·2

Onsets following long and short vowels have very similar durations, and are not significantly different, as determined by analysis of variance. We therefore conclude that mora sharing provides the simplest analysis of both vowel and coda consonant shortening in Levantine Arabic.

3.3 Phonemic vowel shortening: Egyptian Arabic

We have analysed the shortening of long vowels in closed syllables in Levantine Arabic as an effect of the sharing of the second vocalic mora with the following coda consonant. We should note that other Arabic dialects exhibit a contrasting pattern of vowel shortening, generally described as a phonological process. The urban dialects of Lower Egyptian (including Cairene and Alexandrian) are generally described as shortening long vowels in closed syllables:

(22) *Lower Egyptian Arabic*
  a. kitaab 'book'
  b. kitabhum 'their book'

Broselow *et al.* (1995) present detailed analysis of the durational patterns of two speakers of Lower Egyptian Arabic. The data show that shortening in this dialect, unlike that in Levantine, actually neutralises the distinction between phonemically long and phonemically short vowels by reduction of a long vowel in a closed syllable to monomoraic. (23) shows a comparison between lexical long vowel in open syllable, lexical long vowel in closed syllable, and lexical short vowel in closed syllable in the two dialects:

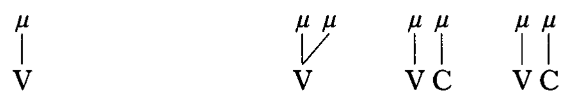
(23) *Vowel and consonant duration comparison* (msec)

	taa.bV	**ta(a)b**.CV		n**ab**.CV	
		V	C	V	C
Jordanian	161	131·6	67·6	79·9	88·4
Alexandrian	129·3	55·6	72·6	75·8	83·7
Cairene	115·4	78·1	85·5	81·2	85·9

As discussed above, the Jordanian long vowel in a closed syllable is significantly shorter than the long vowel in an open syllable ($p < \cdot 00001$). It is also significantly longer than a short vowel in a closed syllable. It is clear that the Egyptian pattern is quite different. The lexically long vowel in a closed syllable, while significantly shorter than the long vowel in an open syllable ($p < \cdot 00001$ for both the Alexandrian and Cairene speakers), is in fact somewhat shorter than the lexical short vowel.[9] Thus, we assume that Egyptian shortening is properly described as mora loss, rather than as mora sharing, consistent with the following (surface) structures.

(24) *Egyptian Arabic syllable rhyme structures: non-final position*

a. *light* V   b. *heavy* VC   VC   VC (from VVC)



Consonant durations also support these structures. The lexical length of vowels has no significant effect on the duration of a following coda, consistent with the analysis of all codas as occupying their own mora.

4 Summary: mora structure and duration

We have now seen four patterns of moraic structure corresponding to inputs containing long and short vowels in open and closed syllables. The durational patterns of these languages are consistent with the posited structures: segments dominated by two moras are longer than those dominated by one, and segments exclusively occupying a mora are longer than those sharing a mora. Fig. 1 demonstrates the representative patterns with one speaker of each language/dialect. We find two degrees of vowel length in Hindi, four in Malayalam, three in Levantine and two in Egyptian. We also find two degrees of coda consonant length in Levantine (Jordanian), the only language with contextually determined mora sharing. The striking cross-linguistic differences in the figure are entirely consonant with the moraic structures assigned to these languages on the basis of their phonological patterning.

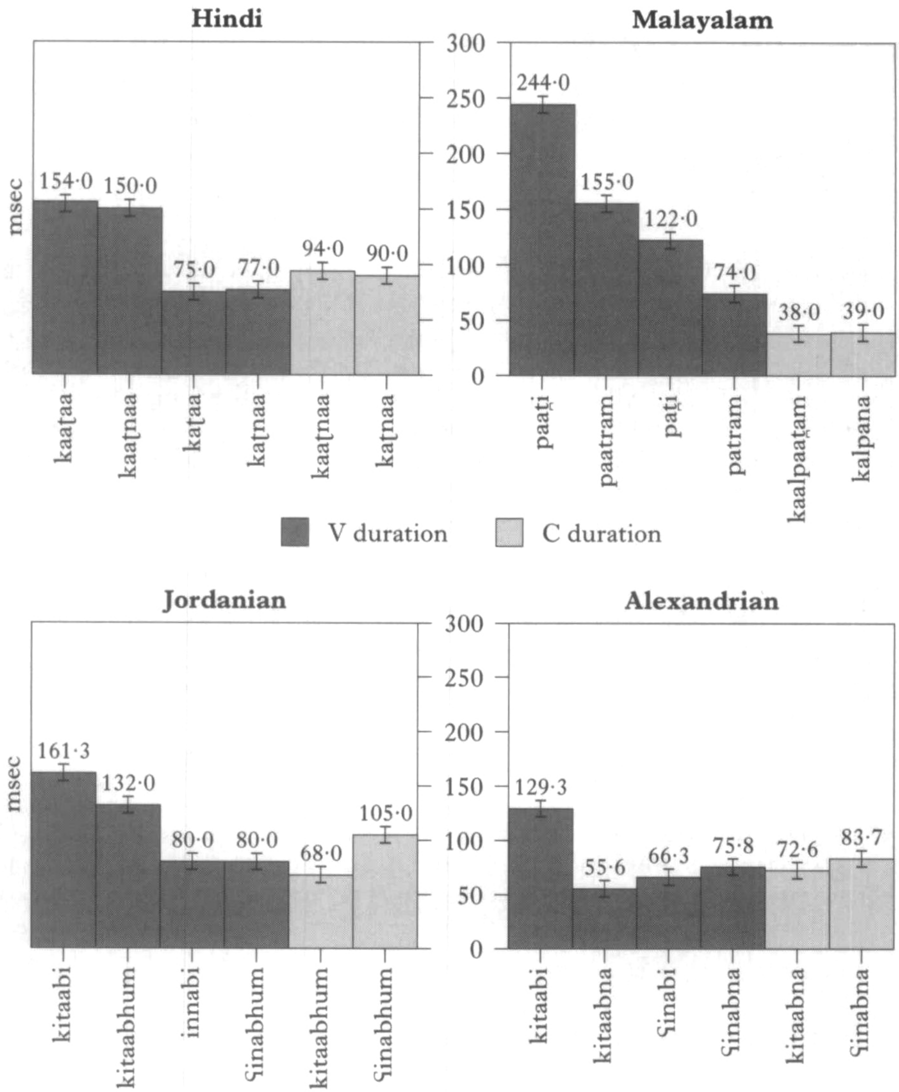
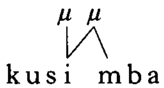


Figure 1
Rhyme segment duration comparisons.

Furthermore, the vowel duration patterns found in the languages with mora sharing are strikingly similar to those reported for other cases of mora sharing. Of particular interest is the case of Runyambo, a Bantu language which is argued to contrast three vowel lengths: monomoraic, bimoraic with the second mora shared with a following consonant and exclusively bimoraic (Hubbard 1994, 1995). Hubbard argues that the mora-sharing structure arises as a result of compensatory lengthening of a vowel preceding a root-internal nasal+stop sequence. This compensatory lengthening is analysed as association of the vowel with the mora dominating the nasal consonant, resulting in a vowel dominated by its original mora, plus a mora shared with the following consonant: for example, *ku+siimba* 'to erect something' is realised as in (25):

(25)



Compensatorily lengthened vowels should therefore contrast with short (monomoraic) vowels, and 'true' long vowels, which are bimoraic with no mora sharing. Table IV compares relative vowel durations in proportional terms for Runyambo[10] and for the two mora-sharing languages discussed here, Malayalam and Levantine Arabic.

	μ	μ + shared μ	$\mu\mu$
Runyambo	1	1·4	2·2
Malayalam	1	1·6	2·2
Arabic	1	1·6	1·9

[Table IV. Comparative vowel duration ratios for three languages proposed to have mora-sharing structures.]

We see that in all three languages, phonemically long vowels are about twice the length of a comparable phonemically short vowel, and that a vowel which shares a second mora with a following consonant has about one and a half times the duration of a comparable short vowel. The fact that the mora-sharing structure has a similar phonetic interpretation across a diverse set of languages constitutes strong support for moraic structure as a major determinant of segmental duration patterns. We now turn our attention to the grammars that give rise to the differences in moraic structure reflected in Fig. 1.

5 Constraints on moraic structure

In a derivational account of moraic structure, the Hindi, Malayalam and Arabic patterns can be derived by assuming a rule of Weight-by-Position, which assigns a mora to a coda consonant (Hayes 1989). This rule would apply to all codas in Hindi, to none in Malayalam and only to codas following short vowels in Levantine Arabic. Egyptian would require an additional rule removing a mora from a long vowel in a closed syllable. In this section we provide an alternative analysis of the Hindi, Malayalam and Arabic data consisting of a set of constraints on moraic structure, with different rankings of these constraints enforced in each language. We then broaden the scope of the investigation to situate these patterns within a theory of human language, by considering additional output patterns corresponding to the four inputs CV, CVV, CVC and CVVC. We argue that these constraints produce a more restricted set of outputs than would be possible if we assumed the possibility of contextually determined rules of Weight-by-Position and mora loss, which would allow for combinations of outputs that seem not to be attested in the world's languages.

5.1 Constraint ranking in Hindi, Malayalam and Arabic

We have argued above that one aspect of representation shared by the three languages under discussion is the association of coda consonants with a mora. We assume that this is an effect of a constraint requiring all segments in syllable coda to be dependents of a mora. (We leave open the possibility that the operative constraint might actually be more general, requiring all segments in syllable rhyme to be dominated by a mora.) This constraint will be highly ranked in all three languages (and possibly universally):

(26) MoraicCoda: All coda consonants must be dominated by a mora.

In languages in which coda consonants always contribute to syllable weight, MoraicCoda will obviously always be obeyed. Weightless consonants could conceivably be attached directly to the syllable node, incurring a violation of MoraicCoda. However, as discussed in §2.4.2, the mora-sharing representations forced by high ranking of MoraicCoda are consistent with the phonetic patterns of these languages, while an analysis of weightless consonants as attached directly to the syllable node in these languages would provide no explanation of the shortening seen in segments that are analysed here as mora sharing. In the following discussion, we will assume that all the languages under consideration rank MoraicCoda highly enough to force all coda consonants to link to a mora, even where this results in a violation of other constraints. (We do not, however, rule out the possibility that some language could rank Moraic Coda below other constraints, resulting in adjunction of a coda consonant directly to a syllable node, in which case we would expect to find phonetic patterns differing from the ones attested above.) Because all the languages under consideration rank MoraicCoda highly enough that it is never violated, we will not show the effect of this constraint in the tableaux below, focusing instead on constraints that are ranked differently across the languages.

The dimensions along which the language differ are their tolerance of trimoraic syllables, of mora sharing and of consonantal moras. We posit three constraints whose function is to choose between the possible options for ensuring that all coda consonants report to a mora:

(27) a. SYLLBIN: Syllable weight should not exceed two moras.
b. NOSHAREDMORA: Moras should be linked to single segments.
c. NOCMORA: The head of a mora must be a vowel.

(27c) might be generalised to establish a sonority threshold for mora heads, incorporating Zec's (1988) insight that languages tend to restrict the set of mora-heading segments to some minimal sonority value (see Sprouse 1996 for one such proposal).

One additional constraint is needed, to assign a cost to the Egyptian strategy of avoiding trimoraic syllables by shortening long vowels in closed syllables:

(28) MORAFAITH: If the number of moras linked to $S_i = n$, and $S_i \Re S_o$, then the number of moras linked to $S_o = n$.

MORAFAITH is concerned with the relationship between segments and moras, rather than with the total number of moras. The constraint compares each input segment (S_i) with the output segment (S_o) with which it corresponds ($S_i \Re S_o$; McCarthy & Prince 1995). The constraint is violated when there is a mismatch between the number of moras linked to the input segment and the number of moras linked to the corresponding output segment. Thus, the Egyptian reduction of CVVC to CVC violates MORAFAITH because the vowel is linked to two moras in the input but to only one mora in the output. This constraint differs from, for example, Sprouse's (1996) constraint CORR(μ), which requires that each input mora have a correspondent in the output. While such a constraint is no doubt necessary to describe mora conservation, CORR(μ) would not prevent Egyptian-type reduction of CVVC to CVC, since in this case both input and output have two moras (with reassignment of the second vocalic mora to the consonant).

We should note several additional properties of MORAFAITH. First, MORAFAITH does not require perfect isomorphism between input and output mora structure: for example, a short vowel linked in input to one mora will in a Malayalam CVC output end up sharing that mora with a coda consonant. But so long as that vowel is linked to one mora in both input and output, no violation of MORAFAITH is incurred – the number of segments sharing that mora is irrelevant. MORAFAITH applies equally to vowels and to consonants, and therefore the linking of a (non-geminate) coda consonant to a mora will always incur a violation of MORAFAITH, since non-geminate consonants are underlying non-moraic. However, MORAICCODA, which we have assumed is highly ranked in all these languages, forces this violation. The utility of this approach is explored in §5.2.

The four constraints NoSharedMora, SyllBin, NoCMora and MoraFaith yield twenty-four permutations, which yield only four different output patterns. Any grammar ranking NoSharedMora and MoraFaith over SyllBin will yield the Hindi pattern: a bimoraic analysis of CVC and a trimoraic analysis of CVVC:[11]

(29) *Hindi:* NoSharedMora, MoraFaith ≫ SyllBin, NoCMora

input μ | C V C	NoSharedMora	MoraFaith	SyllBin	NoCMora
☞ a. μ μ | | C V C.		*		*
b. μ |\ C V C.	*!	*		
input μ μ \/ C V C				
☞ c. μ μμ \/ | C V C.		*	*	*
d. μμ |/\ C V C.	*!	*		
e. μ μ | | C V C.		**!		*

We consider first the input containing a short vowel. The two plausible candidates are (29a), in which each segment occupies its own mora, and (29b), in which the vowel and consonant share a single mora. The high ranking of NoSharedMora in Hindi chooses (29a). Similarly, with inputs containing a bimoraic vowel, the mora-sharing candidate (29d) (which surfaces in Levantine Arabic) is ruled out by high-ranking No SharedMora. The choice between the two remaining contenders, the winning trimoraic CVVC (29c) and the Egyptian Arabic winner (29e) with shortened vowel, is left to MoraFaith. Each of the outputs violates MoraFaith at least once, since the coda consonant is linked to no moras in the input, but (because of the effect of high-ranking MoraicCoda) ends up linked to one mora in the output. However, (29e) incurs an additional violation of MoraFaith, since it involves a change in the moraic linking of the vowel as well as the consonant: in the input, the vowel is linked to two moras, while in the output candidate it is linked to a single mora.

In contrast to Hindi, which shuns mora sharing, Malayalam will not allow consonants to head a mora. Thus, any ranking of NoCMora over NoSharedMora will favour the Malayalam output (the motivation for ranking MoraFaith above NoSharedMora is discussed in §5.2):

(30) *Malayalam:* NoCMora, MoraFaith, SyllBin ≫ NoSharedMora

input μ C V C	NoCMora	MoraFaith	SyllBin	NoSharedMora
a. μ μ C V C.	*!	*		
☞ b. μ C V C.		*		*
input μ μ C V C				
c. μ μμ C V C.	*!	*	*	
☞ d. μμ C V C.		*		*
e. μ μ C V C.	*!	**		

Both (30c) and (30e) realise input CVVC by allowing the coda consonant to head its own mora, so these candidates (the winners in Hindi and Egyptian, respectively) are ruled out by NoCMora.

The Levantine Arabic pattern, in which mora sharing is resorted to only when necessary to avoid trimoraicity, will result from ranking No SharedMora above NoCMora, which makes bimoraic CVC optimal.

(31) *Levantine Arabic:*
SyllBin, MoraFaith ≫ NoSharedMora ≫ NoCMora

input μ C V C	SyllBin	MoraFaith	NoSharedMora	NoCMora
☞ a. μ μ C V C.		*		*
b. μ C V C.		*	*!	
input μ μ C V C				
c. μ μμ C V C.	*!	*		*
☞ d. μμ C V C.		*	*	
e. μ μ C V C.		**!		*

Ranking of MoraFaith and SyllBin above NoSharedMora rules out the Hindi and Egyptian analyses of CVVC.

And finally, the Egyptian Arabic pattern is derived by ranking Mora Faith below the constraints prohibiting shared moras and trimoraic syllables. This ranking makes the loss of vowel length the most desirable option for the realisation of CVVC syllables:

(32) *Egyptian Arabic:*
SyllBin, NoSharedMora ≫ MoraFaith, NoCMora

input μ | C V C	SyllBin	NoSharedMora	MoraFaith	NoCMora
☞ a. μ μ | | C V C.			*	*
b. μ |\\ C V C.		*!	*	
input μ μ \\/ C V C				
c. μ μμ \\/ | C V C.	*!		*	*
d. μμ |/\\ C V C.		*!	*	
☞ e. μ μ | | C V C.			**	*

These four patterns, corresponding to the four languages under discussion, exhaust the possible outcomes for any ranking of these constraints. In §5.3 we return to the issue of typology – in particular, the relationship between coda weight and the surface realisation of CVVC inputs. First, we turn our attention to a related problem, the weight of geminates, and argue that this set of constraints provides a solution to the problem of weightless geminates.

5.2 Malayalam geminates

In Hayes' (1989) proposal for moraic representation, geminate consonants are distinguished from single consonants by being underlyingly linked to a mora. When these inherently moraic consonants are prevocalic, they will retain their mora, but also link to the onset of the following syllable, producing the dual prosodic status normally associated with geminates. Tranel (1991) points out that in some languages, including Malayalam, all closed syllables – including those closed by the first part of a geminate – are treated as monomoraic. This is problematic for analyses in which geminates are distinguished from single consonants by being attached to a mora. However, as Davis (1994), Broselow (1995) and Sprouse (1996) have pointed out, the dual prosodic status of geminates does not require that geminates head a mora in surface representation.[12] In our constraint system, MoraFaith is crucial in ensuring that the optimal correspondent to an underlyingly moraic consonant is one that is linked to a mora on the surface. However, because MoraFaith looks only at the number of moras linked to a segment, and not at whether those moras are shared, it will be equally satisfied by retaining the geminate's input mora, or by linking the geminate to the preceding vocalic mora. The high rank of NoCMora will therefore choose the mora-sharing analysis of a geminate:

(33) *Malayalam geminates:*
NoCMora, MoraFaith, SyllBin ≫ NoSharedMora

input μ μ μ / V C V	NoCMora	MoraFaith	SyllBin	NoSharedMora
☞ a. σ σ / μ μ / V C V				*
b. σ σ / μ μ / V C V		*!		
c. σ σ / μ μ μ / V C V	*!			

Equally, MoraFaith will discourage an originally non-moraic consonant from attaching to a preceding mora, so where the consonant can surface as a non-moraic onset, it will do so:

(34) *Malayalam medial single* C*:*
NoCMora, MoraFaith, SyllBin ≫ NoSharedMora

input μ μ / V C V	NoCMora	MoraFaith	SyllBin	NoSharedMora
a. σ σ / μ μ / V C V		*!		*
☞ b. σ σ / μ μ / V C V				

MORAFAITH therefore serves two functions: to ensure that vowel length is not lost except under pressure from stronger constraints, and to ensure that underlying geminate consonants will be dominated by a mora in the output (though because MORAFAITH is indifferent to whether that mora is shared or independent, language-specific rankings of constraints on preferred mora structure will determine the output moraic status of the geminate). In Hindi and Arabic, MORAFAITH will also ensure that underlyingly moraic consonants remain linked to a mora in the output, though prohibitions on mora sharing will favour candidates in which the geminate's mora is not shared with a vowel.

5.3 Typology of syllable-weight oppositions

We have now considered the possible combination of outputs corresponding to inputs CV, CVV, CVC and CVVC. We found four patterns, varying in terms of the surface realisation of codas (weightless *vs*. weight-bearing).

(35) *Attested surface realisations*

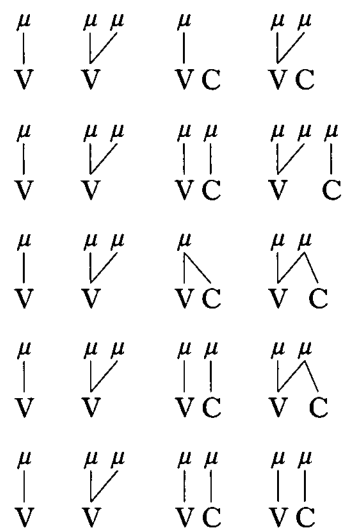
input

output Type A: Hindi

Type B: Malayalam

Type C: Levantine Arabic

Type D: Egyptian Arabic



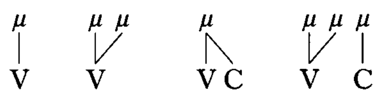
In Type A, exemplified by Hindi, coda consonants always occupy a mora. Type A languages are not troubled by trimoraic syllables, and CVVC is realised as trimoraic. The other three language types avoid trimoraic syllables, which presents potential problems in the realisation of CVVC. In Type B languages, represented by Malayalam, a coda consonant invariably shares a mora with the preceding vowel, permitting CVVC to be realised as bimoraic. In Type C languages, represented by Levantine Arabic, codas are independently moraic after a short vowel, but a coda shares a mora with a preceding long vowel, avoiding trimoraic CVVC. Type D languages, exemplified by Egyptian Arabic, instantiate another strategy for avoiding trimoraicity: codas are uniformly assigned weight, but CVVC is never allowed to surface. In Egyptian, input CVVC is realised with loss of a vocalic mora as CVC. (An alternative strategy for avoiding surface CVVC, exemplified by Makkan Arabic, is the use of vowel epenthesis to transform input CVVC to output CVV.CV.)

The four output patterns are derived from various rankings of four constraints: MoraFaith, SyllBin, NoSharedMora and NoCMora. These constraints therefore represent a strong claim about possible syllable-weight oppositions, since any ranking of these four constraints will yield one of the output patterns in (35). We now turn our attention to the patterns that this system predicts should not occur.

One pattern that is not derivable from our constraint set is the complement of Type C: a language in which codas add weight after long vowels but not after short vowels. In this 'anti-Levantine' pattern, we should find a three-way syllable-weight opposition, with CV and CVC counting as light, CVV as heavy and CVVC as superheavy. Phonetically, an anti-Levantine language should be characterised by the complement of the Levantine pattern: shortening of short (but not long) vowels in closed syllables, and shortening of consonants after short (but not long) vowels:

(36) *Predicted not to occur: anti-Levantine*

output: CV CVV CVC CVVC



The Levantine pattern of contextually determined coda weight was produced by ranking NoSharedMora below SyllBin, to ensure that mora sharing was resorted to only when necessary to avoid trimoraic syllables. But there is no ranking that would force mora sharing in CVC but not in CVVC syllables. SyllBin would rule out the trimoraic CVVC output above, and is irrelevant to the CVC input. The mora-sharing analysis of CVC violates NoSharedMora, while the non-sharing analysis of CVVC violates NoCMora. Thus, our constraint set cannot derive the pattern in (36). In this respect, our analysis differs in predictive power from rule-based analyses employing context-sensitive Weight-by-Position rules: a rule that assigns weight to a coda following a long but not a short vowel (the complement of the rule that would be required for Type C language) is a logical possibility. Such a rule could be banned from the grammar only by making reference to the undesirability of trimoraic syllables – that is, to surface constraints.

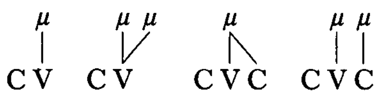
We know of only one candidate for an anti-Levantine language. This is a dialect of Hindi described by Gupta (1987), who described her own speech (the paper gives no information on her region of origin). According to Gupta, her dialect distinguishes four degrees of syllable weight: CV and CVC *vs.* CVV *vs.* CVVC *vs.* CVCC. This opposition is obviously a problem for any theory in which weight is associated with moraic representation, since it is difficult to see how the heaviest syllable type, CVCC, could justifiably be associated with four moras. Given the fact that most work on Hindi describes CVC as heavy, and given the well-established variability of Hindi speakers' intuitions concerning stress position (Ohala 1986), we would like to wait for additional work on this dialect (in particular on the relation between word-level stress and phrasal stress) before admitting the anti-Levantine pattern into the set of clearly attested patterns.

A second logically possible combination of outputs that our constraint set predicts not to occur is the complement of Type D, in which codas are weightless in CVC, but CVVC syllables are not tolerated, surfacing as CVC:

(37) *Anti-Egyptian: weightless codas in* CVC, *but* CVVC *not tolerated*

input: CV CVV CVC CVVC

output:



Again, no ranking will give just this combination of outputs. High ranking of MoraFaith will ban mora loss in CVVC. The monomoraic analysis of CVC derives from ranking of NoSharedMora below NoCMora. But if mora sharing is preferred to consonantal moras, the realisation of CVVC should be as in Levantine Arabic, with a coda sharing the preceding vocalic mora. Again, there is no constraint that would provide pressure for mora sharing in CVC but for loss of a mora in CVVC; mora sharing should be a valid option for preserving vowel length while still avoiding trimoraic syllables.

Our hypothesis, then, is that the realisation of input CVVC as surface CVC is always a response to the pressure to avoid trimoraic syllables, combined with a distaste for mora sharing. Hayes (1995: 303), discussing the relationship between coda weight and the possibility of surface CVVC, outlines four logical possibilities:

(38) *Relationship between coda weight and* CVVC (Hayes 1995)

a. Weighted coda C, CVVC allowed
b. Weighted coda C, CVVC forbidden
c. Weightless coda C, CVVC allowed
d. Weightless coda C, CVVC forbidden

Our analysis would further subdivide type (a) into languages allowing two types of surface CVVC structures: trimoraic CVVC (Hindi), and bimoraic (mora-sharing) CVVC (Levantine Arabic). Hayes notes the large inventory of languages falling into categories (a–c) and the relative paucity of candidates for category (d). Category (a) includes Estonian, General Central Yupik, Klamath, Latin and Seminole/Creek.[13] Under category (b), we find, in addition to Egyptian and certain other Arabic dialects, Choctaw/Chickasaw, Hausa, Tiberian Hebrew, Hixkaryana, Hopi, Japanese, Kashaya, Maithili, Sierra Miwok, Turkish and Yana. In our account, these are languages that prohibit both trimoraic syllables and mora sharing, leaving violations of MoraFaith as the optimal choice. Category (c), with uniform mora sharing, includes Malayalam as well as a host of others: Asheninca, Cahuilla, Cayuga, Chuvash, Eastern Ojibwa, Huasteco, Javanese, Komi, Kuuku-Yaʔu, Kwakwála, Lenakel, Menomini, Nyawaygi, Ossetic, Potawatomi, Sarangani Manobo, Tumpisa Shoshone, Votic, Wargamay, Western Cheremis and Yidinʸ. Category (d) corresponds to the anti-Egyptian pattern, and we predict it to be empty: in our terms, the lack of CVVC results from high ranking of SyllBin and NoSharedMora. If a language has weightless codas in CVC, it must rank NoSharedMora relatively low, making possible the bimoraic analysis of CVVC.

Hayes proposes as candidates for membership in category (d) two dialects of Yupik, St Lawrence Island Yupik and Pacific Yupik (Hayes' analysis is based mainly on Leer 1985a, b and Woodbury 1987). The facts of Yupik stress are quite complex, and have been the subject of extensive work in addition to the above-mentioned analyses (Rice 1988, Hewitt 1991, Kager 1993, among others). While a full analysis is beyond the scope of this paper, we will briefly summarise the facts and sketch a possible reanalysis in which the absence of CVVC is in fact due to the ability of codas to bear weight in Yupik.

The fundamental stress foot in Yupik is iambic. Iambic feet are constructed from the left edge of the word, with a preferred pattern of ternary stress. In these dialects, both CVV and CVC constitute a foot in word-initial position. In non-initial position, CVV and CVC contrast in that CVV is always stressed, while CVC may be either stressed or unstressed, depending on its position. (39a) shows stress on the second syllable from the left when it contains a long vowel, while (39b) shows unstressed CVC in the same position:

(39) a. kál.máa.nuq 'pocket'
b. át.saχ.su.qú.ta.qu.ní 'if he (REFL) is going to get berries'

Hayes' interpretation of these facts is that coda consonants are weightless (except in initial syllables), so that CVV in all positions must head a foot, while CVC may occur in unstressed positions.

Although CVC is light, according to Hayes, CVVC is prohibited. First, CVVC is actually reduced to CVC, as in Egyptian Arabic (when CVVC constitutes a foot; see Woodbury 1987 for details of the relationship between Compression and Defooting). Second, short vowels in the right branch of a foot are lengthened in open but not closed syllables:

(40) *Pacific Yupik Iambic Lengthening*
a. (atá) ka → (atáa) ka 'my father'
b. (át) ma(kutáχ) (tutə́n) 'you're going to backpack'
(*(át) ma(kutáaχ) (tutə́ən))

The failure of iambic lengthening to transform CVC to CVVC is ascribed to the prohibition on CVVC syllables.[14] These facts constitute a serious problem for our constraint set, in which reduction of CVVC to CVC takes place only under pressure to avoid mora sharing, combined with a prohibition on trimoraic syllables. Thus, a language that shortens CVVC to CVC must have the ranking NoSharedMora ≫ NoCMora, ruling out the shared mora analysis of CVVC. But if Hayes is right that Yupik CVC is generally monomoraic, then Yupik must have the ranking NoCMora ≫ NoSharedMora.

Hayes' arguments are grounded in a derivational approach, in which CVC and CVV must be moraically distinct at the point at which foot construction rules apply. However, constraint-based approaches provide alternative analyses. One elegant reanalysis is provided by Kager (1993), who argues that CVC and CVV are both bimoraic, but are structurally distinct. Following Leer (1985a, b), Kager argues, based on tonal facts, that the head of a lexical long vowel is its second mora. Thus, CVC syllables have their heads on the left, while CVV syllables have their heads on the right, and these different structures, combined with a constraint prohibiting a sequence of weak moras within a foot, force different metrical analyses of these syllable types.

Alternatively, we might assume that CVC may serve as either monomoraic or bimoraic, at the pleasure of the metrical parse. As Steriade (1991) points out, CVV and CVC always contrast in their lexical weight: (non-geminate) consonants lack inherent weight, while long vowels are inherently bimoraic. The different patterning of CVV and CVC in Yupik can be made to follow from this fact. CVV syllables cannot be realised on the surface as monomoraic without violating MoraFaith, since the input long vowel is linked to two moras, while its correspondent in a CV output will be linked to only one mora. But while MoraFaith enforces a bimoraic analysis of CVV, it is indifferent to whether CVC is realised as monomoraic or bimoraic (assuming that coda consonants must end up linked to some mora, under pressure from MoraicCoda). Since the coda consonant in a CVC input is not linked to a mora, both the Hindi/Arabic strategy of linking a coda consonant to its own mora and the Malayalam strategy of linking a coda consonant to the preceding vowel mora will incur a single violation of MoraFaith, by linking a previously unlinked coda consonant to a single mora. The choice between the bimoraic and monomoraic realisations of CVC then falls to other constraints. And since constraints on foot form and word rhythm are stronger than both NoSharedMora and

NoCMora in Yupik, CVC surfaces as either monomoraic or bimoraic, whichever fits the optimal rhythmic pattern.[15]

The moraic versatility of CVC syllables can explain the apparent failure of Iambic Lengthening in CVC syllables. As Sprouse (1996) argues, Iambic Lengthening is not necessary in CVC syllables, because these syllables are already bimoraic in the lengthening environment. Recast in terms of our constraints, the analysis of the failure of iambic lengthening in closed syllables is as follows:

(41) *Pacific Yupik:* CVC *in iambic lengthening context*

input μ μ (kutaχ)	FormPerfectIambs	MoraFaith	NoCMora
a. μ μ (kutaχ) [second μ shared by a and χ]	*!	*	
b. μ μμ (kuta χ) [second and third μ shared by a]		**!	
☞ c. μ μμ (kutaχ) [moraic coda χ]		*	*

This analysis makes interesting phonetic predictions: we would expect to find (subphonemic) durational differences between the monomoraic VC in non-head environments and the bimoraic VC in the head of a foot, similar to the differences between independently moraic and shared moraic segments in Levantine Arabic.

Once the possibility of either weighted or weightless codas is allowed for in Yupik, the shortening of CVVC to CVC can be viewed as a case of emergence of the unmarked, in the form of a preference for weighted rather than weightless codas. In CVC syllables, the choice between a shared mora coda and a moraic coda is determined by constraints on ideal foot form, which are stronger than either NoSharedMora or NoCMora. But when metrical constraints are irrelevant, the basic ranking No SharedMora ≫ NoCMora is revealed. CVVC provides such a case. Like CVV, CVVC will end up in a strong metrical position. Highly ranked SyllBin rules out a trimoraic analysis of CVVC, leaving two bimoraic options: the Levantine-type shared mora analysis or the Egyptian-type reassignment of a vocalic mora to a coda consonant. The fact that the Egyptian option is chosen suggests that Yupik prefers consonantal moras to mora sharing.

Sprouse (1996) offers a different solution to the Yupik shortening: a constraint which prohibits sharing of a weak mora but not a head mora. Because this constraint forbids the second mora of a syllable to be shared, it allows monomoraic CVC but not bimoraic CVVC. This analysis faces an empirical problem: if Kager (1993) is correct in assuming that lexically long-vowelled syllables in Yupik have their heads on the right, mora sharing in CVVC should be indistinguishable from mora sharing in CVC. A second problem with a constraint banning shared weak moras but not shared head moras is that if constraints on mora structure are seen as tied to sonority, it is not clear why a language should permit head moras of diluted sonority (that is, moras dominating VC), but should at the same time prohibit non-head moras of diluted sonority. Our major reservation concerning this solution, however, is that the introduction of a constraint against the sharing of weak moras makes the pattern of non-moraic codas but CVVC → CVC an option on a par with the other options outlined in (38). Given the relative paucity of candidates for language choosing this option,[16] we are not convinced that this increase in the descriptive power of the grammar is warranted.

5.4 Conclusions

Our aim in this paper has been twofold: to demonstrate a convergence between phonological representations and phonetic facts, and to ground these phonological representations in a theory of cross-linguistic differences in syllable weight. We began with the assumption that moraic representations provide a valid reflection of syllable-weight oppositions, and we proposed moraic analyses of several languages based on their phonological patternings. In our examination of four languages, we found a striking correspondence between durational patterns and independently motivated moraic representations. This suggests that moraic structure is directly reflected in phonetic timing in these languages. Because we carefully controlled many of the other factors which could affect timing, such as segmental differences and rhythmic/prosodic structure, our findings do not directly support the strong claim of Hubbard (1994) that moraic structure actually takes precedence over segmental factors in determining timing. However, a natural extension of our work might test this claim (for example, by comparing the durations of independently moraic labials and velars with mora-shared labials and velars, to determine the relative influence of moraic status and place on duration). At any rate, it seems clear that, when other factors are controlled, contrasts or differences in moraic association are clearly reflected in segment duration patterns.

Having established that our proposed moraic representations were consistent with both the phonological and phonetic patterns of the individual languages we examined, our next concern was to provide a restrictive theory of the range of variation in syllable-weight opposition across languages. We argued that differences in moraic structure result from variable ranking of a small set of constraints, either constraints on outputs (SyllBin, NoSharedMora, NoCMora), or constraints on the correspondence between input and output (MoraFaith). The various possible rankings of these constraints give rise to four basic patterns for the realisation of input CV, CVV, CVC and CVVC. We propose that these four patterns represent an initial hypothesis concerning the range of variation found in human language.

Appendix A: Malayalam syllable structure

An alternative account of the weightlessness of coda consonants is proposed by K. P. Mohanan (1986) and T. Mohanan (1989), who argue that apparent codas in Malayalam are actually onsets, at least at some level of the grammar. T. Mohanan offers a careful review of arguments on both sides, concluding that a no-coda constraint is in effect, beginning in stratum 3. This forces the conclusion that clusters such as [rʃ] in /d̪arʃanam/ 'vision', which are initially heterosyllabic, are at a later level resyllabified to form an onset – despite the fact that onsets of this type, which constitute a clear violation of sonority sequencing principles, are highly marked.

Some of the arguments in favour of considering all word-internal consonants to be onsets involve the contrasting intuitions of Hindi and Malayalam speakers concerning the segmentation of words into syllables and the counting of segments. Another argument involves the fact that Malayalam speakers insert schwa word-finally after all consonants but [m n]. However, the prohibition on word-final consonants need not imply that syllable-final consonants are also prohibited; rather, it could result from a constraint on what sorts of segments can occur at the right edge of a prosodic word. The possibility of this constraint suggests an alternative analysis of facts that Mohanan (1989) offers as a third argument for codaless syllables in Malayalam: the contrast between Hindi and Malayalam versions of a language game involving insertion of *pa*:

(42)	*real form*	*Hindi game form*	*Malayalam game form*
	d̪arʃanam	**pa**d̪ar-**pa**ʃa-**pa**nam	**pa**d̪a-**pa**rʃa-**pa**nam

Mohanan argues that in both languages, *pa* is inserted before each syllable, forcing the analysis of the Malayalam form as /d̪a.rʃa.nam/. However, an alternative analysis exists within Optimality Theory. The schwa-insertion facts support the position that Malayalam employs a high-ranking constraint barring all consonants but [m n] from word-final position; this constraint would outrank constraints on initial position. If we assume that each *pa*-unit constitutes a prosodic word, all consonants but these two would be banned from final position. This would force the insertion of *pa* before [r], rather than after [r], in the Malayalam forms above, since while /r/ can occur syllable-finally, it cannot occur at the right edge of a prosodic word. The Hindi forms can be derived from the effects of a higher-ranked constraint that requires identity between the syllable edges of the actual language output and the language game output (reminiscent of the output–output anchoring constraints in McCarthy to appear).[17] This account might also explain the differences in the performance of Hindi and Malayalam speakers 'when asked to pronounce words slowly, syllable by syllable with pauses between syllables' (Mohanan 1989: 591). Given the word *bʰakt̪i* 'devotion', for example, Hindi speakers produced *bʰak-t̪i* while Malayalam speakers produced *bʰa-kt̪i*. If each piece of the word in the segmentation task constitutes, for the speaker, a prosodic word, we would expect Malayalam speakers to divide the word so as to avoid illegal prosodic word-final segments.

Appendix B : Word-lists

1 Hindi

naap-aa	'measured'	p^haas-aa	'trapped'
naap-naa	'to measure'	p^haas-naa	'to trap'
nap-aa	'was measured'	p^has-aa	'was trapped'
nap-naa	'to be measured'	p^has-naa	'to be trapped'
kaaṭ-aa	'cut'	paal-aa	'nurtured'
kaaṭ-naa	'to cut'	paal-naa	'to nurture'
kaṭ-aa	'was cut'	pal-aa	'was nurtured'
kaṭ-naa	'to be cut'	pal-naa	'to be nurtured'

2 Malayalam

pat̪i	'husband'	pan̪t̪i	'row or seating for a wedding'
pat̪n̪i	'wife'	kaan̪t̪i	'magneticism, bright, magnetic'
patram	'newspaper, leaf'	kal(p)pana	'order, imagine'
paat̪i	'half'	kaali	'cattle'
paatram	'vessel'	kaalpaat̪am	'foot'
pan̪i	'fever'		

3 Arabic

kitaab-i	'my book'	ʔinnabi	'the prophet'
kita(a)b-na	'our book'	ʕinab-na	'our grapes'
kita(a)b-hum	'their book'	ʕinab-hum	'their grapes'

Appendix C : Statistical tables

	speaker 1			*speaker 2*		
	df	F values	p value	df	F values	p value
VV *vs.* **VVC**	1,22	·0130	·910	1,22	1·084	·309
V *vs.* **VC**	1,22	·0004	·983	1,22	·5076	·484
VV (all) *vs.* **V** (all)	1,46	243·1	·0001	1,46	480·3	·0001
VVC *vs.* **VC**	1,22	·3961	·536	1,22	·9025	·352

[Table V. Summary of results for ANOVAs evaluating the significance of differences in vowel and consonant durations in the four types of Hindi syllables compared in (6).]

	speaker 1			*speaker 2*			*speaker 3*		
	df	F values	p value	df	F values	p value	df	F values	p value
VV *vs.* **VVC**	1,10	29·84	·0001	1,10	10·20	·0096	1,10	27·05	·0004
VVC *vs.***V**	1,10	64·83	·0001	1,10	18·17	·0017	1,10	50·67	·0001
V *vs.* **VC**	1,10	15·59	·003	1,10	34·09	·0002	1,10	32·50	·0002
VVC *vs.* **VC**	1,10	·1845	·677	1,10	·180	·680	1,10	·2419	·6335

[Table VI. Summary of results for ANOVAs evaluating the significance of differences in vowel and consonant durations in the four types of Malayalam syllables compared in (7).]

	Jordanian			*Syrian*			*Lebanese*		
	df	F values	p value	df	F values	p value	df	F values	p value
VV *vs.* **VVC**	1,16	60·82	·00001	1,16	18·931	·0005	1,16	23·92	·0002
VVC *vs.***V**	1,16	293·7	·00001	1,16	484·87	·00001	1,16	117·2	·00001
V *vs.* **VC**	1,16	·0055	·9416	1,16	3·106	·0971	1,16	·3996	·5362
VVC *vs.* **VC**	1,16	23·83	·0002	1,16	22·210	·0002	1,16	9·491	·0072

[Table VII. Summary of results for ANOVAs evaluating the significance of differences in vowel and consonant durations in the four types of Levantine Arabic syllables compared in (18).]

NOTES

* Authors' names are listed in alphabetical order. This work was supported in part by grant SBR-9310058 to the first author from the National Science Foundation. Portions of this work were presented at the University of Wisconsin, CUNY Graduate Center, the University of Pennsylvania and SUNY at Stony Brook, and we are grateful to those audiences for useful discussion. We also thank Abigail Cohn, John Kingston, John McCarthy, four anonymous reviewers and the editors for helpful comments, criticism and suggestions. We are particularly indebted to our subjects for their patience and to our linguistic consultants, Rita Bhandari, Supriya Chakravarty and Anil Sivakumaran, for their assistance.

[1] K. P. Mohanan (1986) and T. Mohanan (1989) argue that apparent codas in Malayalam are actually onsets. We review their arguments in Appendix A.

[2] Because of disagreement in the literature concerning stress placement in different dialects of Hindi, we also asked our subjects to read word-lists designed to reveal their stress assignment patterns. Both speakers stressed words in accord with the description in §2.1.

[3] (9a) consists of the root *kat-* plus the perfective suffix *-aa*, which is exceptional in remaining unstressed in this position (for example, see Gupta 1987 for contrasts such as *jágaa* 'woke up' and *jagáa* 'cause to wake up'). Thus, for perfective forms with a light first syllable and the *-aa* suffix, stress was on the first syllable, an exception to the general stress rule.

[4] See Hsieh (1993) for an earlier study of Hindi with similar results, and Moser (1994) for evidence of similar durational patterns in Dutch, another language that has been claimed to allow trimoraic syllables (Hayes 1989).

[5] Some Classical Arabic forms consisting of four light syllables exhibit stress on the preantepenultimate (Hayes 1995); however, true colloquial forms of this shape are not found. Given that all educated Arabic speakers are bidialectal, it is difficult to judge the extent to which the Classical forms are integrated into the colloquial system. McCarthy (1979) analyses all final long stressed vowels as [VVh], but the assumption that final consonants fail to contribute weight makes this unnecessary.

[6] Following common practice, aspiration of voiceless stops was not included as part of the vowel duration.

[7] For these data each word appeared in three different frame sentences. There was no significant effect of sentence frame on the relative durational patterns, so results are pooled across frame sentences.

[8] For this earlier study, the short vowel in open syllable context was represented by [a] in *ʕínabi* 'my grape', with initial stress, contrasted with stressed [a] in the closed second syllable of *ʕinábna* 'our grape'. Thus it might be argued that the similar durations of the short vowels are due to strictly phonetic effects – that is, there could in fact be phonetic vowel shortening in the closed syllable case (*ʕinábna*), but this shortening might be effectively cancelled out by the stress difference between *ʕínabi* and *ʕinábna*. However, in the Jordanian data, durations are similar even when stress is controlled.

[9] In fact, for the Alexandrian speaker, the shortened vowel was actually significantly shorter than the lexically short vowel. We do not at present have an explanation for this, though we do note that this speaker was the least consistent of all the subjects in maintaining comparable rhythm and prosody across utterances.

[10] The Runyambo ratios given here are based on Hubbard's (1995) data for [a] vowels only, to provide a more accurate comparison with our own data, which involved [a]'s.

[11] Alternative strategies are available for the realisation of input CVVC while avoiding both mora sharing and trimoraic syllables: for example, vowel insertion to create CVV.CV (employed in Makkan Arabic; Abu-Mansour 1995) or deletion of the final consonant to create CVV. These strategies would be ruled out in the languages under consideration by high ranking of DEPV and MAXC (McCarthy & Prince 1995), which prevent (respectively) vowel insertion and consonant deletion.

[12] Both Davis (1994) and Sprouse (1996) discuss a dialect of Hindi described by Gupta (1987) in which CVC is light, but a syllable closed by a geminate is heavy. Sprouse accounts for this pattern as an effect of high ranking of CORR(μ), which would force a geminate to keep its own mora.

[13] Hayes lists Hindi under the category of languages with weighted codas in which CVVC is forbidden; however, he does discuss dialects of Hindi in which CVVC occurs.

[14] Since schwa cannot be long, lengthening would be blocked in the final foot of (40b) in any case.

[15] See Hayes (1994) for several cases of contextually determined coda weight (including Yupik).

[16] Yawelmani is another case in which codas appear to be weightless with respect to one aspect of grammar (template satisfaction), but in which CVVC shortens to CVC (Archangeli 1991). In general, it is not unusual for templates to stipulate not only particular moraic requirements, but also that those moras be associated with either vowels or consonants (certain Arabic templates, for example, are satisfied only by vowel length, others by gemination). The general problem of moraic inconsistencies (Steriade 1991, Hyman 1992, Hayes 1995, Broselow 1995, among others) requires careful examination within a constraint-based approach.

[17] Mohanan (1989) gives the form *ban̪d̪*^{h}*anam* 'imprisonment'; game form ***paba-pan̪d̪***^{h}***a-panam***. This form could conceivably surface as ***paban-pad̪***^{h}***a-panam***, as it does in Hindi. However, we assume that the nasal shares a place node with the following dental stop in the actual language form, and that an output–output constraint favouring the preservation of shared place is ranked highly enough in Malayalam to prevent the splitting up of /n̪/ and /d̪^{h}/.

REFERENCES

Abu-Mansour, Mahasen (1995). Optimality and conspiracy in the syllable structure of Arabic. In Beckman *et al.* (1995). 1–20.

Archangeli, D. (1991). Syllabification and prosodic templates in Yawelmani. *NLLT* **9**. 231–283.

Beckman, J., L. Dickey & S. Urbanczyk (eds.) (1995). *Papers in Optimality Theory*. Amherst: GLSA.

Broselow, Ellen (1992). Parametric variation in Arabic dialect phonology. In E. Broselow, M. Eid & J. McCarthy (eds.) *Perspectives on Arabic linguistics IV*. Amsterdam: Benjamins. 7–45.

Broselow, Ellen (1995). Skeletal positions and moras. In J. Goldsmith (ed.) *The handbook of phonological theory*. Cambridge, Mass. & Oxford: Blackwell. 175–205.

Broselow, E., M. Huffman, S. Chen & R. Hsieh (1995). The timing structure of CVVC syllables. In M. Eid (ed.) *Perspectives on Arabic linguistics VII*. Amsterdam: Benjamins. 119–140.

Cowell, M. (1964). *A reference grammar of Syrian Arabic*. Washington: Georgetown University Press.

Davis, S. (1994). Geminate consonants in moraic phonology. *WCCFL* **13**. 32–45.

Farwaneh, S. (1992). Directional syllabification and syllable structure in Arabic dialects. Paper presented at 66th Annual Meeting of the Linguistic Society of America, Philadelphia.

Gupta, A. (1987). Hindi word stress and the Obligatory-Branching parameter. *CLS* **23:2**. 134–148.

Hayes, B. (1981). *A metrical theory of stress rules*. PhD dissertation, MIT. Revised version distributed by Indiana University Linguistics Club. Published 1985, New York: Garland.

Hayes, B. (1989). Compensatory lengthening in moraic phonology. *LI* **20**. 253–306.

Hayes, B. (1994). Weight of CVC can be determined by context. In J. Cole & C. Kisseberth (eds.) *Perspectives in phonology*. Stanford: CSLI. 61–79.

Hayes, B. (1995). *Metrical stress theory: principles and case studies*. Chicago: University of Chicago Press.

Hewitt, M. (1991). Binarity and ternarity in Alutiiq. *Papers from the Arizona Phonology Conference* **4**. 44–60.

Hsieh, R. (1993). *Syllable timing patterns in Hindi*. Ms, SUNY at Stony Brook.

Hubbard, K. (1994). *Duration in moraic theory*. PhD dissertation, UCB.

Hubbard, K. (1995). 'Prenasalised consonants' and syllable timing: evidence from Runyambo and Luganda. *Phonology* **12**. 235–256.

Hyman, L. (1985). *A theory of phonological weight*. Dordrecht: Foris.

Hyman, L. (1992). Moraic mismatches in Bantu. *Phonology* **9**. 255–265.

Kager, R. (1993). Alternatives to the iambic-trochaic law. *NLLT* **11**. 381–432.

Kelkar, Ashok (1968). *Studies in Hindi-Urdu I: introduction and word phonology*. Poona: Deccan College.

Kenstowicz, M. (1983). Parametric variation and accent in the Arabic dialects. *CLS* **19**. 205–213.

Kenstowicz, M. & Kamal Abdul-Karim (1980). Cyclic stress in Levantine Arabic. *Studies in the Linguistic Sciences* **10**. 77–98.

Krauss, M. (ed.) (1985). *Yupik Eskimo prosodic systems: descriptive and comparative studies*. Fairbanks: Alaska Native Language Center.

Leer, J. (1985a). Prosody in Alutiiq (the Koniag and Chugach dialects of Alaskan Yupik). In Krauss (1985). 77–133.

Leer, J. (1985b). Toward a metrical interpretation of Yupik Prosody. In Krauss (1985). 159–172.

Letterman, Rebecca (1994). A phonetic study of Sinhala syllable rhymes. *Working Papers of the Cornell Phonetics Laboratory* **9**. 155–182.

McCarthy, J. (1979). On stress and syllabification. *LI* **10**. 443–465.

McCarthy, J. (to appear). Extensions of faithfulness: Rotuman revisited. *NLLT*.

McCarthy, J. & A. Prince (1986). *Prosodic morphology*. Ms, University of Massachusetts, Amherst & Brandeis University.

McCarthy, J. & A. Prince (1995). Faithfulness and reduplicative identity. In Beckman *et al.* (1995). 249–384.

Maddieson, I. & P. Ladefoged (1993). Phonetics of partially nasal consonants. In M. Huffman & R. Krakow (eds.) *Nasals, nasalization, and the velum*. Orlando: Academic Press. 251–301.

Mohanan, K. P. (1986). *The theory of Lexical Phonology*. Dordrecht: Reidel.

Mohanan, T. (1989). Syllable structure in Malayalam. *LI* **20**. 589–625.

Moser, Adriane (1994). Mora structure and duration in Dutch. Ms, SUNY at Stony Brook.

Ohala, M. (1986). A search for phonetic correlates of Hindi stress. In B. Krishnamurti

(ed.) *South Asian languages: structure, convergence and diglossia*. Delhi: Motilal Banarsidass. 81–100.
Pandey, P. (1989). Word accentuation in Hindi. *Lingua* **77**. 37–73.
Prince, Alan & Paul Smolensky (1993). *Optimality Theory: constraint interaction in generative grammar*. Ms, Rutgers University & University of Colorado, Boulder.
Rice, Curtis (1988). Stress assignment in the Chugach dialect of Alutiiq. *CLS* **24:1**. 304–315.
Shukla, S. (1990) Syllable structure and word stress in Hindi. *Georgetown Journal of Languages and Linguistics* **1**. 235–247.
Sprouse, R. (1996). Vowels that borrow moras: geminates and weight in OT. *NELS* **26**. 393–408.
Steriade, D. (1991). Moras and other slots. *Proceedings of the Formal Linguistics Society of Midamerica* **1**. 254–280.
Tranel, B. (1991). CVC light syllables, geminates and Moraic Theory. *Phonology* **8**. 291–302.
Woodbury, T. (1987). Meaningful phonological processes. *Lg* **63**. 685–740.
Zec, D. (1988). *Sonority constraints on prosodic structure*. PhD dissertation, Stanford University.