The Representation of Vowel Length[*]

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1. Introduction

Length is the phonological correlate of durational differences between sounds, tied to the phonological concept "quantity". The concept of length usually considers duration segmentally, attributing length to particular segments (the vowel or consonant is the locus of the property "long" or "short", and not the syllable, foot or word). Length being a phonological attribute, distinctions are discrete mental categories, not physical measurement, and like most phonological attribute in generative theories, it is traditionally treated binarily.

Establishing vowel length in a language is not always straightforward. English is both said to have and not have vowel length, so that "peat" may be analyzed as having a long vowel (Halle 1977) as contrasted to "pit", thus [i:] versus [i]; or, the distinction can be treated as a tense / lax opposition (Chomsky & Halle 1968) thus [i] versus [ɪ]. Because of the influence of voicing on vowels — they have shorter duration before a voiceless obstruent — English has a cline of four durational patterns illustrated in *bead, beat, bid, bit*. Phonetic duration does not automatically translate into phonological length, and durational differences, especially ternary oppositions, are not necessarily of a continuous type (1, 2, 3, 4 units), but may instead reflect multiple, intersecting phonological phenomena.

Some languages distinguish "full" and "reduced" vowels. Chuvash (Krueger 1961) has two reduced vowels [ă, ĕ] which contrast with full vowels [i ü ɨ u a e o]; the two Proto-Slavic "yers" [ĭ ŭ] (see Scheer this volume) are widely claimed to be "reduced", and a number of Ethiopian Semitic languages have multiple reduced vowels (Pam 1973). Rather than introducing a new orthogonal vowel property to the inventory of features, one which seems to never combine with independent length, the Chuvash vowels could be treated as short /a e/ versus long /i: ü: ɨ: u: a: e: o:/. This would have the typologically peculiar consequence that all high vowels are long. However, in support of a prosodic distinction between these vowels, stress assignment is sensitive to the full / reduced distinction whereby reduced vowels are skipped over in favor of stressing full vowels.

Segmental influences on duration, discussed in Lehiste (1970), include tongue height, place of articulation and stop/fricative properties of the following consonant, as well as pitch (especially under contrastive pitch movements), stress, and the fact of a syllable being open or closed. It can be unclear whether a perceptible durational pattern should be attributed to category-change, so should we claim that in the phonology, /bit/ "beat" → [bit] and /bid/ "bead" → [bi:d] (similarly /bɪt/ "bit" → [bɪt], /bɪd/ "bid" → [bɪ:d])? Or should we leave pre-voiceless durational adjustments to phonetics and have the output of the phonology be [bit], [bid], [bɪt] and [bɪd]? Answering these questions involves foundational issues in the theory of phonological and phonetic grammars which are well beyond the scope of this paper. Unfortunately, many issues

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pertaining to the phonology of vowel length require understanding this relationship. If we cannot clearly identify "long vowels" contrasted with "short vowels", it will be difficult to develop a theory of how long versus short vowels are represented.

A theoretical puzzle confronting linear (SPE-type) theories of representation was how to resolve numerous contradictions in phonological length. The paradox is that, sometimes long vowels behave as though they are single segments distinguished from short vowels by a feature, and sometimes they behave as though they are two segments. The resolution of this contradiction played an important role in the development of autosegmental phonology. This goal of this chapter is to familiarize the reader with the basic facts of vowel length and attempts to explain them. Section 2 considers the fundamental problems pertaining to the featural treatment of vowel length. Section 3 shows how autosegmental representations resolve those problems, but also raise new questions as we attempt to make more precise the nature of the higher-level representational atoms that express length. Facts such as compensatory lengthening which seem to elucidate vowel length are often cited as evidence to support an autosegmental representation of length, but many autosegmental treatments of compensatory lengthening gloss over important details, which undermines the explanatory value of the autosegmental account. On balance, it seems that the autosegmental account of length does broadly resolve the fundamental one-segment / two-segment paradox, but important details remain to be ironed out. Finally, section 4 considers the claim that some languages have a three-way vowel length contrast. Such (rare) languages potentially are important for a theory of length; unfortunately, for the vast majority of such languages, so little is known that it is difficult to say that length ternarity is a real phenomenon, rather than an epiphenomenon arising from binary length and some orthogonal dimension.[1]

2. Segmental Theories of Representation

The classical SPE feature-theoretic account of vowel length is that long vowels are [+long] and short ones are [-long], thus rules affecting vowel length manipulate a feature on a par with nasality, rounding or backness — for which a segmental transcription such as [a:] or [ā] would be appropriate. It was also recognized in works such as McCawley (1968) that long vowels could also be represented as sequences of identical vowels, thus [aa].

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[1] A reviewer notes a number of substantive asymmetries in vowel-length phenomena, some of which have at least implicitly influenced theorizing on length. For example, length is often related to syllable structure so that long vowels appear in open syllables and short vowels appear in closed syllables, and there are rules of open-syllable lengthening and closed-syllable shortening. Furthermore, closed-syllable lengthening or open-syllable shortening appear to be unattested. Vowels may lengthen before voiced consonants, but they do not shorten before voiced or lengthen before voiceless. The latter fact is not widely attested in languages and appears not to have been elevated to the status of fact which it is agreed that phonological theories must explain, whereas the former fact, especially the widely-attested prohibition against syllables of the type [XVVC$_\sigma$], has had an impact on theorizing about vowel length, in that we have sought to reduce the generalization *[XVVC$_\sigma$] to a general representational limit. The purpose of this chapter is to investigate the representation of length, not all facts relevant to length. It is just outside the scope of this paper to investigate why no language has been attested with closed-syllable shortening, yet such question are certainly germane to a wide-spread concern of representational theorizing, namely saying why certain kinds of rules exist yet others are not found.

Lithuanian evidence for treating long vowels and diphthongs identically is discussed in Kenstowicz (1970), which supports a representation of long vowels as adjacent identical short vowels. One argument is that rising and falling tones only appear on long vowels and diphthongs or else syllables ending with a liquid or nasal, i.e. bisegmental vowel plus sonorant sequences. There are words like *kâimas* "village", *vãikas* "child" with diphthongs, *kârtis* "pole", *kãrtis* "bitterness" with a V+resonant sequence, and *matî:ti* "to see", *matĩ:s* "he will see" with long vowels. There are no level-H toned syllables with a diphthong, vowel plus consonant, or long vowel. In contrast, only level H or L (unmarked) appear on short vowels, as in *mésti* "to throw", *dúri:s* "door". This pattern is explained if the language allows just one H on one segment within the word, where coda sonorants can bear tone, and crucially, long vowels are really two-segment sequences, thus /mat́iiti/, /matĩ́s/, /káimas/, /vaíkas/, /kártis/, /kar̃tis/. If long vowels simply have the feature [+long], explaining the distribution of H tone becomes very complex.

Another argument for equating long vowels with vowel sequences is an accent shift before endings with an underlying initial H, which is described very simply as deleting the first of two adjacent H tones. This description only works if long vowels are represented as VV, and becomes more complex if stated in terms of monosegmental long vowels and a primitive rising / falling / level distinction. A H underlyingly on the last tone-bearing unit of the stem (retained before the toneless accusative singular suffix *-a:*) seems to shift to the underlyingly H-initial instrumental singular suffix, as illustrated by the alternation *pieštúk-a: ~ pieštuk-ú* "pencil (acc. sing. ~ instr. sing)", the latter from /pieštúk-úo/.

(1)	pieštúk-a:	pieštuk-ú	← /pieštúk-úo/	"pencil"
	mígl-a:	migl-á	← /mígl-úo/	"mist"
	vaík-a:	vaik-ú	← /vaík-úo/	"child"
	pŏ:n-a:	po:n-ú	← /poón-úo/	"master"
	kâim-a:	kâim-u	← /káim-úo/	"village"
	vê:j-a:	vê:j-u	← /véej-úo/	"wind"

Retranscribing long vowels as sequences and decomposing contour tones into H on V_1 versus V_2 makes the nature of the alternation clearer: H deletes before adjacent H.

There are shortening rules in Lithuanian which treat long vowels and diphthongs analogously. One rule shortens a word-final falling-toned long vowel or diphthong, which accounts for alternations in adjectives in their indefinite and definite forms. Examples are *ger-**úo*** → *ger-ú* "good (instr. sg. masc. indef)", *ger-úo-j-**úo*** → *ger-úo-j-u* "good (instr. sg. masc. def.)"; *ger-**áa*** → *ger-á* "good (instr. sg. fem. indef)", *ger-áa-j-**áa*** → *ger-áa-j-a* "good (instr. sg. fem. def.)". Long vowels and diphthongs also shorten before syllable-final liquids, cf. *gîr-ti* "to praise", *gíir-ee* "he praised"; *púl-ti* "to tumble", *púol-ee* "he tumbled", again pointing to the functional identity of long vowels and bisegmental diphthongs.

Another demonstration of the phonological equivalence of long vowels and diphthongs comes from Finnish, where long vowels shorten and diphthongs lose their initial element before the plural suffix *-i-*.

(2)	*part. sg.*	*part. pl*	
	puu-ta	pu-i-ta	“tree”
	maa-ta	ma-i-ta	“earth”
	süü-tä	sü-i-tä	“reason”
	pii-tä	pi-i-tä	“silicon”
	suo-ta	so-i-ta	“swamp”
	tüö-tä	tö-i-tä	“work”
	tie-tä	te-i-tä	“road”

If long vowels are really two vowels, this process can be stated as (3):

(3) $V \rightarrow \varnothing$ / __VV

Arguments for long vowel / diphthong equivalence exist in Hausa, where long vowels shorten and diphthongs simplify before CC. This acounts for alternations such as *ɗa:* “son”, *ɗa:-n-a:* “my son”, *ɗa-n-ka* “your (m.) son”, *kai* “head”, *kai-n-a:* “my head”, *ka-n-ka* “your (m.) head”. If long vowels were single segments with a feature [+long], this could not be stated as a single rule.

Another argument for treating long vowels as two vowels comes from mora-counting tone systems such as that of Kimatuumbi (Odden 1996), which, like Lithuanian, only allows contour tones on long vowels. Tone assignment in Kimatuumbi involves rules such as “assign H to the third vowel after the subject prefix”, with long vowels counting as two vowels. No coherent generalization covers this pattern, if long vowels are single [+long] segments.

(4)	“you should V”	“you should go V”	
	ulʊbé	ukalʊbé	“ask”
	upakatíke	ukapakátike	“shake down”
	ukačabánike	ukakačábanike	“be confused”
	učaŋgă:le	ukačaŋgâ:le	“wonder”
	uba:mbí	ukabă:mbi	“peg for”
	upapă:kiye	ukapapâ:kiye	“grope”
	ula:mbáte	ukală:mbate	“lick”
	uke:ŋgê:mbe	ukakĕ:ŋge:mbe	“dig up”

Analysis of long vowels as two segments, as in (5), yields a simple analysis: H is assigned to the third vowel after the subject prefix.

(5)	"you should V"	"you should go V"	
	ulʊbé	ukalʊbé	"ask"
	upakatíke	ukapakátike	"shake down"
	ukačabánike	ukakačábanike	"be confused"
	učaŋgaále	ukačaŋgáale	"wonder"
	upapaákiye	ukapapáakiye	"grope"
	ulaambáte	ukalaámbate	"lick"
	ukeeŋgéembe	ukakeéŋgeembe	"dig up"

Similar arguments show the equivalence of long vowels and vowel sequences in Kikuria tone assignment (Odden 1987). In short, there is ample evidence that long vowels act like two vowels.

Work by Pyle (1971), Kenstowicz (1970), and Fidelholtz (1971) also noted evidence for treating vowel length with a feature. Southern Paiute (6a) and Tubatulabal (6a) were often cited as illustrating different treatments of length according to language. In Southern Paiute, devoicing only affects one half of a long vowel (arguing for a sequence), but in Tubatulabal, reduplication of the first V copies vowel length (requiring a featural representation).

(6)	a.	mantcáḁqàḁ	"to hold out one's hand"
		maróo̥qwày'ɨq·wḁ	"(I) stretch it"

	b.	*telic*	*atelic*	
		to:yla:n	o:-do:yla:n	"to teach him"
		togo:yʔan	o-togo:yʔan	"to decoy it for him"

Sometimes long vowels act like both a single segment and a sequence in one language. Kenstowicz motivates a rule in Lithuanian rounding /a:/ to [o:], affecting the output of a rule lengthening vowels in certain verbs in the non-present. When the vowel is underlying short /a/, the surface result is [o:].

(7)	tupú	tuúpti	perch
	dreb^{y}ú	dréebti	splash
	vag^{y}ú	voógti	steal

The problem is that the concept "long *a*" is difficult to capture in the sequence theory, since that theory says that length is not a feature that can be referred to. One would have to refer to "[a] which is preceded or followed by another [a]". Since arguments for the sequence theory succeeded because of the resulting simplifications, these complications are important.

Pyle (1971) shows that in West Greenlandic, lowering of high vowels before uvulars affects long and short vowels equally, thus /aluq/ → [aloq] "sole", /pu:q/ → [po:q] "bag". If long vowels were vowel clusters, we predict /puuq/ → *[puoq] — note also that vowel lowering does not skip a vowel, thus /ukiuq/ → [ukioq] "year", not *[ukeoq]. Contrarily, though, a metathesis rule breaking up final consonant clusters (*me:raq*, /me:raq-t/ → [me:rqa-t] "child sg, pl.") does not apply when the cluster is preceded by a vowel sequence (*umiaq*, /umiaq-t/ → [umiat] "canoe

sg, pl."), or by a long vowel (*ika:q*, /ika:q-t/ → [ika:t] "scaffold sg, pl."). Thus like Lithuanian, West Greenlandic supports both modes of representation.

Pyle and Kenstowicz consider various resolutions of this conflict. Two main approaches emerged: rule ordering, and functional-typological principles. The first proposal is that dual behavior is the result of specific rule ordering — at a point in the derivation, adjacent identical vowels merge into a single featurally-long vowel. In West Greenlandic, metathesis applies to a pre-merger presentation so that /ikaaq-t/ and /uniaq-t/ behave differently from /meeraq-t/, but high-vowel lowering applies after merger so /puuq/ → *pu:q*, which behaves like /aluq/ and unlike /ukiuq/.

Alternatively, rules could be distinguished as being segmental (vowel harmony, rounding, lowering) or prosodic (accentual, metathesis, insertion, deletion, syllabification). Segmental rules treat long vowels as single segments, but prosodic rules treat long vowels as sequences.[2] In Lithuanian, all rules requiring a sequence representation could be ordered before any rules requiring a featural representation. The most serious problem for the ordered-rule account is that it forces adoption of phonetic features for contour tones as primitives. In light of surface forms in (1) like [pǒ:na:], [vê:ja:], additional features such as [+rise] would be needed to represent the output of the phonology, if underlying identical vowel sequences are collapsed into a single [+long] segment. Decades of research in autosegmental tonology has yielded innumerable problems with the notion of treating contours as featural primitives.

The rule-typological approach holds that, with respect to length, representations do not have a definite nature, and they switch between a sequence interpretation versus a feature interpretation of length, depending on the nature of the rule applying to the representation. Thus the prosodic rule of metathesis in West Greenlandic will "see" long vowels as clusters, ergo /ikaaqt/, and the segmental rule of lowering will "see" long vowels as single segments, ergo /pu:q/. This approach is (supposedly) falsified by an example which is generally cited to support the existence of a feature of length, namely Dinka length-switch. As argued by Fidelholtz, Pyle and others, pluralization in Dinka involves reversing vowel length.

(8)

sing.	*pl.*	
tim	tiim	"tree"
ciin	cin	"hand"
kal	kaal	"fence"
leec	lec	"tooth"

This is usually formalized along the following lines, and appears to strongly justify having a feature for representing vowel length.

(9) $[V,\alpha long] \rightarrow [-\alpha long] / [+noun,+plural,\_\_\_]$

[2] At the time, there was a developing belief that "prosodic" rules were subject to substantially different formal conditions: see Howard (1972), Jensen & Stong-Jensen (1973) on the interpretation of variables and the direction of rule iteration.

Obviously this rule requires a featural analysis of length, and yet as a prosodic rule affecting length, it must by hypothesis refer to a sequential representation. It should be pointed out, however, that the supposed length-switch rule of Dinka has been overstated. There are numerous changes characterizing the relationship between singulars and plurals, including lengthening, shortening, diphthongization, tone changes, vowel quality changes, consonant changes and suppletion.[3]

(10)	gɔ́l	gɔ́ɔ́l	"clan"
	bo̤o̤k	bo̤k	"animal skin"
	d̤o̤k	d̤a̤k	"boy"
	kwir	kwer	"road"
	dit	diɛt	"bird"
	ruon	run	"year"
	lwet̤	lwét̤	"lie"
	bél	bel	"sugar cane"
	cók	co̤k	"foot"
	kàl	ka̤l	"fence"
	dwé̤l	dwɛ̤̀l	"temporary house"
	yíc	yì̤ì̤t̤	"ear"
	ɲáŋ	ŋɛ̤ŋ	"crocodile"
	cìn	cì̤ì̤n	"intestine"
	kèw	kèè̤t̤	"gazelle"
	kow	kuoot̤	"thorn"
	kat	kɛ̤́ɛ̤́t	"shelter"
	diir	d̰ír	"cricket"
	wɔ́ŋ	ɣɔ́k	"cow"
	tik	dyà̤r	"woman"

Ladd, Remijsen & Manyang (2009) argue that there is some predictability, but nevertheless there simply is no length-switching rule, thus no such argument for treating length as a feature.

Another counterexample to the function / representation hypothesis is Tubatulabal reduplication (6b), which is not a segment quality rule but rather a prosodic rule, yet one that copies the length of the first root vowel in the same way that it copies vowel quality features. Any rule of prevocalic vowel-shortening (as exists in Kikamba) which specifically only applies to long vowels and not vowel sequences is a problem for the rule-functional claim. The reason is that a rule which lengthens or shortens a vowel is by definition a prosodic rule, and prosodic rules are hypothesized to always treat long vowel in the same manner as vowel sequences. In Kikamba, long vowels shorten before another vowel, as illustrated below with the remote future prefix *-kâ:-* (*-káa-*).

[3] These examples were provided to me by the late Keith Denning, based on his fieldwork.

(11)	to-kâ:-tálâ	"we will count"
	to-kâ:-konà	"we will hit"
	to-ká-o-à	"we will buy"
	to-ká-i-o-à	"we will buy them"
	to-ká-.a.à	"we will divide"

As discussed in section 4, Kikamba contrasts identical-vowel sequences with long vowels. Forms like [tokáioà] demonstrate that the prevocalic shortening seen in the mapping /tokáa-o-a/ → [tokáoà] is not the result of a general vowel-cluster reduction rule. Only long vowels undergo shortening, thus long vowels are, contrary to hypothesis, not treated the same as vowel sequences.

A severe problem for a two-segment theory is posed by Gokana, discussed in Hyman (1982). A rule of postvocalic shortening shortens the 3sg object suffix, /EE/ seen in [bāè dɪvēē] "they hit him", whereby /bāè sà-EE/ becomes [bāè sà-ɛ̄] "they chose him". This poses the same problem that Kikamba prevocalic shortening poses. In addition, Gokana inserts [r] between long vowels after the logophoric suffix, /EE/[4] seen in [bāè dɪv-èè] "(they$_i$ said) they$_i$ hit (it)", whereby /bāè sɪ̄ɪ̀-EE/ becomes [bāè sɪ̄ɪ̀-rèè] "(they$_i$ said) they$_i$ caught (it)", but /bāè sā-EE/ surfaces as [bāè sā-ɛ̀] "(they$_i$ said) they$_i$ chose (it)" without r-epenthesis (and with postvocalic shortening), because insertion requires a sequence of long vowels. When the logophoric suffix is preceded by a sequence of adjacent identical vowels — a long vowel, according to the vowel-sequence theory — there is no insertion, as shown by /bāè kɛ̃̃ɛ̃̃-ɛ̃̃-EE/ → [bāè kɛ̃̃ɛ̃̃-ɛ̃̃-ɛ̃̃] "(they$_i$ said) they$_i$ woke (it) up". Gokana thus phonologically distinguishes true long vowels from adjacent identical vowel sequences, which is not predicted to be possible by the sequence theory.

The theory that segmental rules always treat long vowels as monosegmental is also falsified by the Mackenzie dialect of Eskimo, noted by Pyle, which also lowers high vowels before uvulars but where /naluuq/ → [naluoq] "throws out". Various segmental rules of Southern Paiute treat long vowels as sequences, and can affect just one part of a long vowel, for example final devoicing noted in (6), as well as a rule whereby /ɨ/ → [i] before i (which may later delete), where /ụnik̟ aŋumɨɨts̟ i/ → [ụnik̟ aŋumɨɨts̟] "after they had done so".

Kimatuumbi presents a worst-case scenario for segmental theories of length which attempt to attribute sequence-like versus feature-like properties of length either to ordering or rule type. As noted above, the language gives strong evidence for the sequence theory, from tone assignment, which counts a long vowel as equivalent to two short vowels. The data of (5) omits one important type of stem, namely CVVCV, where the H would be word-final. In such cases, the predicted H tone is retracted to the penult, being realized as a rising tone.

(12)	u-kaáte	← /u-kaaté/	"you should cut"
	u-toóle	← /u-toolé/	"you should take"

To even coherently represent rising tone while explaining the robust constraint that contour tones only exist on long vowels, long vowels must be represented as bisegmental. Yet this tone-

[4] Insertion only affects the logophoric suffix and the 2pl subject suffix /II/.

retraction rule must refer to the fact that the penult contains a long vowel, arguing for a feature representation of length. The rule only applies after long vowels and not adjacent VV sequences, as shown by *utauné* "you should chew" without retraction (see *ukataúne* "you should go chew" showing that *u* can bear H). One cannot even impose an identity condition on the triggering penultimate vowel (i.e. "when preceded by a sequence of identical vowels"), thanks to the fact that the language lexically contrasts identical vowel sequences from long vowels, the former not triggering tone retraction ([baasá] ← /ba.asá/ "envelope").

Kimatuumbi has a rule which shortens long vowels in a phrasal head followed by a modifier. Vowel sequences do not simplify.

(13)	a.	nika-kálaaŋga	"I will go fry"
		nika-kálaŋga ĺí	"I will not go fry"
		nika-kálaŋga kinjáambú	"I will go fry cassava leaves"
		nika-kálaŋga yóopáta eéla	"I will go fry to get money"
	b.	nika-táuna	"I will chew"
		nika-táuna ĺí	"I will not chew"

Assuming an ordered identical-vowel merger rule, such a rule would have to apply before Shortening, so that long vowels could be created and thus referenced by a rule mentioning [+long] in the input and [-long] in the output. This is not ultimately tenable.

Tone assignment in the subjunctive is assigned after shortening has applied, as the data below show — H is on the third surface vowel after the subject prefix, regardless of underlying length.

(14)	učaŋgaále	"you should wonder"
	učaŋgalé ĺı	"you should not wonder"
	upapaákiye	"you should grope"
	upapakíye mundó	"you should grope in the bucket"
	ulaambáte	"you should lick"
	ulambaté mboópo	"you should lick the knife"
	ukeeŋgéembe	"you should dig up"
	ukeŋgembé kindoólo	"you should dig up sweet potatoes"
	ubeénde	"you should shout"
	ubendé ukumú	"you should shout at Ukumu"

In an ordered vowel-merging solution, vowel sequences must merge prior to Shortening (to be targetted by Shortening), and Shortening precedes subjunctive tone assignment (which precedes retraction). But Subjunctive tone assignment requires a sequence representation of long vowels, and is flanked by rules requiring a featural representation of vowel length.

Finally, Kimatuumbi contrasts long vowels and adjacent identical vowel sequences, as in (15a) with true long vowels (which condition tone retraction and undergo Shortening), versus those of (15b) with sequences which do not trigger retraction or shortening

(15)	a.	ntuúmbwi ← /ntuumbwí/	‘canoe’	ntumbwí waángu	‘my canoe’
		ngaási ← /ngaasí/	‘ladder’	ngasí yaángu	‘my ladder’
		nkaáte ← /nkaaté/	‘bread’	nkaté waángu	‘my bread’
	b.	baará	‘ocean’	baará yaángu	‘my ocean’
		baasá	‘envelope’	baará yaángu	‘my envelope’
		luusá	‘permission’	luusá lwaángu	‘my permission’

While the insight that long vowels are in some sense like two vowels is correct, there are many reasons to not literally treat long vowels as a sequence of segments. Further developments in representational theory resolves the conflict in these insights.

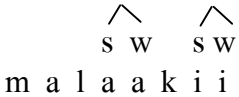
3. Nonlinear Representations

When facts of this type were considered from the perspective of autosegmental and metrical phonology in the mid-70’s, it was obvious that, once the presumption of a 1-to-1 mapping between features and segments is abandoned, nonlinear representations provide exactly the flexibility required to resolve these paradoxes. Just as a contour tone is represented as a many-to-one mapping between tones and vowels, a long vowel can be represented as a many-to-one mapping between something and a vowel. The crucial question is, what is that something which long vowels have two of?

3.1. Skeletal accounts

In McCarthy (1979: 34), long vowels were still seen as two-segment sequences, but with the imposition of higher structure including a rhyme. “Long vowel as unit” behavior such as uniform lowering of long vowels before uvulars in West Greenlandic is handled by applying the rule at the level of the rhyme. Rules may thus specify whether they apply at the segment level or higher, which yields an ambiguous treatment of long vowels. Long vowels as in Tiberian Hebrew *mala:ki:m* are represented as in (16), where a long vowel is two things (two segments) and one thing (one rhyme) at the same time.

(16)



Vowel-lengthening is treated as node-adjunction within the rhyme, where the segment is filled in by automatic feature copying.

Ingria (1980) represents a long vowel as a single segment having two metrical positions.

(17) V: in an open syllable V: in a closed syllable

Since the focus of that article is compensatory lengthening arising from consonant deletions, little attention is paid to how underlying length is represented. It is simply noted (p. 469) that "Each long vowel and consonant must contain the information that it is to be associated with two positions in the syllabic tree, whereas short vowels and consonants will be associated with only one position".

The earliest, most successful nonlinear theory of length is CV theory, which is rooted in McCarthy's (1979) prosodic template proposal for Semitic morphology. McCarthy made a connection between vowels and V, consonants and C (p. 247) that [syllabic] and [consonantal] are represented on the template tier rather than the segmental tier. McCarthy (1982) drops the feature [syllabic] but reintroduces the SPE feature [vocalic] to drive mapping of segments to the CV tier. The Clements & Keyser (1983) version of the theory fully phonologizes the CV tier as a strictly suprasegmental tier, containing only formal elements C, V which are independent of morphology, and dispenses with [syllabic]. A segment dominated by V is interpreted as a syllable peak, and a segment dominated only by C is interpreted as a non-peak.[5] The C-V distinction subsumes the functions of [syllabic], but is not identical to it. The feature [long] is also abandoned (p. 12), and "long vowels are universally represented by means of the multi-attachment of a single vowel matrix to two positions on the CV-tier". The appeal of the theory is that it resolves the long-standing problem of the ambiguity of length, simplifies feature theory, and explains a problematic connection between syllabicity and compensatory lengthening, discussed below.

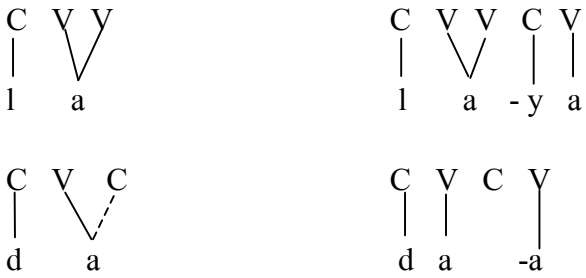
By reducing length to simple multiple-linking of prosodic atoms to segments, CV theory predicts the possibility of a futher distinction in types of long vowels: a long vowel dominated by VC, versus one versus VV. This actually arises in Turkish, which contrasts two kinds of superficially identical long vowels.

(18)	nom sg.	pl.	dat.	poss.	
	la:	la:-lar	la:-ya	la:-s~~i~~	"la (musical note)"
	da:	da:-lar	da-a	da-~~i~~	"mountain"
	sap	sap-lar	sap-a	sap-~~i~~	"stalk"

[5] It is argued that certain long vowels in Klamath and Turkish are dominated by the sequence VC (see below), which is in line with the interpretation that any linkage to V causes a syllable-peak interpretation of the segment. However, a post-glide epenthesis rule is also posited (p. 135) in Klamath whereby C-dominated /w/ becomes CV-dominated, and /wq'as/ → [wuq'əs] "quartz". It seems that only VC in the syllable rhyme is interpreted as a uniform syllable peak.

The noun *la:* has a regular VV long vowel, and by regular principles of Turkish, the dative and possessive have the allomorphs *-ya*, *-sɨ* after that long vowel, and *da:* has a long vowel arising from association to *a* of an empty C position which is part of the root.

(19)



The presence of the empty C triggers the suffix variant *-a,* and the empty C syllabifies as the onset of the second syllable.

The theory draws substantial support from the fact that it gives a simple account of the difference — one never squarely dealt with in linear theorizing — between disegmental, disyllabic [a.a] and phonetically distinct monosegmental monosyllabic [a:]. as exists in Kikamba. In principle, a monosyllabic long vowel dominated by VC could also behave differently from one dominated by VV, as is the case in Turkish, but the phonetic interepretation of the two long vowels would be identical, since "syllabicity" requires *some* V node to dominate the segment, not that *every* node dominating the segment must be a V.

One significant argument for the CV theory of vowel length is its explanation for a Klamath puzzle noted by Kisseberth (1973), a rule shortening long vowels after a heavy syllable under certain conditions. The rule only affects vowels which arise from vocalizing a glide between consonants, not underlying long vowels or long vowels from vowel-glide sequences. This process applying to vocalized glides is seen in (20a), and not in (20b) with other long vowels.

(20)	a.	mboty**'**-a	"wrinkle"	/mbody'-a/
		mbod**i:**-tk	"wrinkle up"	/mbody'-dk/
		mbo-mpt**i**-tk	"wrinkled up (distr.)"	/mbo-mbody'-dk/
	b.	yə-yd**i:**s	"spirit stones (distr.)"	/ya-yadi:-s/
		sdə-sd**i:**n-k'a	"little heart (distr.)"	/sda-sdayn-k'a/

With only one representation of "long vowel" it would be impossible to distinguish shortenable [i:] derived from /CyC/ versus non-shortening underlying /i:/. CV theory explains this representationally, where an underlying long vowel is dominated by VV but an underlying glide between consonants will, due to a separate rule of pre-glide epenthesis be represented as VC.

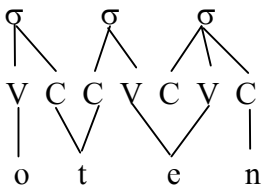
(21)

Clements & Keyser achieve the restriction on shortening in the formulation of the rule Vowel Shortening (p. 171).

(22) $C \rightarrow \varnothing$ / V ___ [ ]

Parallel facts of Finnish are discussed in Clements & Keyser (1983) and Keyser & Kiparsky (1984), namely the anomalous treatment of certain long vowels with respect to gradation, vowel length alternations, and consonant gemination, which point to another representation of long vowels, as a monosegmental disyllabic VCV span illustrated in the word [otte:n] "grip (gen. sg)".[6]

(23)



While the extra power of being able to distinguish VV and VC long vowels as well as monosyllabic and disyllabic versions of long vowels might seem to be a disadvantage of the theory, it is actually a substantial argument for the theory to the extent that it explains such facts.

A significant argument for CV and other non-linear theories of vowel length is how compensatory lengthening (CL) can be explained. A classical case is Klamath, where glottal stop deletes syllable-finally and the preceding vowel is lengthened, for example /sleʔ-a/ → [sleʔa] 'sees' vs. /sleʔ-ca-a/ → [sle:ca] 'goes to see'. The problem is capturing the relationship between vowel lengthening and deletion of glottal stop. In SPE-style accounts, the connection is usually fortuitous, for example there might be some rule lengthening vowels before select syllable-final consonants, and then a separate rule deleting those consonants, so that the derivation procedes by steps: /sleʔ-ca-a/ → *sle:ʔ-ca-a* → [sle:ca]. White (1972: 140) simply posits the transformational rule Glottal Lengthening to derive simultaneous lengthening and deletion in Klamath.

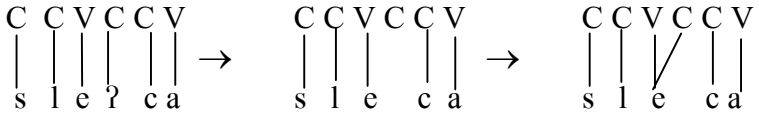
(24) <V> ʔ C → <1> ∅ 3
1 2 3 → +long

The theoretical objection to such a rule is that unrestricted rewrite rules are quite powerful, overgenerating the class of "compensatory" actions, and it is just as easy to describe a hypothetical and unattested process of glottal-stop deletion with compensatory vowel rounding.

An autosegmental account (similar to that of Ingria 1980) involves the detachment of a segment from a skeletal position, with the latter reattaching to a neighboring segment, resulting in the branching prosodic structure that is interpreted as length. The fundamental insight of this

[6] This type of representation is how Strict CV Phonology (Lowenstamm 1996) treats all long vowels.

analysis is that CL is conservation of existing prosodic information, amounting to the reorganization of existing substance, not the addition of new substance, just as the creation of contour tones under vowel merger is the rearrangement of simpler input tones.

(25) 

Kimatuumbi presents numerous examples of CL (see Odden 1996), showing the necessary connection between lengthening and desyllabification or deletion — it is not possible to decompose the processes into two independently-applying rules. See also Clements (1986) for a similar account of Luganda (though with an important difference regarding onsetless syllables, to be discussed below). The Glide Formation (GF) rule of Kimatuumbi turns high vowels into glides before another vowel. The verbs in (26) show the (C)V subject prefix changing its vowel into a glide, lengthening the following vowel.

(26)	ni-téliike	“I cooked”	ny-ʊ́ʊ́bɪliile	“I expected”	ʊ́bɪlya	“to expect”
	tu-téliike	“we cooked”	tw-eékite	“we laughed”	éka	“to laugh”
	u-téliike	“you(sg.) cooked”	w-aákite	“you(sg.) hunted”	áka	“to hunt”

(27) shows that an underlying short vowel remains short when preceded by a vowel not undergoing GF.

(27)	ga-ʊ́bɪliilwe	“they (Cl. 6) are expected”	naaba-ʊ́bɪliile	“I expected them”
	ba-ékite	“they laughed”	a-eké	“he should laugh”
	aa-ákite	“he hunted”		

Underlying long vowels do not shorten after another vowel or word-initially. Thus this alternation is CL from GF, not shortening applying in some other context.

(28)	áandika	“to write”	tw-áandiike	“we wrote”
	ʊ́ʊma	“to win a case”	w-ʊ́ʊmite	“you won”
	ɪ́ɪmba	“to dig”	ny-ɪ́imbite	“I dug”
	tuga-ɪ́ɪmbite	“we dug them”	ba-ɪ́ɪmbite	“they dug”

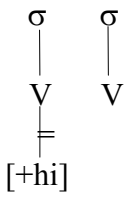
Further data strengthen the connection between vowel lengthening and desyllabification. When the prevocalic high vowel is H toned, GF is optional, resulting in the following patterns of free variation.

(29)

patúekíté	~ patw-éekíté	"when we laughed"
chaúakáé	~ chaw-áakáé	"what you were hunting"
pakíutíilwé	~ paky-úutíilwé	"when it (Cl. 7) was harvested"
aabíkite múaanjú ~ aabíkite mwáanjú		"he put it in the firewood"

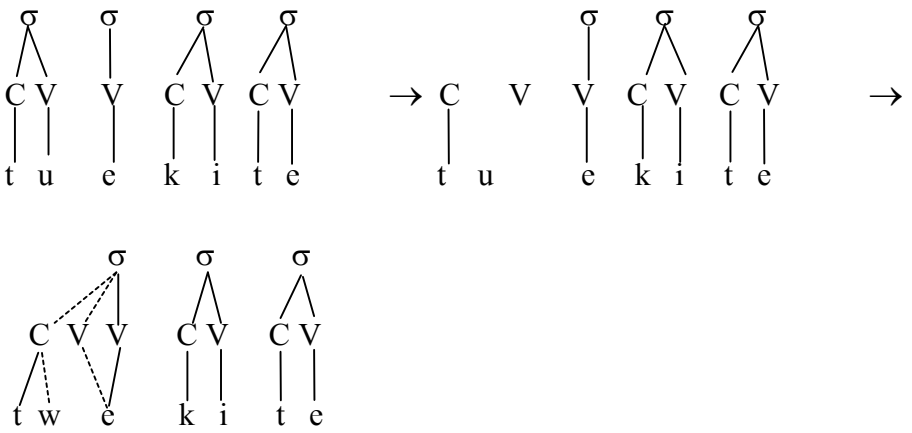
The rule of Glide Formation could be formalized as follows, leaving aside the tone condition.

(30)



(30) delinks a [+hi] vowel from its V-slot before a vowel. Certain "virtual steps" ensue, which repair the results, especially Linking Convention (1) of Clements (1986) which automatically associates a free V with a vowel. In the derivation of *tweékite* from /tu-ékite/, removing the vowel from V leads to deletion of syllable structure, since syllables need nuclear segments. The surviving material reassociates with the syllable which follows, analogous to tone reassociation with the segments which cause them to float. The stranded high vowel links to the preceding C-slot which constututes the onset of the underlying syllable /tu/.

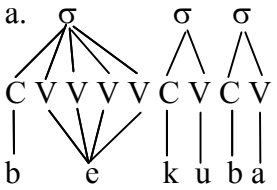
(31)

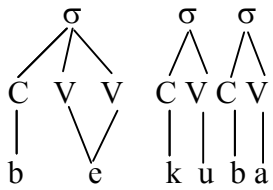


The optionality facts rule out accounting for the connection between GF and lengthening by independent rules. A rule optionally lengthening vowels after prevocalic high vowels would incorrectly allow lengthening without GF, e.g. *chaúakáé* could be subject to lengthening without GF, predicting **chaúaakáé*, as well as allowing GF without lengthening (**chawákáé*). Nor can there be a rule lengthening vowels after glides, see *baaéleewite* "they understood" inter alii.

A recurrent observation in languages with CL involving GF and other segment deletion processes is that an already-long vowel does not become overlong. We observed in (28) that the long vowel of Kimatuumbi *áandika* "write" is not further lengthened in /tu-áandiike/ → [tw-

áandiike] “we wrote”. To explain similar facts of Luganda (/ba-a-ee-kuba/ → [beekuba] “they struck themselves”), Clements (1986) postulates a rule trimming all but the last two V nodes in a consecutive sequence of V-nodes, thus Luganda (32a) becomes (32b).

(32) a. 

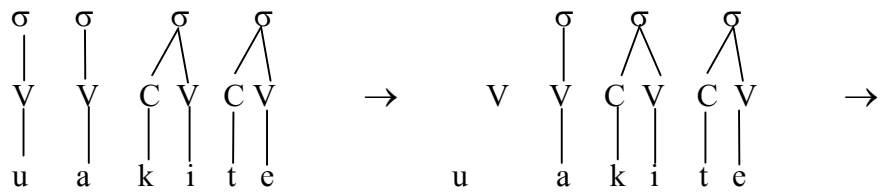
→ b. 

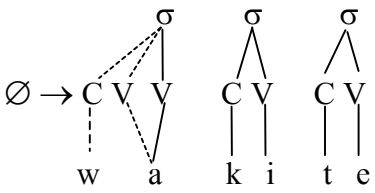
Such patterns of consecutive vowel trimming are found in numerous languages such as Kimatuumbi and Makua (Cheng & Kisseberth 1979), indeed no language has been uncovered which synchronically generates ternary length by compensatorily lengthening an already long vowel. The featural account of length automatically explains this because [long] has only two values.

A rule that results in such V-trimming is descriptively possible, but is unsatisfying in that it is a bare stipulation, which follows from nothing — unless it follows from a parochial structure-preservation principle, and CL has only been studied in languages with at most two degrees of vowel length (see section 4 for discussion of ternary length). It has been a theoretical desideratum to understand why CL does not ever generate *[twaáandiike]. One response has been to presume a representational limit on V slots within a syllable to a maximum of two, but there are no parallel limits on Cs within the syllable. The limit on vowel length to a binary opposition is somewhat of a formal embarassment for the autosegmental account.

A problem with the autosegmental theory of CL is the need to posit ad hoc conventions for glide formation in an onsetless syllable. The initial impact of this problem for the theory was reduced by the fact that Luganda does not have CL in such a context. In Luganda (and a set of closely related Bantu languages: see e.g. Odden 1995), there is no CL when an onsetless vowel desyllabifies, thus Luganda /o-a-gula/ → [wagula] “you bought”, contrast /tu-a-gula/ → [twa:gula] “we bought”. Clements (1986: fn 1) treats this by a relabeling rule which directly changes word-initial V into C. Therefore, CL is not always a consequence of GF, even in languages like Luganda with vowel length and CL. Another language which presents this problem is Classical Sanskrit, where prevocalic high vowels become glides and do not cause lengthening of the following vowel (/iti abravit/ → [ity abravit] “thus he said”. However, some vowel merger processes do exhibit CL, namely the rule /ai, au/ → [e:, o:] (/ca iha/ → ce:ha] “and here”).

In Kimatuumbi, GF does take place in a context analogous to Luganda [wagula], as we observed in (26) with /u-ákite/ → [waákite] “you hunted”.

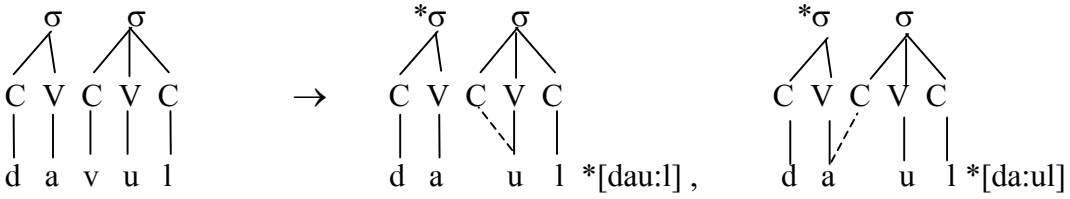
(33) 



Creation of a C slot is necessitated by the fact that CV positions always mediate between the segment and the syllable. This complicates CV theory by necessitating a convention inserting an onset which does not already exist, and is counter to the insight that CL is simply rearrangement of segmental and prosodic material.

CV theory predicts the CL from deletion of an onset consonant, which in fact does not happen in Turkish and numerous other languages with CL associated with consonant deletion.

(34)



This situation is almost unattested, except for an analysis of Onondaga in Michelson (1986) where a vowel is lengthened when preceded by an empty C preceded by another C, thus /te-wak-Cęhwętati/ → [tewakę:hwętá:ti] "I have made an opening" (cf. [te-ha-ęhwę́:tats] "it's making an opening" where the same root exhibits a short vowel if no consonant precedes the empty C). Hayes (1989) reanalyses this as epenthesis into CC′V_i followed by vowel spread giving CV_iC′V_i, whereafter the empty C′ is deleted. See Topintzi (this volume) for the situation of Samothraki Greek.

An alternative to the CV theory of vowel length, first proposed in Hyman (1982), is that timing is expressed via generic "x" which does not distinguish consonants and vowels. A similar proposal is made in Kaye, Lowenstamm & Vergnaud (1985), who simply posit "positions" without further modifiers. A theory of X positions as part of an X-bar theory of syllables is set forth in Levin (1985), with higher levels of syllable representation to include N, N′ and N″. The important feature of this theory is that it preserves the robust "links to two positions" generalization of CV phonology, but reanalyzes the weakly-supported type distinctions between VC and VV long vowels. Levin shows that the Turkish VC-type long vowels of (18) can be accommodated into a single-type skeletal theory by distinguishing VV long vowels as two slots lexically prelinked to the segment (*la:*), versus one slot linked and one slot unlinked (daC′).

(35)

The fact that *da:* patterns with *sap* and not *la:* (*da-ɨ, sap-ɨ, la:-sɨ*) is explained in the CV account by the fact that both roots end in C, not V, and *-ya* is found only after V. Levin's analysis is that

an allomorphy rule deletes a suffix consonant only after an unsyllabified X-slot, prior to linkage of unsyllabified X slots to the syllable by N′-projection. See White (1972), Levin (1985: 207-256) for analysis of the rather complicated facts of Klamath. A prediction of the CV account of vowel length is that there could be a distinction between lexically-linked VV versus lexically-linked VC long vowels, i.e. a Turkish-like language, but where the C-slot is always associated to the preceding vowel. Since no such language has been uncovered, that may indicate that the C/V distinction for vowel length is superfluous, or it may simply point to the fact that evidence proving such a distinction would be very subtle.

CV-theoretic prosodic templates that distinguish Arabic vowel-lengthening versus consonant-lengthening patterns as CVVCVC versus CVCCVC are modeled in X-theory as XXXXXX, but in the vowel-lengthening case the third X-slot is lexically prespecified as projecting N′. An argument in support of a generic timing-slot advanced by Levin is an analysis of a "boundary-lengthening" pattern in Mokilese where certain suffixes cause lengthening of either a preceding vowel or consonant

(36)	wɔl	"man"	pwo	"pole"
	wɔlle	"this man"	pwo:y	"this pole"

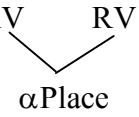
A similar case is made, based on a trisegmental pattern of Mokilese progressive reduplication which is treated templatically as XXX.

(37)	pɔdok	pɔd-pɔdok	"to be planting"
	pa	pa:-pa	"to be weaving"
	ca:k	ca:-ca:k	"to be bending"
	onop	onn-onop	"to be preparing"
	andip	and-andip	"to be splitting"

It does appear, then, that the C / V distinction is not strictly necessary, as long as one enriches underlying representations with higher level structure with a nucleus node.

A conceptually related theory is that of Selkirk (1990), who dispenses with skeletal positions entirely and relies on "root node" to indicate length, so that a long vowel has two root nodes,[7] but one set of shared place features.

(38)

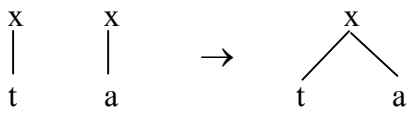


3.2. Moraic accounts

Building on the idea of generic prosodic positions, Hyman (1985) argues that one-to-many mappings between skeletal positions and segments should be further exploited, and proposes that on-

[7] In Selkirk's theory, root nodes have intrinsic featural content so that "RV" would be [-cons,+son].

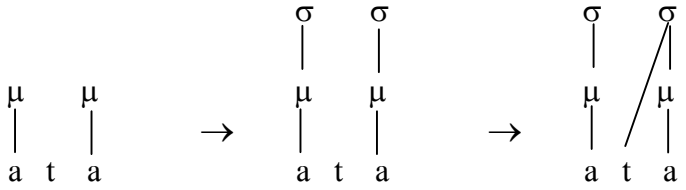
set consonants lose their skeletal position by joining to the position of the nuclear vowel through a universal Onset Creation Rule (OCR).

(39) 

This theory of representation eventually develops into moraic theory.

Hyman's main concern is developing a syllable-free theory which still represents the notion of syllable-weight, a notion proposed by Kuryłowicz (1948) to unify syllables with long vowels or coda consonant for purposes of stress, tone or prosodic morphology. Capturing the notion "heavy" in a theoretically coherent fashion had proven difficult. Although "heavy syllable" correlates to branching, it has been challenging to say where such branching is relevant, since the onset is irrelevant to syllable weight (but see Davis 2008), and a branching nucleus (long vowel) always defines a heavy syllable if a language has any notion of syllable weight, while a branching rhyme (XVC syllable) only sometimes does, and furthermore, some languages (Lithuanian) distinguish sonorant rhymes as defining heavy syllables versus obstruents for defining light ones. Hyman's theory of weigh units (which he equates with the traditional mora) handles these facts quite simply, deriving onset-weightlessness from OCR (39), with a range of options regarding coda consonants which either leaving coda consonants with their underlying weight unit (contributors to syllable weight), or merge that weight unit with the preceding vowel (codas are weightless).

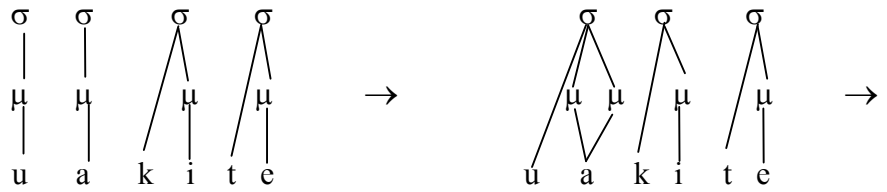
The notion of mora as the basic unit of phonological timing is developed more fully in McCarthy & Prince (1986), Zec (1989) and Hayes (1989). A strong argument for moraic theory over skeletal theories of length is advanced in Hayes (1989), who shows how a moraic theory of length coupled with the principle that onset consonants have no moraic value explains the onset asymmetry for compensatory lengthing, noted for example in Turkish /savmak/ → [sa:mak] but /davul/ → [daul], *[da:ul], *[dau:l] in Sezer (1986): see also (34) above. A characteristic of these later developments in moraic theory (exemplified by Hayes 1989) is that it is unnecessary to underlyingly assign weight units to all segments, and rather than postulating that every segment has a mora and invoking mora-trimming to merge the morae of onset consonants with those of a vowel, underlying representations will *typically* assign one mora to a short vowel and two to a long vowel; a consonant might have an underlying mora if it is geminate or syllabic. The weightlessness of onsets then reduces to the fact that consonants ordinarily neither have an underlying mora nor do they receive one by rule, and instead directly syllabify to the left of a syllable by a syllable adjunction rule.

(40) 

The generalization that long vowels always defines a heavy syllable is a consequence of the moraic characterization of "heavy", namely having two moras within a syllable. Long vowels always have two moras; onsets do not contribute a mora (thus are weight-irrelevant), and coda consonants can vary in their influence on weight, depending on whether they receive a mora.

The moraic theory of direct attachment to the syllable without intervening timing units resolves the onset problem with skeletal theories of timing and CL. It was noted above that skeletal theories of CL do not provide a straightforward account of onset-creation coexisting with CL from GF in an underlyingly onsetless syllable. In (33) it was seen that GF in Kimatuumbi results in compensatory lengthening of the following vowel, so /u-ákite/ becomes [w-aákite] 'you(sg.) hunted', which required auxiliary insertion of C to syllabify the onset. The moraic theory accounts for this pattern easily since the theory does not require prosodic positions for onset consonants: the high vocoid directly attaches to the syllable.

(41)



A final argument for the mora is mora-based tone systems such as that of Kimatuumbi, where H is assigned by counting V's — but only V's — from the beginning of the verb. Skeletal theories face the problem of ignoring C slots in tonal computations. Compare the problem of identifying the fourth "vowel" for Kimatuumbi subjunctive tone assignment, given the representations of skeletal versus moraic theories.

(42)

V C V C V C **V** C V	μ μ μ **μ** μ	
u p a k a t í k e	u p a k a t í k e	"shake down"
V C V C C V **V** C V	μ μ μ **μ** μ	
u č a ŋ g aá l e	u č a ŋ g aá l e	"wonder"
V C VV C C **V** C V	μ μμ **μ** μ	
u l aa m b á t e	u l aa m b á t e	"lick"
V C VV C C **V**V C C V	μ μμ **μ**μ μ	
u k ee ŋ g ée m b e	u k ee ŋ g ée m b e	"dig up"

Moraic theory directly represents the prosodic irrelevance of onset consonants via the fact that they project no prosodic unit, thus the fourth timing unit is easily identified. Skeletal theories re-

quire special interpretive procedures which render C's or non-nuclear X's invisible to the rule which scans for a fourth skeletal position.[8]

Moraic theory constitutes an advance in our understanding of vowel length on various points: it resolves the problem of onset skeletal-position generation associated with CL, it explains why long vowels always define syllable weight, and it allows a simple representational account of mora-counting processes. Nevertheless, various problems with moraic theory have emerged in the literature, and if moraic theory is wrong as a theory, then it is wrong as a theory of vowel length. For example Vago (1992) points to difficulties in a moraic analysis of Hungarian length; Tranel (1991) shows for a number of languages how the predicted weight / length equation is incorrect (geminate consonants do not uniquely contribute to weight); the notion of "weight" is vastly more subtle than the μ/μμ distinction implied by moraic theory (Crowhurst & Michael 2005).

It is proposed in Tranel (1991), Hume, Muller & van Engelenhoven (1997), Odden (1997), Muller (2001) that prosodic theory needs both skeletal representations of length and moraic structure, a proposal which potentially allows preservation of the insights of both moraic and skeletal theories. A striking problem for moraic theory noted by Hume, Muller & van Engelenhoven is that in Leti, long consonants do not contribute to syllable weight as diagnosed by initial-stress assignment (which only affects long vowels)

(43)	tuvúri	"kind of shell"
	rɔ́:nénu	"they eat turtle"
	vappúre	"wild pig"
	ppunárta	"nest's edge"

However, long vowels and consonants form a natural class in blocking a prosodic reduction process of "downgrading" with a range of segmental and stress consequences. When the first word in a syntactically-eligible structure contains only obviously light syllables, diphthongs or non-geminate consonant clusters, as in (44a), downgrading is possible. When the first word contains a long segment, either a vowel or a consonant, downgrading is blocked.

(44)	a.	Separate phrasing	Downgraded	
		sívi térannu	sɪvɪ térannu	"the egg of the chicken"
		spóu ttɛ́nanne	spou tt͡ɪnannɪ	"keel of the boat"
		ntútnu wái	ntutnu wái	"he lights the fire"
	b.	No downgrading		
		nvá:lu vátu		"he flings the stone"
		ppátne únne		"truck of the orange"

[8] Strict CV Theory, which posits that all phonological strings are of the form (CV)*, does not face this problem since each mora is represented as an independent nucleus.

The problem then is that if length entails moraicity and weight is expressed by bimoraicity, we reach contradictory conclusions for Leti. A mixed theory with both skeletal position and moras, on the other hand, would allow heavy syllables (relevant for stress) to be defined with reference to bimoraicity, and length to be represented skeletally. In Leti, consonants including long consonants have no moraic value, whereas vowels do.

In general, the branching-prosody claim for representing long vowels is well-supported, but evidence saying clearly what long vowels have two of is hard to come by.

4. How many lengths are there?

The vast majority of languages with vowel length are treated as having two degrees of length — long and short. This is as predicted given a Jakobsonian binary analysis, and thus reputed cases of ternary (or greater) length are a matter of theoretical interest. The descriptive literature includes many more distinctions, up to eight degrees of phonetic length in Finno-Ugric descriptive practices, as reported in Sammallahti (1998),[9] though nearly all claims for more lengths than two are claims for three lengths. The question is whether that which phonologically distinguishes binary long versus short extends in the same way to short, long and overlong, or analogous terminological distinctions. In most languages where ternary vowel length has been suggested, there is so little evidence available regarding the phonology of the distinction that one only has transcriptional distinctions as the fact needing to be explained.

The most famous case of ternary length in Estonian, probably first recorded in the 1622 *Agenda Parva* (see Särg 2005), illustrated by a classical minimal triple with short, long and overlong vowels. In this section, diacritic notations of vowel length are regularized so that [v:] refers to long and [v::] refers to extra-long. Often the first non-short length is notated as [v˙] and the second is notated as [v:].

(45)	saada	[sa::da]	“to get”
	saada	[sa:da]	“send!”[10]
	sada	[sada]	“hundred”

As argued by Lehiste (1966, 1970, 1978) and Prince (1983), segmentalization of this distinction obscures Estonian phonology, which is best treated as having a long/short opposition plus an intersecting distinction pertaining to foot structure, where Q3 arises when a syllable exhausts the foot and Q2 results when a heavy syllable is followed by a syllable within the foot. In overlong [sa::da], the long syllable exhausts a foot, /(sa:)da/, whereas the plain long vowel in /(sa:da)/ is one of two syllables within the foot.

The strongest arguments for foot- plus binary-length treatment come from an analysis of phonological facts of Estonian: overlength only occurs in a stressed syllable, it affects computation of subsequent stresses, it is automatic on all final-stressed vowels, the distribution of over-

[9] These are systematic surface patterns, not underlying contrasts.

[10] Estonian orthography does not represent the distinction between Q2 and Q3, except in stops via the convention Q2=<p>, Q3=<pp>.

length relative to plain length is not contrastive within the syllable (long vowels and consonants are either both Q2 or neither Q2, so syllables and not segments are overlong). See Prince (1983) for an extensive generative analysis.[11]

Foot structure also explains multiple surface lengths in Tiberian Hebrew and Finnish. In Finnish and Estonian (Lehiste 1970), short vowels are subphonemically longer when preceded by a light stressed syllable.[12] Since this process is allophonic, the pattern has not generated claims for additional phonological vowel lengths. Tiberian Hebrew presents a surface unpredictable distinction between long, short and ultra-short — so-called ḥāṭēph — vowels, a system which is from the perspective of contrasts analogous to Estonian's three-way length difference.

(46)	ʔa:sáf	"gather"
	ʔaḥáy	"my brothers"
	ʔăzáy	"therefore"

In the analysis of McCarthy (1979), the ultra-short vowels are the phonetic implementation of short vowels in an open syllable on the weak branch of a foot. Evidence from rhthmic retraction where stress clash resolution skips over an ultra-short vowel, and the fact that there cannot be two consecutive ultra-short vowels, argues in favor of a foot-contrast based account of the distinction (not unlike the difference in English in the ultima of "latest" and "latex").

The supposed ternary length of Applecross Gaelic (Ternes 1973) is at least in part derived from higher-level foot-like prosody. Examples such as [s̆ĩn,] "we", [s̆i:n,] "venison", [s̆ĩ::n,] "to sing", or [tuɬ] "to go", [u:ɬ] "apple", [su::l] "eye" demonstrate a three-way distinction. Evidence from alternations related to limits on morae within the first two syllables links overlength to higher prosody. Overlength only appears in monosyllables, so when the plural suffix is added to a root with an overlong vowel, that vowel shortens — see [u:ɬ] "apple" [u:ɬən] "apples"; [su::l] "eye" [su:lən] "eyes". Disyllables allow only a two-way length contrast in the first syllable, thus [tɨl'ak] "leaf" [fɨ:lak] "seagull", and long diphthongs are subject to shortening under affixation ([mĩa:ɬ] "louse"~ [mĩaɬən] "lice"), because vowel length appears only in the first two syllables, which may contain no more than three morae. Ternes discusses various reductions of the distinction, including a contrast between [v:] and [v.v] — see the discussion of Kikamba below. Anna Bosch (p.c.) informs me that [v:] versus [v.v] is a phonologically more appropriate representation, and vowels in hiatus can also be distinguished from long vowels and diphthongs by pitch, stress and glottal properties.

Other languages claimed to have more than three degrees of length have been reanalysed. Whitely & Muli (1962) claim a four-way length distinction for Kikamba, citing examples such as (orthography normalized) *ko-kɔma* "to lie down", *ko-bɔ:ta* "to accomplish something", *ko-kɔ::ma* "to grunt", *ko-sya:::* "to give birth frequently. An in-depth analysis of Kikamba phonetics and morphophonemics (Robert-Kohno 2000) reveals that the durational differences are a fact,

[11] The Saami languages are often mentioned in the context of ternary length; however, the ternary contrast, when it exists, appears to be limited to consonants. Vowel length in Saami languages is underinvestigated, and there is the possibility that ternary vowel length exists.

[12] It is of some interest that these languages show iambic lengthening even though stress is trochaic.

but analytically they reduce to the fact that Kikamba has both vowel length ([kokɔ̋mɑ́] "to lie down" versus [kobɔ̋ɔ̀tà] "to accomplish") and heterosyllabic identical vowel sequence ([ko-kɔ.ɔ̀mà], [kokɔ́.ɔɔ̀tà] "to pull". The fact that [ko.e.à] "to cry", [ko.i.e.à] "to keep watch for" and [ko.ɔ̋ɔ̀tà] "to dream" are also possible shows that there is no phonologically principled upper limit on vowel sequences. This gives rise to surface degree-5 or higher length in forms such as [néńéké.é.é.éetɛ̂] "I have cried for it$_7$" (/né-né-ké-é-é-éetɛ̂/ = FOC-1S-OBJ$_7$-CRY-APPLIC-ASPECT). While identical vowel sequences across languages often exhibit rearticulations that give evidence of their bisegmentality, Kikamba provides no such phonetic clues, relying only on subtle differences in duration to directly attest to the distinction [o:] versus [o.o], [o.o.o]. Kikamba thus points to one one direction that an analyst might look in representing multiple degrees of vowel length, that is to reduce them to one or two "lengths" in the traditional sense plus a distinction — in principle unlimited — between single and multiple syllables.

Multiple vowel lengths have been claimed for certain Northern and Western dialects of German. In the dialects around Dithmarschen and Stavenhagen (Hock 1986 citing Grimme 1922), it is said that there are three vowel lengths, but as also noted by Hock as well as Kohler (2001), there are vowel quality and tonal distinctions operative in these dialects, making the claim for three lengths suspicious. Insofar as the argument for ternary length in German is based just on surface differences and not morphophonemic patterning where the hypothesis of ternary length elucidates other areas of the grammar, these facts cannot be taken as indicative of ternarity. Another supposed case of ternary vowel length is Hopi, based on Whorf (1946) who mentions three lengths. Jeanne (1982) shows that there are two lengths but two surface-contrastive pitches on long vowels.

Stronger evidence for ternary vowel length is available. Two dialects of Mixe, those of Coatlán (Hoogshagen 1959) and San José el Paraíso (van Haitsma & van Haitsma 1976) present three vowel lengths, illustrated by the following minimal triples from Coatlán.

(47)	poš	"a guava"	po:š	"a spider"	po::š	"a knot"
	pet	"a climb"	pe:t	"a broom"	pe::t	"Peter"

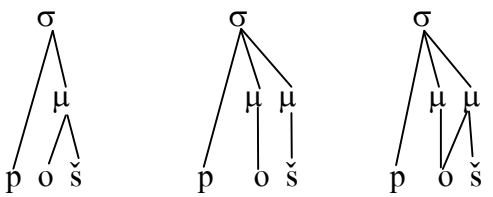
The longest quantity only appears in stressed syllables.

Analysis in terms of a vowel-cluster versus long vowel contrast, similar to Kikamba, would not be appropriate for Mixe, since the language has no vowel sequences. The distinction is phonemicized by Hoogshagen as respectively /poš/, /po:š/, /po:hš/, based on the fact that [Vh] but not [V:h] syllables exist. There is no direct evidence from rules in this dialect that reveals how the three lengths behave phonologically. In the dialect of San José El Paraíso, there is an interaction between vowel overlength and consonant voicing where obstruents are allophonically voiced after Q3 vowels, which argues that Q3 is, at least, something that the phonology refers to. The reason for assuming that consonant voicing is phonological is that it is distinctive in loan words. This does not provide a sufficient basis for reasoning to a particular theory of Q3, and it simply shows that a Q3 vowel must be phonologically identifiable.

Based on analysis of the phonetics and phonology of consonant and vowel quantity in a dialect of North Saami, Bals, Odden & Rice (2009) argue for contrastive linkages of vowels and consonants to morae in maximally bimoraic syllables, which generates segmentalized ternary

consonant length distinctions. Applying that analysis to Mixe would yield the following treatment of ternary vowel length.

(48)



The interpretation of these structures follows the insight that a mora correlates with time, and when a unit is shared between two segments, each segment will be shorter than if it exhausts the mora. This would be untenable if a three-way contrast exists in CV monosyllables; final open syllables are uncommon in Mixe and it is not clear whether such contrasts exist.[13]

Yavapai also appears to present three contrastive vowel lengths. Shaterian (1983) indicates such a contrast, without minimal or near-minimal pairs. Ignoring pitch marks, one finds vowel-final monosyllabic[14] triples such as [kčí] "step (v)", [ʔčí:] "fish (n.)", [ʔʔɪ::] "wood". Such examples are important, because they render implausible an analysis along the lines of North Saami or as suggested above for Mixe: there is no coda consonant to engage in a contrastive sharing relationship. There are morphologically-related vowel lengthening processes as illustrated by [wīsa] "mother's older sister" versus [wī:sa] "id. (pl. obj)" but the evidence from Shaterian does not suggest a cumulative effect where Q1 → Q2 and Q2 → Q3. Patterns of morphophonemic alternation in this language are unclear. A later phonetic study, Thomas (1992), establishes the physical reality of the three-way length contrast, providing minimal triples such as [ʔaha] "water", [ʔaha:] "be bitter", [ʔaha::] "cottonwood". These are represented in Shaterian (1983) as [ʔhā] "water", [ʔhā:] "be bitter", [ʔhá(:)] "cottonwood", and in Thomas & Shaterian (1990) as respectively /ʔhà/, /ʔhá::/ and /ʔhâ:/, illustrating the fact that in some interpretations of the data, the longest quantity tends to correlate with the pitch [v̄] (high pitch) rather than [v́]. Thomas & Shaterian (1990) and Thomas (1992) do not find a statistically significant correlation between pitch and the vowel quantities (and do not directly address putative examples of contrastive pitch with constant length such as [hnū] "be ungrateful", [hnû] "scoop out").

Rood (1975, 1996) notes a ternary vowel length difference in Wichita, seen in [hárah] 'there (pointing)' [ha:ŕí:h] 'that one', [ha::rih] 'there, in that place', but one may suspect that this involves paralinguistic elongation. There do not appear to be minimal or near-minimal pairs controlling syllable structure, (contrastive) pitch and word position, but examples such as the following make the claim for contrast plausible.

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[13] An Estonian-style foot analysis would not be an appropriate alternative. In Estonian, Q2 only contrasts with Q3 in stressed syllables when another syllable follows: all word-final stressed syllables are Q3. In Mixe, Q3 appears to exist only in monosyllables.

[14] This assumes the phonemicization of Shaterian (1983) with substantial consonant clusters, which are broken up by epenthetic vowels on the surface.

(49)	tará:ki::s	“he/they saw you all”	←	/ta-a-ra:k-ʔi::s/
	hitíː::ʔeh	“they have it”	←	/hiʔ-ti-iy-iy-ʔahi/
	taté:ʔeh	“I am holding it for thee”	←	/ta-t-a-ʔiy-ʔahi/
	tíː::ʔeh	“he owes him”	←	/ti-uru-ʔahi/
	tíːʔi::s	“out-of-focus saw him”	←	/ti-iy-ʔi::s/
	tati:ci:ʔeh	“I am holding his”	←	/ta-t-uc-i-iʔahi/
	kʔíta:ks	“coyote”		
	ti::yaris	“indefinite is becoming”		

Again, there is no clear evidence coming from a system of alternations revealing how this difference should be treated phonologically.

The most compelling case for ternary vowel length qua length and not an interaction between binary length plus an orthogonal property comes from Dinka, especially as documented in Andersen (1987, 1993), Remijsen & Manyang (2009) and Remijsen & Gilley (2008). Remijsen & Gilley show that the 3-way difference in vowel length is statistically significant. They also point to important clues as to the phonological analysis of length, since certain grammatical categories are associated with vowel lengthening, and there are also lexical vowel length contrasts in verbs. Verbs in the past or 3s have a lengthened vowel, with the consequence that within one and the same category, an underlyingly short vowel becomes long and an underlyingly long vowel becomes overlong.

(50)	*Short stems*		*Lengthened stems*		
	negative	2s	past	3s	
	tét	-tét	tĕet	-tèet	“pick”
	tèet	-téet	téeet	-tèeet	“divulge”

Data of this sort is highly informative, since it shows by processual analogy that the relationship Q1:Q2 is the same as Q2:Q3, making implausible an analysis with just two vowel lengths and a second intersecting prosodic property such as foot structure. What is not clear is whether vowel-overlength is necessarily represented on the surface with three of whatever long vowels have two of, and an account involving contrasts like (48) may be possible. A deeper study of the phonology of ternary length in Dinka will no doubt prove enlightening.

5. Summary

The first task in treating vowel length is distinguishing length from other properties. Difference in duration is what analysts usually pay attention to, but other segmental properties can have durational consequences. Phonological analysis of processes is necessary to argue for a surface difference of “length” versus some other phonetic feature. Since some apparent instances of vowel-length facts can (or must) be reduced to something other than length (foot structure in Estonian, or segment-to-syllable structure differences in Kikamba), claims about length cannot gratuitously assume a duration-length equation.

The evidence for not representing vowel length with a feature analogous to [nasal] or [voice] is compelling, and numerous arguments support the "long vowels are two" theory, but it has been difficult to resolve what long vowels are two of. The initially attractive idea of long vowels being two identical segments does not work as a general theory of vowel length, because of the ambiguity problem (long vowels can act both like single segments and like sequences) and because languages can contrast a single long vowel with two identical short vowels.

With the addition of at least syllable structure, a coherent account of vowel length emerges, based on the idea that a long vowel is a single segment associated to two prosodic positions. Then the question arises, what are those positions: do they reflect a basic consonant versus vowel distinction, or are they generic in nature? The evidence for a C/V distinction is weak in the face of a highly articulated theory of syllable structure, but the evidence for a highly articulated theory of the syllable a la X′ syllable theory is weak in the face of a more stripped-down theory of the syllable with the somewhat richer theory of the timing positions offered by CV phonology. Moraic theory has certain advantages over skeletal theories relevant to vowel length, in its treatment of compensatory lengthening of vowels, in particular the problem of onset-irrelevance. Various problems with moraic theory have been brought out; but these problems seem to center on problems for consonants, not vowel length. At this point, the conclusion that vowel length is represented by two higher-level entities linked to one lower-level thing seems firmly established, but the precise nature of those higher-level entities remains elusive.

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