Doctoral Dissertation

The Phonetics-Phonology-Interfaced Analysis of Prosodic Structure in English: Focused on Syllable Weight

Department of English Language and Literature

GRADUATE SCHOOL
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Abbreviation Keys

A	Approximant
C	Consonant, Coda
F	Foot
L	Liquid
N	Nasal, Nucleus
Ob	Obstruent
OT	Optimality Theory
Ś	Primarily stressed syllable
S	Stressed syllable
V	Vowel
W	Unstressed syllable
μ	Mora
σ	Syllable
ω	Prosodic word

ABSTRACT

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Since the syllable was introduced as a phonological unit, there have been many discussions on the structure of syllable. Among many theories (e.g., sonority, the CV tier, and mora), we adopt the mora theory in this dissertation to explain syllable weight. In English, there exists the asymmetry between the word-internal coda and the word-final coda. Three main theories on this asymmetry are discussed in this dissertation: word-final C extrametricality, catalectic final syllable, and word-final mora-sharing C. This dissertation argues for the mora-sharing word-final consonant to explain the asymmetry between the word-internal coda and the word-final coda.

In previous studies, it has been proven that if a word-final coda shares a mora with the preceding vowel, the duration of the mora-sharing vowel is shortened. However, little

attention has been drawn to the duration of the mora-sharing consonant. This dissertation finds that the duration of the mora-sharing consonant is also shortened compared to the non-mora-sharing consonant (word-internal coda). For example, the duration of the /t/ in *let us* is shorter than that of the /t/ in *lettuce*. It is argued in this dissertation that the duration of the /t/ in *let us* is shorter compared to the duration of the /t/ in *lettuce* because the /t/ in *let us* is sharing a mora with the preceding vowel. Therefore, the hierarchical structure of *let us* should be different from that of *lettuce*.

This dissertation also argues that the syllable plays a critical role in prelexical classification in English. In order to access the meaning of any lexical unit, a recognizer must be aware of where the unit begins because speech signals are continuous. There are two possible solutions to deciding where the lexical unit begins: matching the arbitrary speech signals to stored acoustic templates and undertaking prelexical classification. To achieve greater efficiency, a human recognizer undertakes a prexical classification of the speech signal. English is known to be a stress-timed language. Therefore, English is sensitive to the stress, some phonological phenomena being more sensitive to the foot than the syllable. For example, stress clash and shift occur at the foot level, not syllable. Nevertheless, it is shown in the dissertation that listeners tend to prefer the syllable in terms of prelexical classification. There is also some evidence presented by some researchers (Cutler *et al.*, 1983; Mehler *et al.*, 1981, 1986; Noriss *et al.*, 1985, 1988 among others) that the syllable functions as a fundamental perceptual unit. For example, both *balance* and *balcony* begin with the same three segments *bal-* . However, *ba-* is identified faster than *bal-* in *balance* because *ba-* (not *bal-*) constitutes the syllable. By the same token, *bal-* is perceived faster than *ba-* in *balcony* because *bal-* is the syllable of *balcony*. This dissertation also shows that when English native speakers listen to the two-word readings that sound like one word (e.g., *mark it* sounds like *market*), they tend to perceive them as the one-word readings (e.g., *market*).

Chapter 1

Introduction

1.1 Purpose of the study

The purpose of this dissertation is to argue for the status of the word-final consonant in the structure of syllable in English and the role of syllables as prelexical classification. There exists the asymmetry between the word-internal consonant and the word-final consonant in the English syllable structure. This dissertation analyzes the structure of word-final syllable, using phonetic evidence. In addition, it is shown in this dissertation that syllables can function as an important unit for prelexical classification in non-syllable-timed languages like English as well as in syllable-timed languages like French.

This dissertation explores the prosodic structure with focus on syllable weight. In particular, special attention is given to the CVC weight asymmetry of word-final syllables. The phonetics-phonology-interfaced approach is taken to shed new light on the structure of word-final syllables.

This study supports the word-final mora-sharing consonant proposed by Broselow, Chen, and Huffman (1997) and Lunden (2011) through the phonetic analysis. In order to accept phonetic data as the convincing evidence for the prosodic structure, similarities and differences between phonetics and phonology are reviewed. The phonetic analysis not only shows physical features, as known before, but is also related to psychological and cognitive aspects. Therefore, phonetic data can be used as the evidence to complete the phonological analysis.

Regarding the structure of the syllable, three main theories are reviewed: sonority theory, the CV tier, and the mora theory. As explained before, in this dissertation, much emphasis will be put on mora and syllable weight, and syllable structure will be explored by introducing both phonological arguments and phonetic evidence.

Interestingly, many languages, including English, show an asymmetric status of CVC syllables: CVC is usually heavy in word-internal position, but it is considered light in word-final position. There are three main theories that explain this asymmetric status: word-final C extrametricality (Hayes, 1995), catalectic final syllable (Kiparsky, 1991), and word-final mora-sharing C (Broselow *et al.*, 1997; Lunden, 2011). Word-final C extrametricality and catalectic final syllable provide a phonological solution to a CVC weight asymmetry while word-final mora-sharing provides phonetic evidence.

Two types of experiments were conducted in order to shed new light on the status of a word-final coda. In Experiment 1, an English native speaker was requested to first read a list of carefully chosen pairs of words that sound like one word (e.g., *let us*) and then read a list of single words that sound the same as two words (e.g., *lettuce*). Syllable weight and the duration of its segments are significantly correlated (Broselow *et al.*, 1997). Therefore, to compare the durations, I measured the duration of the word-final consonant of the first word (e.g., /t/ in *let*) and that of the correspondent word-internal consonant (e.g., /t/ in *lettuce*) by using Praat.

Vowels and weight-contributing consonants have their own mora, but weightless coda consonants share a mora with preceding vowels (Broselow *et al.*, 1997). It is postulated in the dissertation that word-final lengthening is a sort of psychological and cognitive mechanism that speakers use to signal the ending of speech (in this case, word). Therefore, when two words are combined, the word-final consonant of the first word is not affected by word-final lengthening. Its duration returns to the original length. By measuring its duration, we can see the internal structure of the word-final CVC before it is affected by word-final lengthening.

In Experiment 2, thirty six English native speakers were asked to listen to the recording of a carefully chosen pairs of words, and to write down as they recognized (e.g., *rock it* or *rocket*), to identify that the syllable plays an important role in prelexical classification both in non-syllable-timed languages like English and in syllable-timed languages like French. In Experiment 2, most listeners respond to the syllables without clear recognition of the word boundary. This can be interpreted as they use the syllable for prelexical classification.

1.2 Organization

Chapter 1 is an introduction to the study which addresses the purpose of the study and the organization. Chapter 2 discusses the relation between phonetics and phonology. As the *interfaced analysis* in the title of the dissertation implies, I take phonetic and phonological approaches to analyzing and accounting for the prosodic structure because they both complement each other. Therefore, the understanding of their relationship is of great importance. A brief historical background and three different views on the relation between phonetic and phonology are introduced. In the latter part of this chapter, the features of glides and vowels are examined to show that phonetic evidence is essential to complete linguistic explanations. In phonology, high vowels /i/ and /u/ are treated as featurally identical to glides /j/ and /w/, respectively, except for syllabicity. However, glides are phonetically different from high vowels in dynamics and constriction degree.

Chapter 3 is a brief review of the syllabic structure. It is shown that syllables are essential phonological units. Next, the structure of syllable and the relations between segments and syllables are considered. Distinguishing syllables seems easy, but it is not easy to say what a syllable is in phonological terms. One of solutions is sonority theory, but it still has unsolved problems. Then, the CV tier is introduced. There are three arguments that support the CV tier: templates, unassociated slots, and compensatory slots. To solve the issues that the CV tier cannot explain, mora is introduced.

In Chapter 4, syllable weight and the role of mora are explored through phonological arguments and phonetic evidence. Hyman (1984, 1985) and McCarthy and Prince (1986) propose moraic theory of prosodic tier structure. Katada (1990, 2014) provides evidence for mora, drawn the Japanese language game *Shiritori* 'hip-taking'. Languages have different syllabic structures. Some languages, including English, have the onset-rhyme asymmetry. Elements in the rhyme have mora while those in the onset do not have mora. This asymmetry can be accounted for in the moraic theory. No mora is assigned to the onset. One mora is assigned to a short vowel. Two moras are assigned to a long vowel or a diphthong. The moraic status of postvocalic consonants (coda) is language-specific. In languages with Wight-by-Position (Hayes, 1989) including English, single mora is given to the coda. Monomoraic syllables are treated as light and bimoraic syllables heavy. Phonological arguments and phonetic evidence are introduced with focus on mora.

Chapter 5 explores CVC weight asymmetry between word-internal and word-final syllables. CVC is usually heavy in word-internal position, but it is considered light in word-final position. Three main theories that explain this asymmetric status are reviewed: word-final C extrametricality (Hayes, 1995), catalectic final syllable (Kiparsky, 1991), and word-final mora-sharing C (Broselow *et al.*, 1997; Lunden, 2011). In the latter part of this chapter, the word-final rhyme is phonetically analyzed. There is a significant correlation between syllable weight and the duration of segments (Broselow *et al.*, 1997). The reason the duration of the word-final coda is long even though no mora is assigned to it is explained by the phonetic analysis.

In Chapter 6, the results and discussions of the experiments conducted are provided. I carried out two experiments to support the appropriate structure of the word-final syllable. In Experiment 1, an English native speaker was requested to first read a list of carefully chosen pairs of words that sound like one word (e.g., *let us*) and then read a list of single words that sound the same as two words (e.g., *lettuce*). I measured the duration of the word-final consonant of the first word (e.g., /t/ in *let*) and that of the correspondent word-internal consonant (e.g., /t/ in *lettuce*) by using Praat. In Experiment 2, thirty six English native speakers listened to the recording of a carefully chosen pairs of words, and they were requested to write down as they recognized (e.g., *rock it* or *rocket*).

In Chapter 7, two-fold conclusions are drawn: First, the word-final coda shares a mora with the preceding vowel. Second, the syllable plays a vital role in prelexical classification even in non-syllable timed languages like English.

Chapter 2

The Interfaced Aspects of Mora in Phonetics and Phonology

In this dissertation, a special focus is on highlighting the status of the word-final consonant. Phonetic data are analyzed to propose the appropriate model of the prosodic structure. Weightless coda consonants share a mora with preceding vowels while vowels and weight-contributing consonants have their own mora. It is difficult to find phonological arguments to prove the fact that non-weight-contributing coda consonants share a mora with preceding vowels, but it is possible to prove it by representing phonetic data (Broselow *et al.*, 1997). Therefore, it might be worth reviewing the relation between phonetics and phonology before delving into the syllabic structure.

There have long been debates over the relation between phonetics and phonology. Both phonetics and phonology have a shared interest in human speech sounds and sound patterns. However, phonetic and phonological representations have been considered different in that phonetics is related to concrete scales while phonology deals with abstract features. Recently, an increasing number of linguists are reviewing the proper relationship between phonetics and phonology.[1] In this chapter, three different perspectives on the relation between phonetics and phonology are introduced and reviewed: Two are polarized (one considers phonetics and phonology are totally different and unrelated as the other views phonetics and phonology as the same module), and the third perspective tries to explain the relation between phonetics and phonology through eclecticism, not dogmatism.[2] A brief historical background is reviewed in section 2.1. Three different views are introduced in

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[1] See Hjelmslev (1953), Fudge (1967), Postal (1968), Foley (1977), Anderson (1985), Hume and Johnson (2001), Keating (1990, 1996), Ladefoged (1990), Flemming (1995, 2001, 2004), Kirchner (1997, 2004), Ohala (1990) Zhang (2004) among others.

[2] Laboratory Phonology has actively conducted research through this perspective. In section 2.4, Laboratory Phonology is introduced and reviewed.

section 2.2, 2.3, and 2.4, respectively.

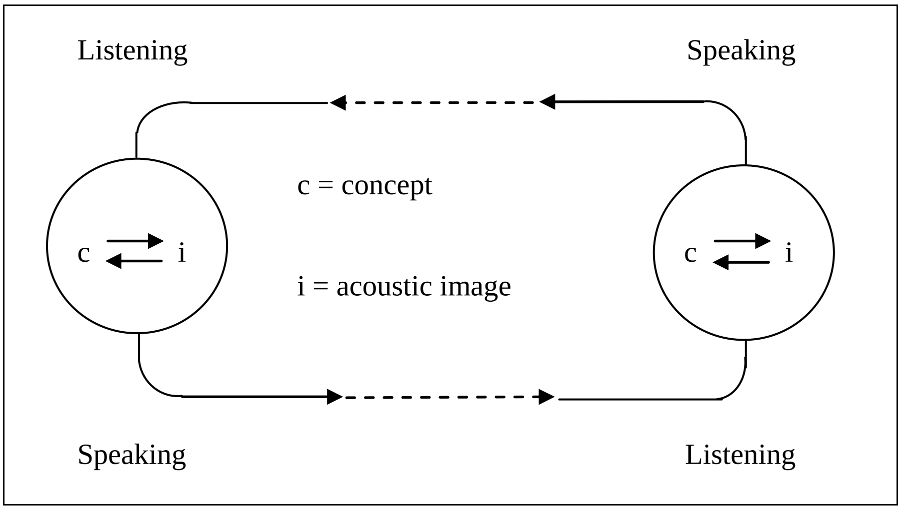
2.1 Brief historical background

The study of phonetics had started to be considered as an independent discipline since the 19th century when it was introduced to European countries from India. German physician and physiologist E. W. Brücke (1819-1892), writing *Grundzüge der Physiologie und Systematik der Sprachlaute für Linguisten und Taubstummenlehre* and Jean-Pierre Rousselot (1846-1924) who was a French priest, phonetician and dialectologist, publishing the two volumes of his *Principes de Phonétique Expérimentale* in 1897 and 1901 founded the groundwork for phonetics. Then, H. Sweet, P. Passy, O. Jesperson, and D. Jones established phonetics as a modern discipline.

It is not until the beginning of the 20th century that phonology is considered an independent field of study. Trubetzkoy, a member of the Prague School, made contributions in phonology. In his posthumously published book *Grundzüge der Phonologie* (1969),[3] he defined "the phoneme as the smallest distinctive unit within the structure of a given language." Trubetzkoy's strict division between phonetics and phonology is compatible with langue and parole[4] suggested by Saussure. The circuit of human language proposed by Saussure is illustrated in (1):

[3] Trubetzkoy, Nikolai (1969). *Principles of phonology*. Berkeley: University of California Press.
[4] French: meaning "language" and "speaking," respectively.

(1)



According to Trubetzkoy, phonology deals with langue while phonetics is related with parole. He claims that it is wrong not to differentiate the two disciplines because only phonology is qualified to belong to linguistics whereas phonetics belongs to physiology. Thereafter, phonology is developed by Chomsky and Halle (1968) into generative phonology, and phonetics is developed by Pike, Jones, Ladegoged.

2.2 The phonological aspect: two discrete modules

The view that phonetics and phonology are discrete has been espoused in generative phonology by Chomsky and Halle (1968), in which the values of features are binary. The features of phonology are abstract and categorical whereas phonetic features are concrete and continuous.[5] According to this view, there is no relation between phonetics and phonology although both phonetics and phonology describe human sounds and sound patterns. They are totally different in nature. Phonology is characterized as abstract and categorical features and phonetic properties are concrete and continuous. Therefore, phonetics is not proper to explain abstract phonological aspects (Foley, 1977; Fudge, 1967;

[5] Phonetic features are characterized as "n-ary". See Postal (1968) for details.

Hjelmslev, 1953). Phonology also focuses on making generalizations of common speech sound patterns of all human languages (Anderson, 1985; Hume & Johnson, 2001; Keating, 1990, 1996; Ladefoged, 1990). The fact that phonology is characterized as symbolic, abstract representations and qualitative categories while phonetics is marked by concrete, physical realization and quantative continuities supports the conclusion that phonology and phonetics are different. In addition, Foley (1977: 52) argues that "Only when phonology frees itself from phonetic reductionism will it attain scientific status."

According to Ohala (1997), the view that there is no interface between phonetics and phonology started from structuralism by Ferdinand de Saussure and was elaborated by the Prague School. The Prague School believed that the phonetic role should be ancillary. Supporting this view, Hjelmslev (1953), Fudge (1967), and Foley (1977) argue that there is a strong division between phonetics and phonology and that phonological elements are not subject to acoustic or articulatory properties but identified in terms of the rules and constraints. Foley (1977) puts an emphasis on phonological processes, considering phonetic elements superficial.

In the abstract phonological analysis, physical and concrete phonetic facts are not in the realm of analysis. An example of the abstract view of phonology can be found in Fudge's (1967) analysis of the Hungarian vowels. Vowel harmony is an important feature of the Hungarian language. The vowels in a word are closely related with the word's overall harmonious status. Fudge (1967: 10) did not divide some vowels into mid and low. Instead, he adopted a symmetric vowel chart, as shown in (2). Note that the specified low group combines mid vowels with low vowels and that the low vowels are also described as non-high.

(2) Hungarian vowel system

	Front		Back	
	Unrounded	Rounded	Unrounded	Rounded
High	i i:	y y:		u u:
Low (non-high)	e e:	ø ø:	a a:	o o:

As seen in (2), high back unrounded vowels do not exist in the vowel system of the Hungarian language. Phonologically, as the exponent of the plural affix, a front vowel /i/, can be attached to the stem with front vowels as in /keze-i/ and the one with back vowels as in /doboza-i/. See (3):

(3) *i*-affixation in Hungarian (Fudge, 1967: 10)

a. /keze-i/ 'his hands'

b. /doboza-i/ 'his boxes'

Let us consider /doboza-i/ in (3b). Attaching front vowel /i/ to the stem with all back vowels is not harmonious. Note again that in the Hungarian language, the vowels in a word are closely related with the word's overall harmonious status. Therefore, attaching this plural affix (front vowel /i/) to the stem with all back vowels is rare in terms of vowel harmony. To explain this uncommon phenomenon, Fudge (1967) argues that the gap of the high back unrounded can be filled with the corresponding high front unrounded vowels, /i/ and /i:/. As a result, from the abstract phonological perspective, the high front unrounded vowels, /i/ and /i:/ take two places, high front unrounded and high back unrounded, in the Hungarian vowel system. Note that the phonetically front vowels are treated by abstract phonology as back vowels. The high front unrounded vowels function, taking over the gap, as high back unrounded vowels. Thus, the value of the high front unrounded vowels is phonetically front but functionally back. They function distinctively in the system of the language. In other words, human speech sound patterns can be properly analyzed from the perspective of abstract phonology, not physical phonetics.

Another example comes from Vago's (1976) analysis of the exception of Hungarian vowel harmony. Vago (1976) analyzes this exception of Hungarian vowel harmony differently than Fudge (1967) does. According to Vago (1976), /ö/ and / ö:/ are the underlying representations of /i/ and /i:/, respectively. Vago (1976: 245) calls these underlying back vowels "abstract" vowels because there are no such vowels in the Hungarian vowel system. Note that phonological representations are different from their phonetic features. Consider the example in (4):

(4) Exception of vowel harmony in Hungarian (Vago, 1976: 244)

a. hö:d 'bridge' + na:l/ne:l 'at' à hi:d-na:l/*hi:d-ne:l

b. hö:d 'bridge' + to:l/tø:l 'from' à hi:d-to:l/*hi:d-tø:l

Gilbers, Schreuder, and Knevel (2004) argue, exploring the boundaries of phonetics and phonology, that the phonological level should be distinguished from that of phonetics. Gilbers *et al.* (2004) provide an example of the schwa insertion process in Dutch. Consider examples of the schwa insertion process in Dutch as illustrated in (5):

(5) Schwa insertion in Dutch (Gilbers *et al.*, 2004: 3)

helm	[hɛləm]	'helmet'	*darm*	[dɑrəm]	'intestine'
half	[hɑləf]	'half'	*durf*	[dœrəf]	'courage'
melk	[mɛlək]	'milk'	*hark*	[hɑrək]	'rake'

not in: *vals* 'out of tune', *hals* 'neck', *hart* 'heart', *start* 'start'

In Dutch, schwa insertion occurs at the end of a syllable between a liquid /l, r/ and a consonant that is different from a liquid /l, r/ in place of articulation. Gilbers *et al.* (2004) call this kind of consonant a non-homorganic consonant. As seen in (5), schwa can be inserted between /l, r/ and /m, f, k/ because a liquid /l, r/ is coronal and a consonant /m, f, k/ is non-coronal in place of articulation. Therefore, a consonant /m, f, k/ is a non-homorganic consonant. On the other hand, schwa is not inserted between /l, r/ and /s, t/ because /s, t/ is coronal obstruent which means /s, t/ is a homorganic consonant.

Note that there are at least two different phonetic realizations of /r/ in Dutch: an alveolar [r] and a uvular [R]. Two different phonetic realizations of /r/ (i.e. alveolar [r] and uvular [R]) show no functional difference, as shown in (6):

(6) Phonetic realizations of /r/ in Dutch

	alveolar	uvular	
rat	[rat]	[Rat]	‘rat’

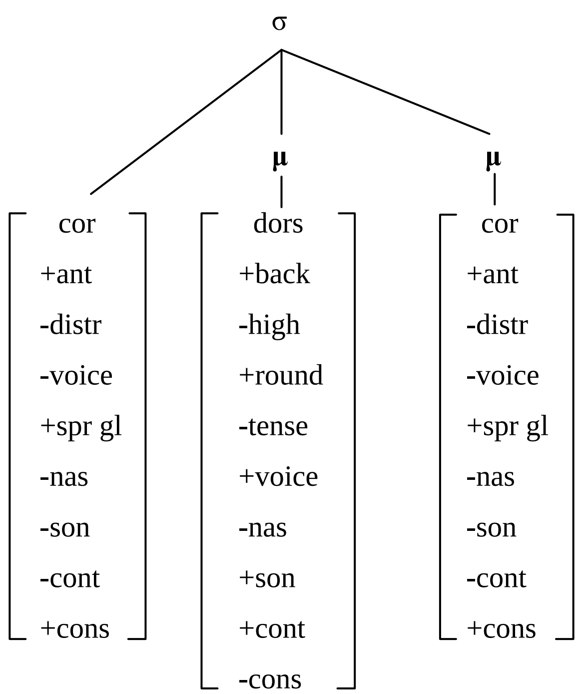
However, an interesting point is that schwa insertion cannot be found, with Dutch speakers with a uvular [R], in between their [R] and non-homorganic coronal obstruent /s/ or /t/. Based on this, Gilbers *et al.* argue that there are two different levels: phonetic and phonological level, and that schwa insertion occurs at the abstract phonological level, not phonetic level. This process can be adequately explained only in phonological ways.

2.3 The phonetic aspect: one single module

There is also an opposing point of view on the relation between phonetics and phonology: both phonetics and phonology can be unified into one single module with great focus on phonetic detail. Some linguists (Flemming, 1995, 2001, 2004; Kirchner, 1997, 2004; Ohala 1990; Zhang, 2004 among others), by introducing certain versions of Optimality

Theory, argue that phonetics and phonology are integrated into a single unit. Howe and Pulleyblank (2001) argue that there need not be any distinction between phonetics and phonology if phonetic details are included into phonological representations. In this unified framework, phonological components are executed in quantitative phonetic values, instead of separate components. There is no formal division between phonetics and phonology. Phonology is considered strikingly similar to phonetics. The output constraints are largely dependent on phonetic details. Flemming (2004: 7-8) insists that in many ways, the temporal representation be considerably limited in standard phonological representations. Consider the phonological representation of the word *taught* [t^hɔt], as illustrated in (7):

(7)



The phonological representation as in (7) does not provide any information related to the precise duration: the duration of segments and the duration of aspiration, let alone the feature of the articulatrs' movement from one segment to the next. In addition, according to Ohala (1971), the /ɔ/ in *tought* is different in its realization from the /ɔ/ in *awe*. It is the characteristic of low vowels that the velum is slightly lowered. This prorerty is not included in phonological representation.

From the point of view that there is a sharp distinction between phonetics and phonology, many of these details of phonetics are accounted for as a consequence of universal phonological principles. Consider the following quotation from Chomsky and Halle (1968: 295): “phonetic transcriptions omit properties of the speech signal that are supplied by universal rules.” However, Keating (1985) argues that there is language-specific variation in phonetic details. Therefore, it should be specified in the grammars of specific languages. Flemming (2001) argues that phonetics and phonology are not basically different in the nature of the representations involved. In fact, most of the primitives of phonological representation are based on phonetics: phonetic definitions provide features and timing units. Phonetic and phonological phenomena can be accounted for within a unified framework which is better able to explain many similarities between the two disciplines. Flemming (2001) also contends that there are no clear criteria that assign a certain phenomenon to phonetics or phonology. Pointing out widely familiar constraint-based analyses of phonological phenomena, Flemming (2001) applies the same constraint-based analyses to phenomena involving phonetic details which are similar to Optimality-Theoretic phonology.[6] Consider consonant-vowel assimilation in F2 as illustrated in Figure 1:

[6] Outputs are selected so as to best satisfy conflicting violable constraints.

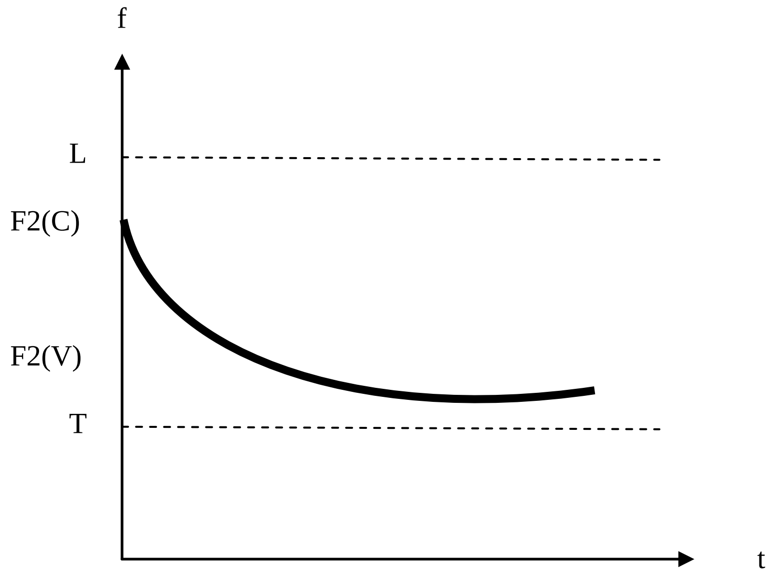


Figure 1

In a CV or VC sequence, F2 (the second formant frequency) at the edge of the consonant and F2 in the vowel affect each other, resulting in targets being systematically ‘undershot.’ Each consonant and vowel has an F2 target, but when those targets are far apart, those targets cannot be achieved because of a dispreference for fast articulatory movements. As seen in Figure 1, the consonant has its F2 target, L (for ‘locus’) and the vowel has its own F2 target, T. Notably, the actual F2 values are inclined towards each other.

Flemming (2001) has found that the relation between F2(C) and F2(V) is highly linear as seen in Figure 2:

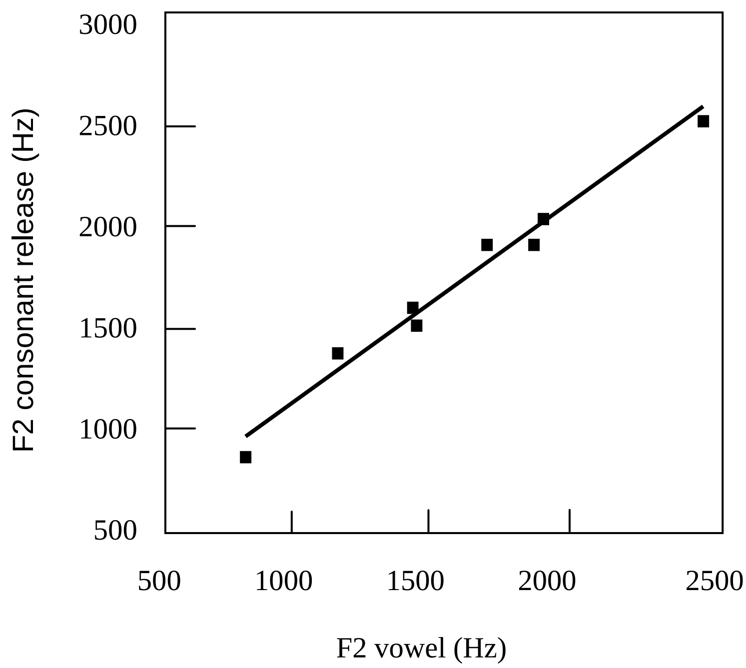


Figure 2

Flemming (2001) has introduced the two equations as shown in (8):

(8)

a. $F2(C) = k_1(F2(V) - L) + L$

b. $F2(V) = k_2(F2(C) - T) + T$

The equation shown in (8a) is called a 'locus equation' (Klatt, 1987). Lindblom (1963) and Broad and Clermont (1987) have found support for the equation shown in (8b).[7]

Partial assimilation between adjacent consonants and vowels can be observed. This assimilation can be viewed as a result of a compromise between achieving the F2(C) and the F2(V). There is a tendency to minimize the difference between the adjacent consonant and vowel. Flemming (2001) proposes two basic constraints by adopting constraint-based analyses of phonological phenomena as shown in (9):

[7] For more details, see Flemming (2001: 17-8).

(9) Flemming (2001: 19)

a. Don't deviate from targets.

b. Minimize articulator velocity (effort).

From the constraints shown in (9), Flemming (2001) formalizes these constraints as constraints on F2(V) and F2(C), as schematically illustrated below in (10):

(10) Flemming (2001: 19)

	Constraint	*Cost of violation*
IDENT(C)	F2(C) = L	ω_c (F2(C) - L)^2
IDENT(V)	F2(V) = T	ω_v (F2(V) - T)^2
MINIMISEEFFORT	F2(C) = F2(V)	ω_e(F2(C)-F2(V))^2

Zhang (2004) includes, analyzing contour tone distribution, constraints, as illustrated in (11):

(11) Zhang (2004: 176-7)

a. *DUR (τ_i): for all segments in the rhyme, their cumulative duration in excess of the minimum duration in the prosodic environment in question cannot be τ_i or more.

b. If $\tau_i > \tau_j$, then *DUR (τ_i) >> *DUR (τ_j)

According to this unified framework, the same motivating constraints are best to analyze the existing parallels between phonetic and phonological phenomena because in many cases, phonetic and phonological phenomena are closely paralled with each other.

2.4 The interfaced aspect: phonetics and phonology

2.4.1 Phonetics as corpus-external evidence

Cohn (2010) claims that recent arguments about theories or models to define the boundary between phonetics and phonology are polarized, being framed in either/or terms. Either this theory is *right* or that theory is *right*. However, Cohn (2010) argues that this sort of polarized view cannot be the best way to enhance our understanding of the nature of human language.

From the views of the two modules introduced in the previous sections, phonetics and phonology are considered completely dependent disciplines, or they can be accounted for by one single unified module. As explored before in the previous sections, there is no simple solution to the solely dependent roles of phonetics and phonology because they are more complicatedly interwoven than supposed. Moving now to the third conditionally interfaced module, the third module adopts eclecticism, on the contrary of the previous two views, assuming that there exists a bridge between phonetics and phonology. In other words, phonetics and phonology are independent from each other but they are significantly interfaced. This conditionally interfaced module is strongly advocated by Laboratory Phonology.[8] According to Cohn (2010: 4), "Laboratory Phonology is an approach to investigating human sound systems, taking it as foundational the premise that progress will be achieved more successfully through integrated methodologies." The development of important phonetic research tools such as ToBi (Beckman & Hirschberg, 1994) and Praat (Boersma & Weenink, 2002)[9] has also fostered research on more sophisticated modeling of human speech. Cohn (2010) argues that integrated methodologies benefit not only phoneticians but also phonologists as well. Phonological methodologies are mostly

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[8] The term *Laboratory Phonology* was coined by Janet Pierrehumbert.
[9] ToBi is a prosodic annotation system and Praat is a free multi-platform acoustic analysis program.

impressionistic and use *corpus-internal evidence*.[10] By focusing on integrated methodologies, phonologists are able to extend their methodologies because integrated methodologies include *corpus-external evidence*. The inclusion of *corpus- external evidence* makes the range of investigating language behavior broader by explaining a speaker's knowledge of the phonology of one's own language. On the other hand, with a help of integrated methodologies, phoneticians are also able to improve phonetics to be more formal, quantitative, and experimental methodology. For example, the focus of experimental approaches was mostly on linguistic phonetics before, but it expanded to include psycholinguistic experimental approaches. Cohn (2010: 10) also adds that "Laboratory Phonology has enriched our understanding of which facets of phonetics inform phonology both methodologically and conceptually, emphasizing the importance of both production and perception." Beckman and Kingston (1990: 5) argue that the assumed division between phonetics and phonology only leads to an elusive conclusion that "we can compartmentalize phonological facts from phonetic facts." Beckman and Kingston (1990) also contend that it is time to erase the assumed division between phonetics and phonology because the list of phenomena that can be accounted for by hybrid methods and models is much larger than supposed so far.

Hayes (1999) maintains, supporting phonetically-driven OT phonology, that phonological representations are not directly related to phonetic details. According to his argument, phonetics is characterized by gradient and changeable properties while phonology is marked as categorical. He also points out that phonetic details can be a source to account for phonological phenomena, but it cannot be a direct basis for phonology. Hayes (1999) takes voicing of postnasal obstruents for example in order to support his argument. Generally, voicing is more favored when following a nasal consonant compared to other consonants. He notes that the post-nasal devoicing phenomenon is not consistent in languages. For example,

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[10] Kenstowicz and Kisseberth (1979) use the term *corpus-internal evidence* which is the transcription of corpus utterances.

English and Ecuadorian Qeuchua show different post-nasal voicing patterns when following a nasal consonant.

English (note that English does not have post-nasal voicing as a phonological process) shows phonetic post-nasal voicing patterns. To test his prediction, Hayes (1999) measures the amount of closure voicing. Then, he finds that there is significantly more /p/ voicing when following /m/ compared to when following /r/, just as predicted. However, he points out that the post-nasal voicing in English is purely quantitative. English speakers maintain the phonemic contrast of /p/ with /b/ after a post-nasal consonant. Here, Hayes (1999) brings out two points: First, it is merely a quantitative distribution of voicing. Second, the distribution of values varies greatly. Hayes shows that the amount of voicing in /mp/ ranges from 13% to 60%.

In contrast, the post-nasal voicing effect is marked as phonological in Ecuadorian Quechua. In Ecuadorian Quechua, a voiceless stop is not phonologically allowed to follow a nasal, and voiceless stops are replaced with voiced stops. Consider the following examples, as in (12):

(12) Hayes (1999: 10)

a. *sača-**p**i* 'jungle-loc.'

b. *atam-**b**i* 'frog-loc.'

As seen in (12a), the suffix /pi/ which means 'loc.' is attached to non-nasal consonants or vowels. As seen in (12b), the suffix /bi/ which also means 'loc.' is attached to nasal consonants. As seen in (12), In Ecuadorian Quechua, there is no contrast between voiced and voiceless in post-nasal position. It can be seen that Ecuadorian Quechua simply follows a categorical strategy, differing from English which has phonetic post-nasal voicing. Hayes (1999) claims that the Quechua case needs additional treatment rather than "simply allowing a phonetic effect to influence the quantitative outcomes to arranging the phonology so that, in the relevant context, an entire contrast is wiped out.”

Smith (2005) argues, based on two types of constraints regulating syllable onsets (ONSET and the *ONSET/X (*MARGIN/X) constraint family), that phonological constraints do not directly encode phonetic information, and that phonological constraints are abstractly expressed in terms of phonological categories. ONSET is a constraint that requires all syllables to have onsets, as defined in (13):

(13) ONSET Syllables have onsets

The *ONSET/X family is derived from the segmental sonority scale and assesses violations based on the sonority of an onset: the higher sonority of a syllable onset is less desirable. *ONSET/X is defined as in (14):

(14) *ONSET/X Onsets do not have sonority level X

*ONSET/X proposed by Smith (2005) is based on *MARGIN/X proposed by Prince and Smolensky (1993), but the difference between *ONSET/X and *MARGIN/X is that *ONSET/X excludes codas because the sonority preference for onsets and codas is different: the low sonority preference for onsets and the high sonority preference for codas. Scale-based markedness constraints have a universally fixed rank determined by the relevant phonetic scale[11] as shown in (15):

(15) Universally fixed ranking determined by sonority scale

*ONS/LOWV >> *ONS/MIDV >> *ONS/GLIDE >> *ONS/RHOTIC >>

*ONS/LATERAL >> *ONS/NASAL >> *ONS/OBSTRUENT

[11] It is the sonority scale.

The constraints, ONSET and *ONSET/X, have the same functional motivation, but their formal properties are distinct. Smith (2005) argues that there is a functional motivation behind onset-related constraints such as ONSET because there is a perceptual advantage gained by a modulation between low and high sonority. Therefore, low sonority is the best for onsets, and the same functional motivation is behind *ONSET/X. Smith (2005) also argues that the two constraints, ONSET and *ONSET/X, have the same function to constraint glide syllable onsets, but they are derived from two distinct phonological structures. To support her argument, Smith (2005: 12) takes two languages (Niuafo'ou and the Sestu dialect of Campidanian Sardinian) for example where null onsets are preferred over glide onsets in stressed syllables, and rhotic and glide onsets in initial syllables, respectively. Smith (2005) concludes that a direct-phonetics model (one single module) is not the only way to account, in a principled way, for a phonetically motivated phonological grammar, adding that "The claim that phonological constraints are distinct from the phonetic factors on which they may be based is compatible with proposals in which phonological constraints are formal, symbolic objects, but the constraint set is nevertheless subject to functionally grounded restrictions."

Fourakis and Port (1986) argue that there are language specific-language phonetic rules applied in a boundary between phonetics and phonology. In fact, a number of phonological processes traditionally postulated to result in complete neutralization are found to be phonetically partial or gradient. The phonetic realization that results from some phonological processes is not identical to the phonetic realization without phonological modification. Fourakis and Port (1986) take stop epenthesis for example. They have observed that in American English, an epenthetic [t] is inserted in words such as *prince* [pʰɹɪ̃nts] and *dense* [dɛ̃nts]. However, the inserted [t] in *prince* and *dense* is phonetically different from the underlying /t/ in *prints* and *dents*. In fact, it is a little shorter. Crucially, it does not seem to be an inevitable consequence of articulatory processes because the epenthetic [t] does not occur in all dialects. Note that South African English does not insert an epenthetic [t] in words such as *prince* [pʰɹɪ̃ns] and *dense* [dɛ̃ns].

Now, let us turn back to Laboratory Phonology which is a good example of a conditionally interfaced module. Cohn (2010) claims that in order to develop adequate models, it is important to emphasize experimental data, not impressionistic data, only paying greater attention to fine detail in empirical studies. It has been revealed by the emphasis on phonetic, sociolinguistic, and diachronic detail that language competence and language performance are closely integrated in nature. Cohn (2010) also argues that experimental work often complements impressionistic phonological analyses.

Beckman and Kingstone (1990) argue that a so-called hybrid methodology is required to account for the relationship between phonological components and phonetic components. Experimental paradigms are required to control for details of phonological structure. There is a large group of phonic phenomena that cannot be accounted for by exclusively either phonetic components or phonological components. Thus, it is essential to adopt the techniques and attitudes of hybrid laboratory phonology to investigate these phenomena. The authors takes fundamental frequency downtrend for example. Phonologists and phoneticians take different assumptions on the same phenomena that F0 tends to fall over the course of an utterance. Beckman and Kingstone (1990: 4) point out that neither the phonological model nor the phonetic model is appropriate. If the observed fundamental frequency downtrend in a language belongs to the province of phonological investigation, it can be audible as a categorical change or register difference, and its immediate cause can be identified by simply investigating the paradigm of phonological environments. On the other hand, if the observed fundamental frequency downtrend in a language belongs to the province of phonetic investigation, it can be quantifiable as a reaction to physically specifiable variables. Beckman and Kingstone (1990) postulate that if the observed fundamental frequency downtrend is not a single homogeneous effect, then this phenomena cannot be accounted for by either model because there will be essential features of the fundamental frequency downtrend observed in a given language.

In support of this view, Cohn (2010) states that Laboratory Phonology is a truly multi-disciplinary approach that bridges the gap between theoretical and empirical approaches to investigating human speech sounds and sound patterns.

2.4.2 Phonetic and phonological distinctions between glides and vowels

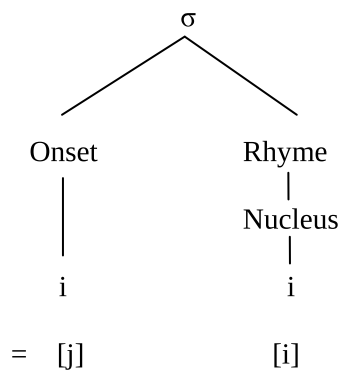
This section examines the features of glides and vowels to show that phonetic evidence is essential to complete linguistic explanations. Because of theoretical economy, high vowels like /i/ and /u/ have been treated as featurally identical to glides /j/ and /w/, respectively since the emergence of syllable theory in generative phonology. Generative phonologists regard glides as nonsyllabic realizations of vowels, believing that using a feature to indicate the distinction between high vowels and glides is redundant because syllable theory provides a means of specifying the syllabicity of a segment. However, Padgett (2008) argues that glides are phonetically different from high vowels in constriction degree, leading to phonological consequences. Glides are phonetically different from vowels in two ways: dynamics and constriction degree. Catford (1988) emphasizes the difference in dynamics, and Ladefoged and Maddieson (1996) the difference in constriction degree.

2.4.3 Phonological distinctions: syllabicity and contrast

The general assumption taken by generative phonologists is that glides and vowels are featurally identical. According to Chomsky and Halle (1968), the feature [syllabic] distinguishes glides from corresponding high vowels. However, since the advent of syllable theory in generative phonology, many phonologists (Clement and Keyser, 1983; Levin, 1985; Selkirk, 1982, 1984 among others) have argued that such a feature is not necessary because a theory of representations distinguishes nuclear from non-nuclear syllable roles, as shown in

(16):

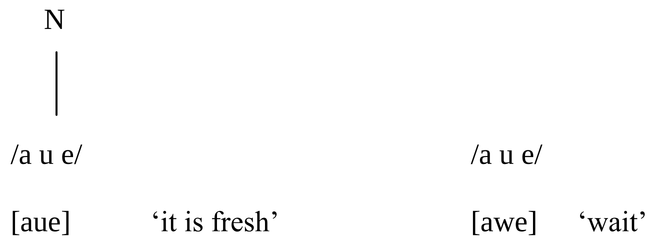
(16) Glide versus vowel status by syllable position



As illustrated in (16), glides and vowels are featurally identical, but nuclear vocoids can be interpreted as vowels and other vocoids as glides. It is true that in many languages glides and high vowels are in complementary distribution just as (16) illustrates.

Notably, the cases in which vowels contrast with glides actually exist. Leven (1985) argues that syllabicity can be contrastive, but prespecifiying vocoids with (non-)nuclear status can handle this issue. Consider the following example as shown in (17):

(17) Vowel versus glide contrast in Usarufa (new Guinea)



In Spanish, the sequences /iV/ and /uV/ typically surface as [jV] and [wV], respectively. Thus, the sequences like [su'iθa] and [mi'axa] are considered exceptional hiatus. Consider examples in (18):

(18) Exceptional hiatus in Iberian Spanish

Nuclear		Non-nuclear	
su'iθa	'Swiss'	'lwisa	'Luisa'
mi'axa	'small piece'	'vjaxe	'trip'

Padgett (2008: 5) mentions that exceptional hiatus is found in many words, but it is not robust, noting that "First, its use is subject to significant dialectal and individual variation. Second, the contrast is largely restricted to prominent positions, specifically to word-initial or stressed syllables. Third, as the name implies, it is the less common realization of /iV/ or /uV/ sequences."

2.4.4 Phonetic distinctions: dynamics and constriction degree

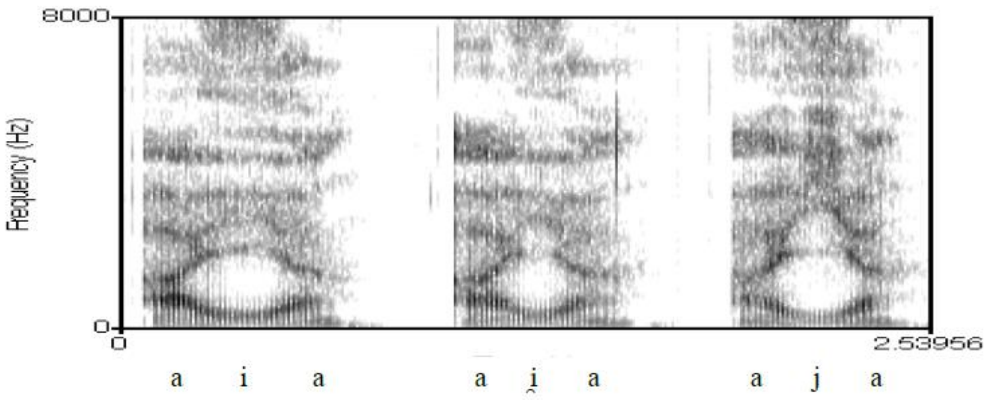
As shown in Padgett (2008), glides and vowels are phonetically different in two ways as summarized in (19):

(19) Two ways in which glides and vowels can differ

	Vowels	Glides
Dynamics	slow formant transitions, possible steady state	fast transitions, always changing
Stricture	intense formants, no frication	less intense, possible frication

Now, consider the spectrogram that illustrates these differences, as shown in (20):

(20) Spectrogram of [aia], [ai̯a], and [aja] (Padgett, 2008)



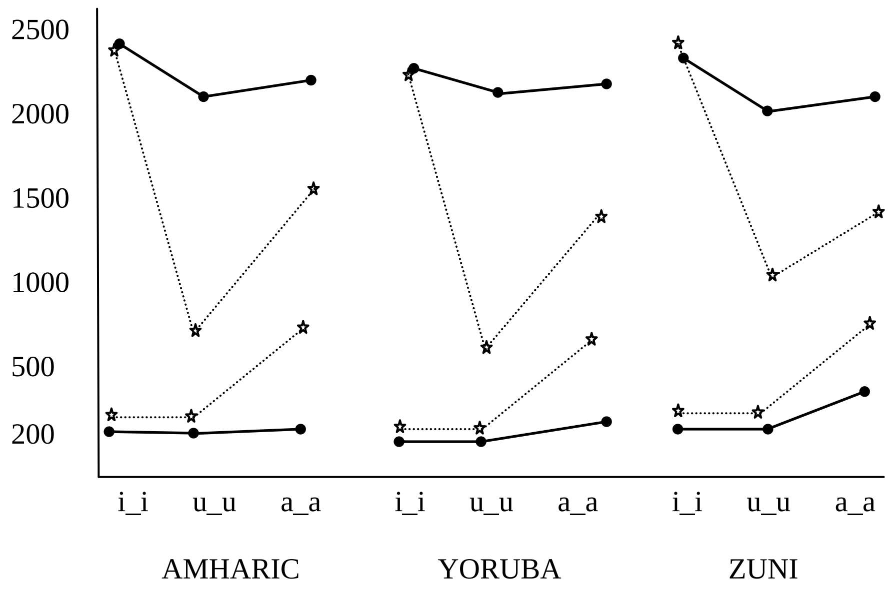
First, let us compare trisyllabic [aia] with disyllabic [ai̯a] by analyzing the spectrogram as in (20). It can be noted that there is a difference in duration of the high vocoid portions. Duration of trisyllabic [aia] has a relatively steady state portion whereas the glide in [ai̯a] is dynamic or changing, showing relatively fast formant transitions. And the second formant transitions in [ai̯a] is steeper, which means the rate of change is faster. Now, let us compare [ai̯a] and [aja]. It can be seen that there is a difference in constriction degree or frication. Compared to [i̯], the [j] of [aja] have less intensity at low frequencies while having more turbulence noise in higher frequencies. For our present purposes, we will ignore the difference between [aia] and [ai̯a] in constriction degree and the difference between [ai̯a] and [aja] in dynamics.

Padgett (2008) differentiates *semivocalic* glides from *consonantal* glides, using traditional terms and symbols, based on this: glides different from vowels in dynamics are *semivocalic* glides, and those different in constriction degree are *consonantal* glides. *Semivocalic* glides are symbolized as [i̯/u̯], and *continental* glides as [j/w]. We now turn to the question of whether semivocalic and continental glides are descriptively distinguishable.

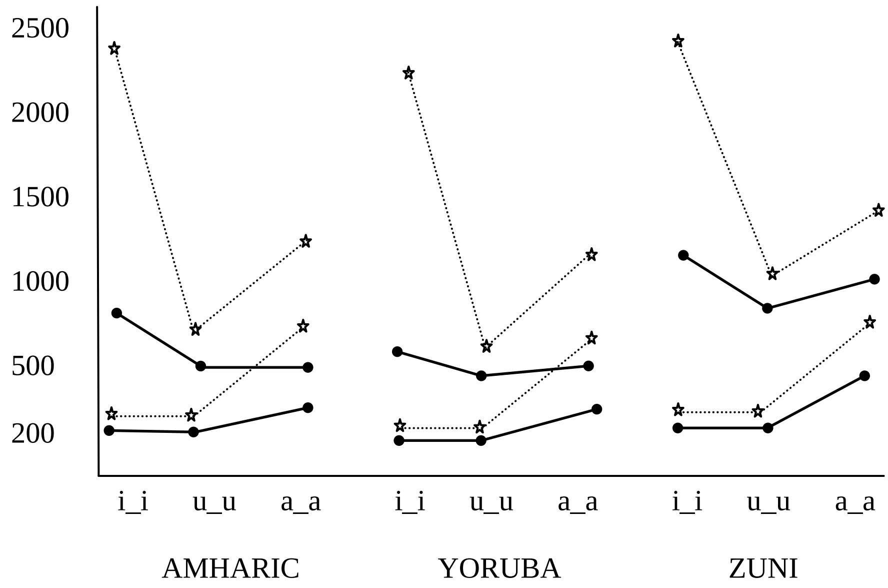
Maddieson and Emmorey (1985) find that vowels and glides show clearly different constriction degree in three languages (Amharic, Yoruba, and Zuni). Consider the experimental data, as shown in (21):

(21) Maddieson and Emmorey (1985: 168)

a.



b.



As (21) shows, mean position of F1 and F2 of /j/ and /w/ is measured in three different vowel contexts (/i_i/, /u_u/, and /a_a/). Glide formants are connected by a solid line while vowel formants are joined by a dotted line. Mean position of F1 and F2 of /j/ is shown in (21a) and /w/ in (21b).

As briefly reviewed in this chapter, there are some debates on the relation between phonetics and phonology. From now on, I will take eclecticism and use phonetic details as evidence to support phonological representations. In the following chapters, phonological explanations will be followed by phonetic evidence to complete the theory. In the next chapter, the structure of the syllable will be discussed as the first step to support my argument.

Chapter 3

The Structure of Syllable

3.1 Syllable as phonological unit

Before discussing the way in which segments are grouped into syllables, we need to accept syllables as phonological units. Once it is shown that syllables are essential phonological units that effectively account for phonological representations, it will be meaningful to consider the structure of syllable and the relations between segments and syllables.

The evidence that the syllable is a phonological constituent is some phonological rules and constraints are sensitive to the syllable, a unit that is larger than a segment but smaller than a word. First of all, let us consider the glottalization in English. The realization of the /t/ in *atlas* is glottalized [$t^ʔ$] while that of the /t/ in *attraction* is not. Note that the /t/ in *atlas* and the /t/ in *attraction* are differently realized because they are in different phonological conditions. The /t/ in *atlas* is syllable-final while the /t/ in *attraction* is syllable-initial. Second, Kahn (1976) argues that plosives are aspirated when they are syllable-initial. The /t/ in the second syllable of *potato* is realized as aspirated [t^h] because it is syllable-initial of a stressed syllable. Third, phonotactic constraints are described, in fact, based on syllable structure. The sequences of segments like the medial cluster /nstr/ in *instruct* is possible. The syllable boundary divides the medial cluster /nstr/ into a syllable final and syllable initial like [ɪn $ strʌkt]. Note that the syllable initial cluster /str/ does not violate phonotactic constraints. Syllables play an essential role in effectively explaining phonological rules and constraints.

Along with segments, syllables are phonological units[12] that form the phonological structure of the language.

3.2 Syllable and sonority

Native speakers intuitively know how many syllables a given word of their language consists of. Nevertheless, it is not easy to say what a syllable is in phonological terms. To consider what a syllable is, the sonority theory will be introduced in this section. Even though it is not universally accepted, it is still useful to understand what a syllable is. For example, at a glance, *bottle* and *real* is likely to be considered single syllables, but the analysis of those examples on the basis of *Sonority Sequencing Generalization*, or SSG (Hooper, 1976; Selkirk, 1984; Spencer, 1996) shows that both words contain two syllables each because they contain two sonority peaks.

3.2.1 Sonority scale

In English, pulmonic egressive air stream is required to produce speech sounds. The air stream does not flow at a constant rate. It is influenced by pulses. Bursts of chest-muscle activity cause this pulsation and vary the flow range of air. This pulse theory of the syllable explains very little because the air stream is inaudible.

Sonority is the manifestation of the translated acoustic energy of the kinetic energy of the air stream pulses. The sonority of a sound is its relative loudness compared to other sounds. The amount of opening in the vocal tract when a speech sound is uttered and its degree of voicing determines sonority. Sounds produced with the vocal tract open have a relatively high degree of sonority while those produced with the vocal tract closed have a

[12] Segments, syllables and feet are considered phonological units.

relatively low degree of sonority, and voiced sounds are more sonorous than voiceless sounds. Therefore, voiceless stops are of minimal sonority while low vowels are of maximal sonority. The sonority scale is given to all sounds between these two extreme sounds.

Selkirk (1984: 112), Hogg and McCully (1987: 33) and Katamba (1989: 104) among other linguists propose different versions of the sonority scale. In this dissertation, the sonority scale of Hogg and McCully is adopted because it is more delicately divided in scale than the other two. The sonority scale proposed by them is shown in (1):

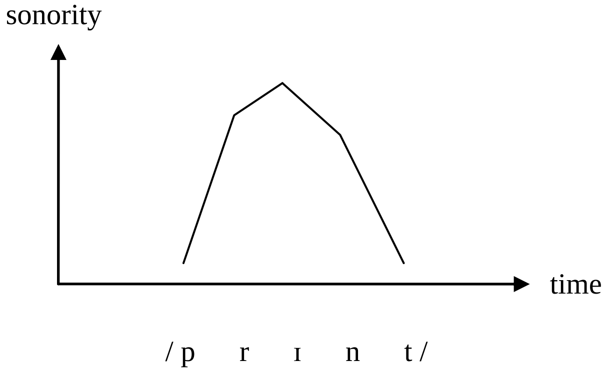
(1) Sonority scale by Hogg and McCully (1987: 33)

class of sounds	sonority value	examples
low vowels	10	/a, ɑ/
mid vowels	9	/e, o/
high vowels	8	/i, u/
flaps	7	/r/
laterals	6	/l/
nasals	5	/m, n, ŋ/
voiced fricatives	4	/v, ð, z/
voiceless fricatives	3	/f, θ, s/
voiced stops	2	/d, b, g/
voiceless stops	1	/p, t, k/

With the help of this sonority scale, it is possible to predict the right number of syllables of a given word on the basis of the theory that syllables are determined by peaks of sonority.

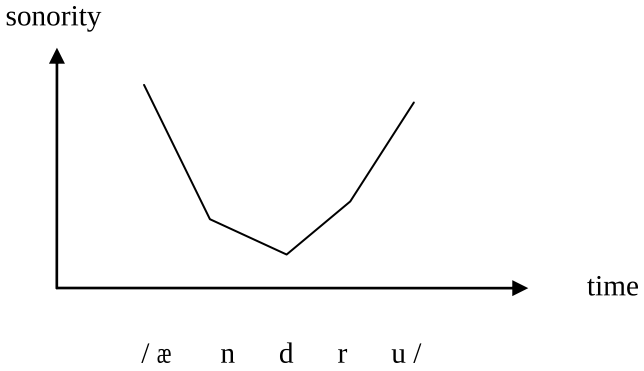
Let us determine the number of syllables the word *print* contains. The phonemic representation of *print* is /prɪnt/. It is monosyllabic. According to the sonority scale in (1), /p/ is less sonorous than /r/ and given 1 in sonority value. The second segment /r/ is less sonorous than the third segment /ɪ/ and its sonority value is 7. The sonority value 8 is given to /ɪ/. The nasal sound /n/ is assigned a sonority value of 5, and the final segment /t/ is assigned the same sonority value as /p/. The sonority profile of *print* is as in (2) shows a single sonority peak:

(2)



Now, let us consider the graphic representation of a bisyllabic word such as Andrew as in (3):

(3)

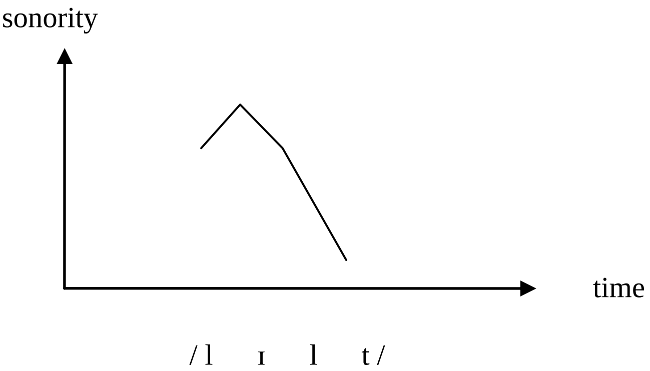


Likewise, the two peaks in the diagram show that the word contains two syllables.

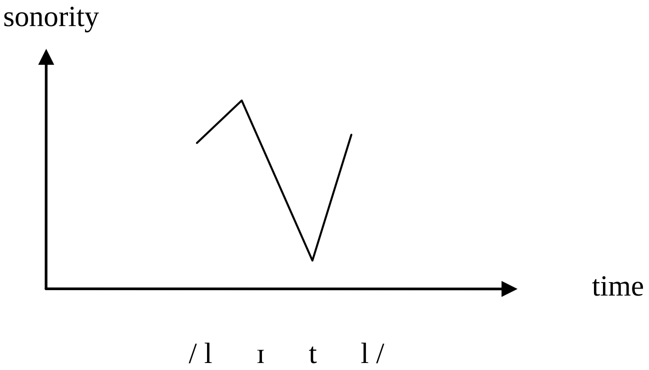
Finally, in order to test whether this theory correctly predicts the number of syllables a given word contains, let us consider a pair of monosyllabic word and bisyllabic word that consist of the same phonemes in different order. Consider a pair of *lilt* and *little*:

(4)

a.



b.



The examples taken so far show that the sonority theory of the syllable correctly predicts the number of syllables. The perceived number of syllables corresponds to the number of peaks in a sonority profile.

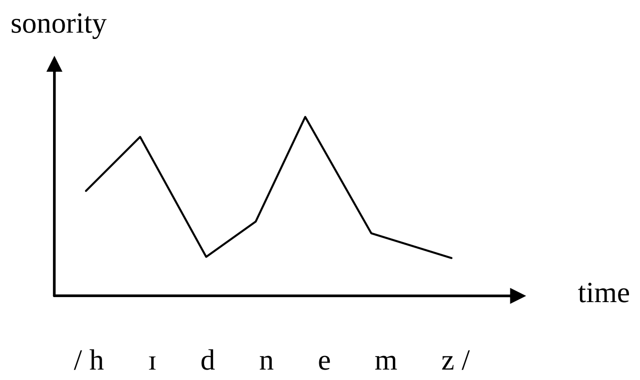
3.2.2 Unsolved problems

According to the sonority theory, sonority peaks correspond to syllable peaks. Note, however, that there are some examples showing that sonority peaks do not correspond to syllable peaks. In this section, we will consider some problems or facts that the sonority theory cannot solve or explain.

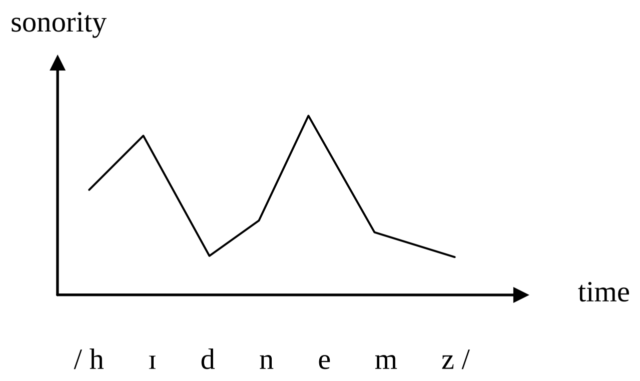
First, let us consider the two phrases *hidden aims* and *hid names*. The first phrase *hidden aims* obviously consist of three syllables because *hidden* is bisyllabic and *aims* is monosyllabic while the second phrase *hid names* contain two syllables because both *hid* and *names* are monosyllabic. Nevertheless, both phrases are represented as /hɪdnemz/.[13] Let us draw a diagram based on the sonority theory as in (5):

(5)

a. *hidden aims*



b. *hid names*



As presented in the diagrams above, the sonority theory shows that *hidden aims* has two sonority peaks as in (5a). According to the sonority theory, sonority peaks correspond to the number of syllables. The phrase *hidden aims* has two sonority peaks which means it consists

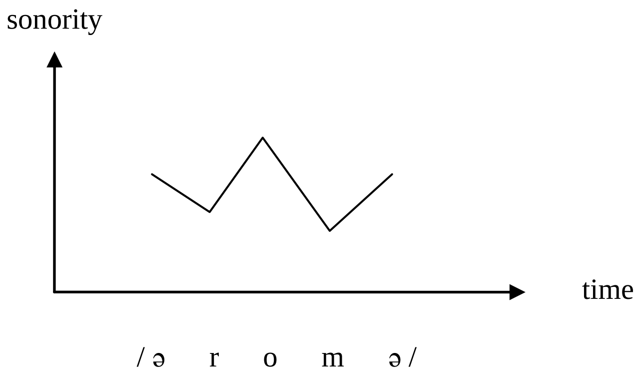
[13] This is the case when juncture is considered. There can be the difference in the pronunciation of the /d/.

of two syllables. In fact, *hidden aims* contains three syllables. The sonority theory fails to predict the exact number of syllables that the phrase *hidden aims* contains.

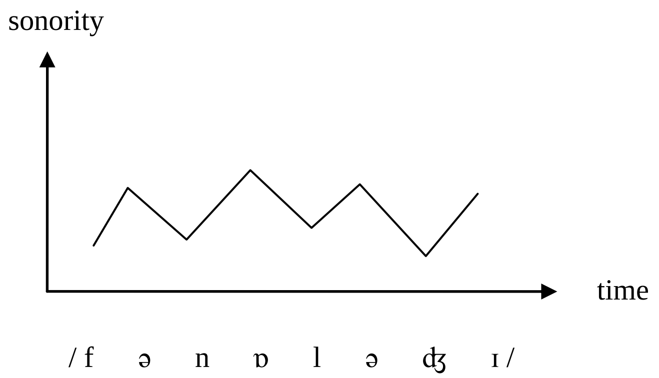
Second, the sonority theory does not answer the question about the position of syllable boundaries within words. Consider *aroma* and *phonology*, as in (6):

(6)

a.



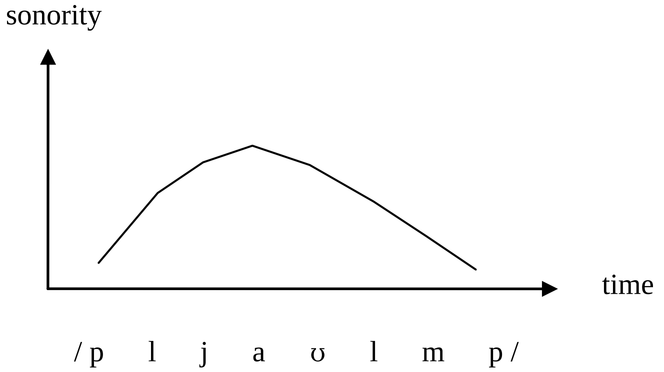
b.



The diagrams in (6) clearly show that *aroma* has three syllables because it has three sonority peaks and that *phonology* contains four syllables because it has four sonority peaks. The sonority theory, however, does not show where the syllable boundaries exist. Speakers syllabify *aroma* and *phonology* as *a.ro.ma* and *pho.no.lo.gy*, not as **ar.om.a* and **phon.ol.og.y*. The sonority theory identifies the troughs between the sonority peaks. However, it does not predict the fact that the consonant that constitutes a trough belongs to the following syllable, not the preceding syllable.

Third, the sonority theory cannot explain the maximum number of phonemes a syllable can contain and the possible string of phonemes. Giegerich (1992) takes a rather absurd example which does not conflict with the sonority but is impossible such as /pljaʊlmp/ as in (7):

(7)



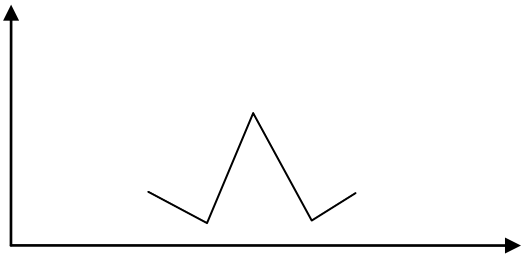
According to the sonority theory, /pljaʊlmp/ is monosyllabic because it has a single sonority peak. Even though it does not conflict with the sonority theory, it is impossible in English because English syllables cannot contain that many phonemes.

Here is another problem. While /klamp/ is possible in English, */knamp/ is not. Both /kl/ and */kn/ show the upward sonority slope. The sonority theory predicts */kn/ is a possible string, but it is forbidden in English.

Finally, let us consider the monosyllabic word *sticks* as in (8):

(8)

sonority



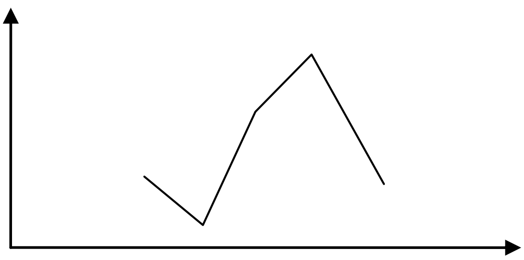
time

/ s　t　ɪ　k　s /

It is clear that *sticks* is a monosyllabic word. However, the diagram in (8) presented by the sonority theory shows that it contains three sonority peaks. The examples shown so far do not conflict with the sonority, but this example conflicts with the sonority because a monosyllabic word contains three sonority peaks. There are some more examples showing that sonority peaks do not necessarily correspond to syllable peaks. Consider *splash* and *text* as in (9):

(9)

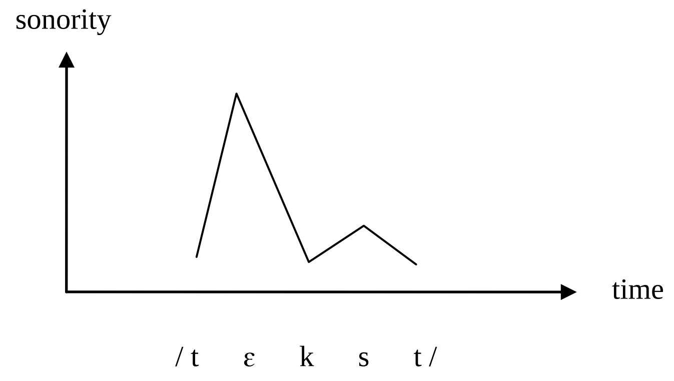
a.　sonority



time

/ s　p　l　æ　ʃ/

b.



In the word *splash* as illustrated in (9a), the first consonant /s/ has one sonority peak, and the vowel /æ/ has the other sonority peak. Much the same as *splash*, *text* in (9b) has two sonority peaks even though it is a monosyllabic word. Interestingly, all the examples shown in (8) and (9) have one thing in common: /s/ is followed by a voiceless stop /p, t, k/.[14]

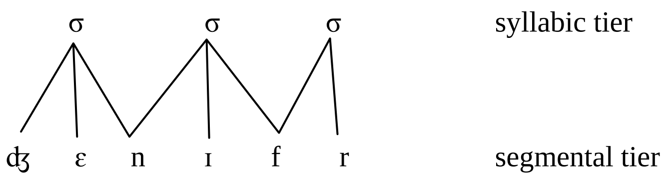
3.3 The CV tier

Clements and Keyser (1983) argue that the CV tier that serves as a timing unit between segments and syllables better states and explains the phonological representation. By focusing on the fact that segmental duration behave independently of the segments, they add the CV tier to the structure suggested by Kahn (1976), making it three-tiered. To better understand, let us compare the two-tiered structure proposed by Kahn (1976) with the three-tiered structure suggested by Clements and Keyser (1983). Let us take *Jenifer* as an example below, as in (10):

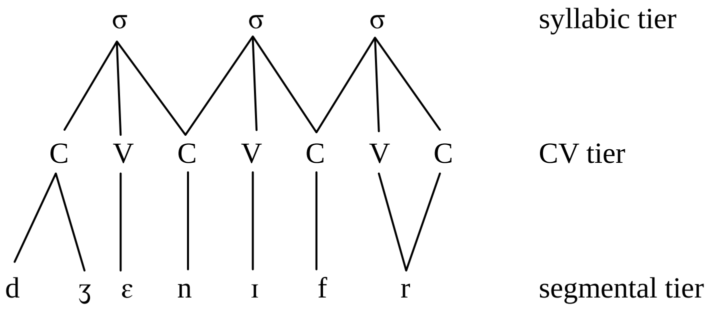
[14] Some linguists such as Giegerich (1992) and Spencer (1996) argue that /s/ should be treated as an appendix to the basic syllable structure because it behaves in an exceptional way.

(10)

a.



b.



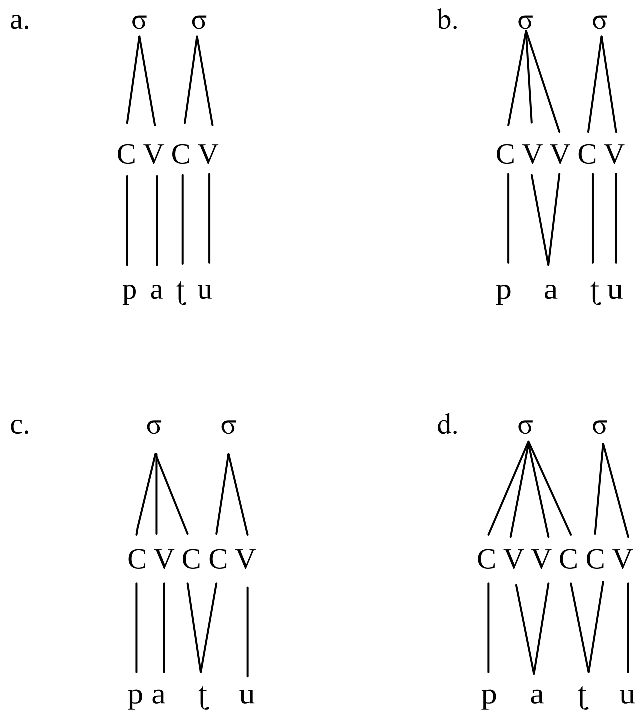
In this section, the focus will be on the CV tier proposed by Clements and Keyser. As is shown in (10b), the syllable does not dominate the segments directly. Clements and Keyser (1983) propose that the CV tier exists as an intermediate level of the structure between the syllable and the segment. Clements (1986) takes a language game, called Ludikya, for Luganda as an example to show that segmental duration is the one of the aspects of the pronunciation of words. The syllables reverse in order in this game. Luganda has a length contrast in both vowels and consonants. In this game, the vowels and consonants reverse, leaving the duration in structure intact, as shown in (11):

(11)	*Luganda*	*Ludikya*	
	mukono	nokomu	'arm'
	mubinikilo	lokinibimu	'funnel'
	baana	naaba	'children'
	ɟɟuba	bbaɟu	'dove'
	kiwoɟɟolo	loɟowwoki	'butterfly'
	kubaɟɟa	ɟabakku	'to work in wood'

In these examples in (11), long segments are indicated by doubling the symbol. In the game, the syllables move round without changing the syllable length. Consider *mukono* (meaning 'arm'). In Ludikya, *mu* and *no* reverse. The first syllable *mu* consists of a short consonant and a short vowel, and the last syllable *no* is also composed of a short consonant and a short vowel. The reversal of the two syllables brings about nothing in the durational structure of the syllable. Another example is *baana*. The first syllable baa (a short consonant plus a long vowel) and the last syllable (a short consonant plus a short vowel) reverse, the durational structure remaining intact. Let us consider *kiwoɟɟolo*. In Ludikya, the first syllable *ki* moves to the last syllable and the last syllable *lo* move over to the first syllable. Then, the two syllables in the middle shift, forming *loɟowwoki*. Again, the durational structure remains intact. Note that the second syllable *wo* composed of a short consonant and a short vowel moves to the third syllable, becoming *wwo* consisting of a long consonant and a short vowel in order not to change the durational structure of the third syllable of the original word *ɟɟo* (a long consonant and a short vowel. Likewise, The third syllable *ɟɟo* becomes *ɟo* in order to fit the duration of *wo*. To explain this, it needs to be expressed in the representation that segmental duration is not dependent on segmental quality. To this end, Clements and Keyser propose skeletal slots that are relevant to the segmental durations, arguing that the segments are dominated by skeletal slots, not immediately by the syllables. Consonants and short vowels belong to single slots while long vowels and geminate consonants are doubly linked to two slots. In addition, the C represents a syllable margin (onset or coda) and V a syllable peak. Therefore, CV slots represent the feature [±syllabic] as well as the segmental duration.

Consider the Tamil words [paʈu, paːʈu, paʈːu, paːʈːu][15] that have the same string of segments but different segmental timing structures, as illustrated in (12):

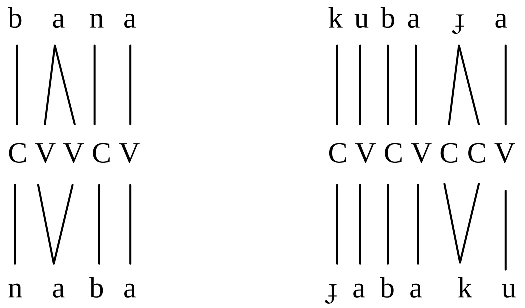
(12)



Now, in order to show that the segments of the syllables in Ludikya reverse with the retention of the CV structure, let us apply the strings of skeletal slots to two different versions (Luganda and Ludikya) of the words, as shown in (13):

[15] Dravidian languages such as Malayalam and Tamil have a duration contrast for both vowels and consonants.

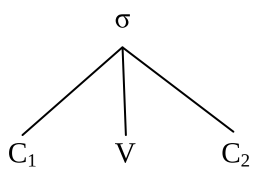
(13)



In (13), the top line words are Luganda while the bottom line versions are Ludikya. Note that in the CV representation shown in (13), a reversal of the segments of the syllables does not alter the CV structure of each word. Now, it is clear that the CV tier provides a representation for the duration and syllabicity of segments.

Clements and Keyser (1983) also argue that the relations of C_1V and those of VC_2 in C_1VC_2 are almost equal. Clements and Keyser propose a flat structure of the syllable, as shown in (14):

(14)



In order to support the flat structure in which the relations of C_1V and those of VC_2 are identical, Clements and Keyser take spoonerism in English and Finnish as an example, as shown in (15):

(15) Spoonerism (English)

pussy cat	cassy put
lost and found	faust and lawned

Spoonerism (Finish)

tykkään urheilust	ukkään tyreilusta 'I like sports'

As shown in (15), when a spoonerism occurs, *pu* in *pussy* and *ca* in *cat* move as a cluster. That is, C_1 and V move as a cluster. Therefore, the relations between C_1 and V are as close as those between V and C_2. The same phenomenon occurs in Finish, too. Consider tykkään urheilust (meaning 'I like sports'). C1 and V (*ty* in *tykkään*) move as a cluster.

3.3.1 Syllabification

When dealing with the sonority theory in the previous section, we considered three problems that cannot be explained by the sonority theory, one of which is related to syllabification. In this section, we will review how the CV tier provides a way of grouping strings of CV slots into syllables. It is obvious that each V slot is associated with a syllable peak. The question is: to which syllable node is the intervocalic C slot such as the middle consonant of *panic* (CVCVC)? It is assumed that intervocalic consonants prefer to be assigned to the preceding syllable rather than the following one.

Kahn (1976) and Clements and Keyser (1983) propose the Onset First Principle[16] to deal with the syllabification issue, which is stated in (16):

[16] It is also known as Maximum Onset Principle (MOP).
Maximum Onset Principle (MOP): First make the onset as long as it legitimately can be; then form a legitimate coda. (Kahn, 1976; requoted from Gussenhoven and Jacobs, 2005)

(16)

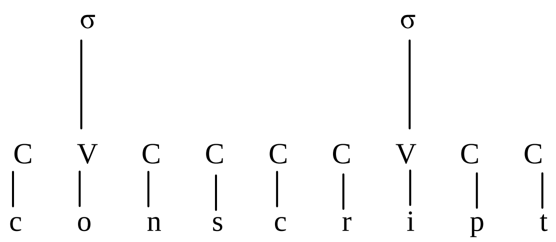
a. “Syllable-initial consonants are maximised to the extent consistent with the syllable structure conditions of the language in question.”

b. “Subsequently, syllable-final consonants are maximised to the extent consistent with the syllable structure of the language in question.”

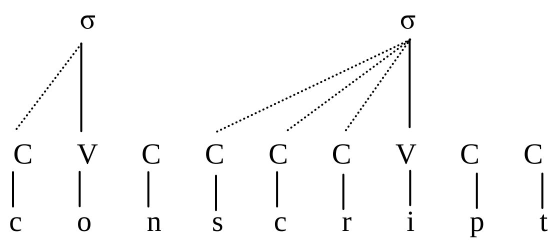
(Clements and Keyser 1983:37)

Principle (16a) applies first, and then principle (16b) applies. For example, a string like [tata] is divided up as [ta.ta] and not [tat.a] (Syllable boundaries are marked by a dot). And a string like [asta] should be syllabified [a.sta], rather than *[as.ta] or *[ast.a] if the [st] onsets are legitimate in the language.[17] Let us illustrate this process as in (17):

(17) a.

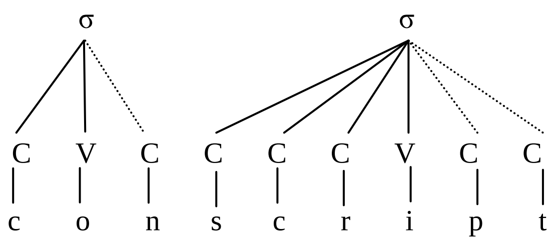


b.



[17] This principle is universal. Therefore, languages allow different syllabification based on their possible legitimate string of segments in the onset. For example, Dutch and English allow [st] in the onset, but Spanish does not.

c.



First, as illustrated in (17a), V slots are linked to syllables. Then, C slots are associated with the V on their right if the resulting sequence is legitimate in the language in question. In English, a syllable is not allowed to start with a consonant cluster that begins with a nasal. In this case, *scri* is a permissible syllable initial consonant cluster, but **nscri* is not because a nasal occurs at the beginning of a syllable initial consonant cluster. Therefore, the maximum of three C slots are allowed to be linked to the following V as in (17b). Finally, the remaining consonants are associated with the V slot preceding them as in (17c).

3.3.2 Three types of argument for the CV tier

In this section, we will review three types of argument for the inclusion of segmental timing slots in phonological representation: templatic use, unfilled and unassociated slots, and compensatory lengthening.

3.3.2.1 Templates

Strings of consonant and vowel positions are referred to as templates. According to McCarthy (1985), templates form independent morphemes in Arabic. In general, affixes are attached concatenatively to roots to create words. In Arabic, however, vowels are inserted nonconcatenatively to the root of a verb that consists only of consonants, usually three, in the process of word formation. Such vowels represent verbal aspect or voice. In Arabic, therefore, a verbal form consists of a verbal root with two or more consonants (generally, three), a conjugation (a CV template) and a verbal aspect with one or more vowels. Consider some morphemes in (18):

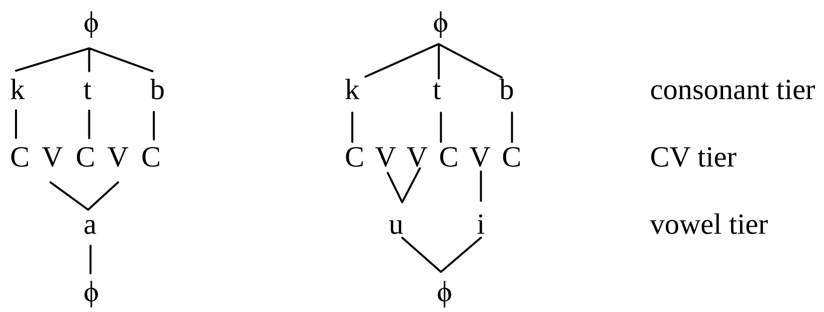
(18)

ktb	'write'
ħq	'be true'
CVCVC	'Plain'
CVCCVC	'Intensive'
CVVCVC	'Influencing'
a	'Active Perfective'
ui	'Passive Perfective'

The root that generally consists of a string of three consonants determines meaning. The differences in CV templates bring about grammatical differences. For example, the CVCVC is plain and the CVCCVC is intensive. In addition, as shown in (18), voice is determined by the types of vowel. For example, active perfective is represented as *a*, and passive perfective as *u* and *i*. Therefore, it can be assumed that the consonant tier, the CV tier, and the vowel tier constitute different morphemes. This concept is called Morpheme Tier Hypothesis, which is proposed by McCarthy (1986). Consider the example below as in (19):

(19)

a. katab c. kuutib



'he caused to write' 'he was corresponded with'

(Here the symbol ϕ stands for a morpheme)

The consonant tier basically provides the meaning of a given word while the vowel tier gives information on its aspect.

3.3.2.2 Unassociated slots

So far I have associated all the slots in the CV skeleton with segments. Clements and Keyser (1983), however, argue that slots may be left unassociated with any segments or syllables. To do so, phonological phenomena can be more effectively accounted for. Clements and Keyser take liaison and *h-aspiré* in French as an example to support the need of unassociated slots.

The French definite article is reflected to agree in gender or number. The French definite article for the singular is [lə] (masculine) or [la] (famine), and [le] for the plural, as shown in (20a). The vowel of the singular definite article is omitted before a noun that begins with a vowel. On the other hand, [z] is inserted to the plural definite article when it is followed by a noun whose initial segment is a vowel.

(20)		Singular	Plural	
	a.	lə bwa	le bwa	‘wood’
		lə pa	le pa	‘step’
		la karaf	le karaf	‘carafe’
		la nɥi	le nɥi	‘night’
	b.	l abe	lez abe	‘priest’
		l ide	lez ide	‘idea’

Elision plays a role in deleting the final V slot of the definite article if it is followed by V as shown in (21):

(21)

V

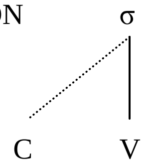
ELISION | → Ø / _ V

[…] DEF

And according to liaison illustrated in (22), any syllable without the onset syllabifies any unsyllabified consonant preceding that vowel:

(22)

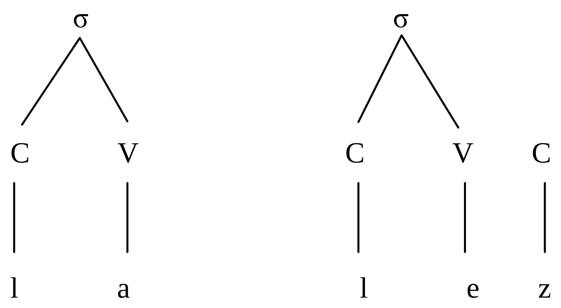
LIAISON



These rules predict that the singular form of the article will lose its vowel before a noun that begins with a vowel, and that unsyllabified final consonant in the plural will be grouped into syllable if it is followed by a V-initial noun as illustrated in (23):

(23)

a. b.



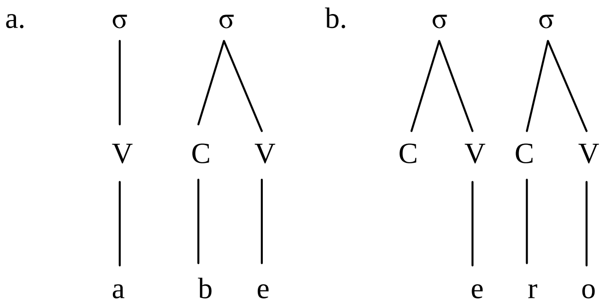
‘DEF-SG-FEM’ ‘DEF-PL’

There are some vowel-initial nouns that show the same behavior as nouns that start with a consonant. Consider *ero* and *ɛn* in (24):

(24)	*Singular*	*Plural*	
	lə ero	le ero	‘hero’
	la ɛn	le ɛn	‘hatred’

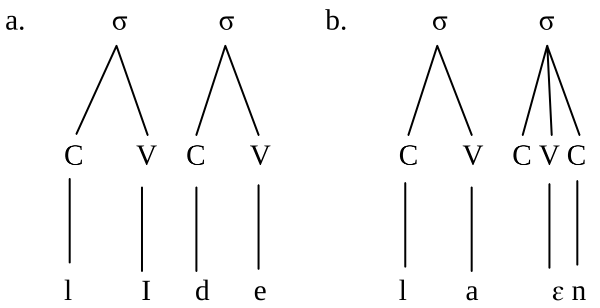
According to elision shown in (21), the singular definite article for masculine [lə] should lose its vowel before *ero* because it is a vowel-initial word. In the case of the plural, [z] should be inserted before a vowel-initial word. However, it is not the case. Why? To answer the question, let us assume that their underlying forms begin with a consonant. Compare *abe* and *ero* as illustrated in (25):

(25)



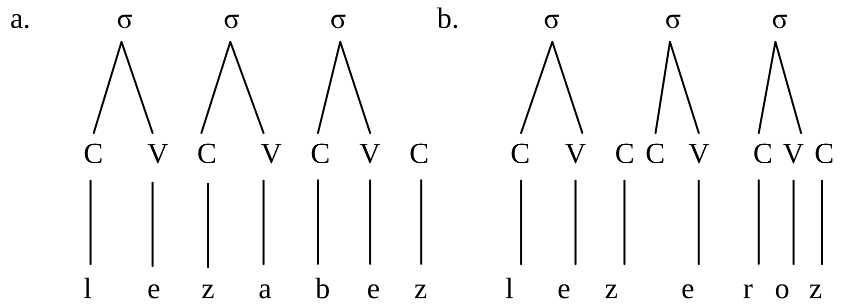
Then, it is correctly explained that pre-V [a] is deleted as in (26a), and that pre-V [a] is retained in the pre-C context as in (26b):

(26)



By assuming the underlying forms with an empty consonant at the beginning, the difference between the presence of liaison [z] in ‘the priests’ and its absence in ‘the heroes’ can also be accounted for. The unsyllabified [z] does not undergo liaison in (27b) because it is not blocked by an empty C unlike the unsyllabified [z] (27a):

(27)



3.3.2.3 Compensatory lengthening

Finally, compensatory lengthening provides convincing evidence for the existence of the CV tier. If a segment is deleted, the time it takes is still preserved. Consider the examples of the Ingwaeonic language, as in (28):

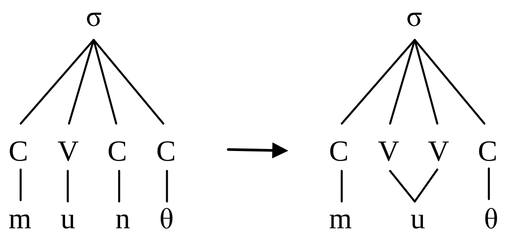
(28)

gans	ga:s	‘goose’
timf	ti:f	‘five’
tanθ	ta:θ	‘tooth’
munθ	mu:θ	‘mouth’

As seen in (28), nasals are deleted before fricatives within the word. Note that short vowels become long vowels after the process of nasal loss.

The CV tier successfully describes the segmental duration, by expressing the change as a retiming of the segments, as shown in (29):

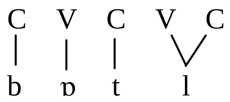
(29)



As seen in (29), the quality of the slot changes from C to V, but the number of the slots remains the same.

In addition, compensatory lengthening can be recognized in syllabic consonants. Consider the example as in (30):

(30)



The second syllable of *bottle* consists of the consonant /l/. As seen in (30), the duration of the syllabic /l/ shows no difference from that of /əl/.

3.3.2.4 Problems

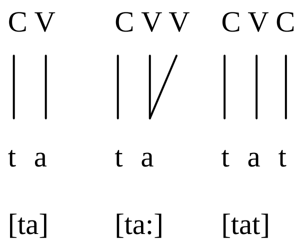
There are two phenomena that the CV tier fails to account for. First, compensatory lengthening only occurs when segments in the rhyme are deleted, and never occurs when segments in the onset are deleted. Second, the location of the word stress is sensitive to segmental composition of the rhyme with segments in the onset being irrelevant.

3.3.5 Mora

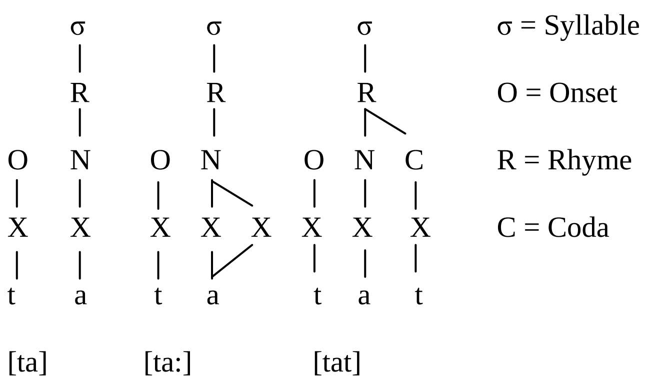
The structure of the CV tier, as in (31a), originally proposed by McCarthy (1979) has been challenged by other prosodic tier structures. To replace the CV tier, the X tier theory has been proposed by some researchers (Levin, 1985; Lowenstamm & Kaye, 1986 among others). In X theory, the symbols C and V are replaced with Xs, a uniform sequence of elements, as illustrated in (31b):

(31)

a. CV Theory



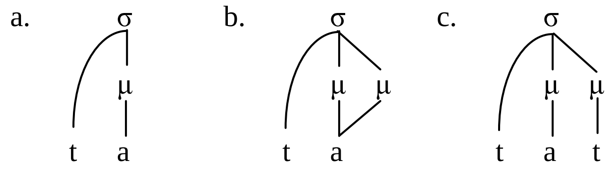
b. X Theory



As seen in (31), both CV theory and X theory are segmental theories of the prosodic tier. In both theories, the number of prosodic elements in an utterance is identical to the number of its segments.

As discussed before, the CV tier fails to account for the difference in status between segments in the rhyme and those in the onset.[18] To resolve this problem, Hyman (1984, 1985) and McCarthy and Prince (1986) have proposed moraic theory of the prosodic tier structure as intermediate level of structure between segments and the syllable. Moraic theory has a uniform sequence of elements as in X theory, but unlike X theory, this theory is not a segmental theory. In this theory, the unit does not represent the notion of mora instead of representing a segment, as illustrated in (32):

(32)



In moraic theory, as a prosodic unit, the mora plays a dual role. First, it plays a role of a weight unit, representing contrast between light and heavy syllables. Syllables have different degrees of prominence in prosodic phenomena, and the difference is represented by the number of moras: a syllable with single mora is treated as light and a syllable with two moras is treated as heavy. Second, it serves as a phonological position. As seen in (32), a short vowel and a coda have one mora while a long vowel has two moras.

In this chapter, theories to account for the structure of the syllable have been reviewed, and the necessity to introduce the mora has been examined. The further discussion on the mora is omitted for simplicity's sake, as it will be discussed in detail in Chapter 4, again, with special reference to the syllable weight and the role of mora.

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[18] This onset-rhyme asymmetry will be discussed in 4.2.1.

Chapter 4

Syllable Weight and The Role of Mora

4.1 Evidence for mora

The mora has been proposed by Hyman (1985), Hayes (1989), McCarthy and Prince (1986), Katada (1990, 2014) and others as an indispensable phonological unit to measure syllable weight.

For example, Katada (1990, 2014) provides evidence, drawn the Japanese language game *Shiritori* 'hip-taking', that mora constitutes an indispensable unit in phonological representation. *Shiritori* is a traditional Japanese game widely played among children in Japan. In this game, players take turns giving a word whose first unit is identical to the last sound unit of a word given by a previous player. Consider the fallowing examples, as shown in (1):

(1) Katada (1990: 642)

a. tubame 'swallow'
medaka 'kilifish'
kao 'face'
oNgaku 'music'
kusuri 'medicine'
riNgo 'apple'
gohaN 'meal'
(game over)

b. budo: 'grapes'

origami 'folding-paper'

miNku 'mink'

ku:ki 'air'

kiriN 'giraffe'

(game over)

A player who gives a word that ends in a syllabic nasal [N] such as *gohaN*, the final word in (1a) or *KiriN*, the final word in (1b) loses the game. Note that there is no Japanese word that begins with a syllabic nasal [N], so the game cannot be continued.

The rule of this game is that a word-final unit must be identical to the following word-initial unit, as illustrated schematically in (2):

(2) Katada (2014: 162)

player 1: [….x_i]

player 2: [x_i….x_j]

player 3: [x_j….x_k]

player 4: [x_k….N] (game over)

Now, this leads to the question: What is the identity of the matching unit x? Is it a syllable or a segment?

Katada (1990) also draws evidence that prefers a mora to a syllable or a segment from words that begins with or ends in a diphthong, a long vowel, or a syllabic nasal [N]. Consider examples given in (3):

(3) Katada (1990: 642-643)

a. diphthongs

medaka

kao

oNgaku

b. long vowels

budo:

origami

miNku

ku:ki

c. syllabic nasal

kusuri origami

riNgo mNku

(game over)

Let us examine the word [kao] in (3a). It can be seen that [kao] consists of a single syllable but is treated as two units ([ka] and [o]). The word-initial unit [ka] is identical to the word-final unit [ka] of the preceding word [medaka] while the word-final unit [o] is identical to the word-initial unit [o] of the following word [oNgaku]. Undoubtedly, this matching unit is neither a syllable nor a segment. Then, what is it? This is the evidence that there exists a mora between a syllable and a segment. It is also noted that similarly, as in (3b), long vowels such as [do:] and [ku:] are treated as two separate units like [do + o] and [ku + u]. Treating it as a single unit (a syllable) will result in the following syllable-matching pairs as shown in (4):

(4) Katada (1990: 643)

a. budo: ‘grape’

*do:butu ‘animal’

b. soNgoku: (a character in a Chinese fairy tale)

*ku:ki ‘air’

As (4) shows, the syllable-matching pairs are never observed. For example, as in (4a), [budo:] is not followed by [do:butu]. If x is a syllable, as illustrated schematically above in (2), the final syllable of the preceding word matches the initial syllable of the following word. But it is now allowed in this game. By the same token, as in (4b), [soNgoku:] cannot be followed by [ku:ki] despite the exact match between the preceding word-final syllable and the following word-initial syllable. Katada (1990, 2014) argues that this is because the matching unit here is a mora, not a syllable. In (3c), the syllabic nasal [N] is also treated as a separate unit. Katada (1990: 645) contends that “moras are essential units operating at a certain point in Japanese grammar.”

Japanese poetry is also cited as evidence for a mora as a separate phonological unit. Inaba (1998) takes *Haiku*, one form of Japanese poetry for example. *Haiku* consists of three lines of five, seven, and five *onsetsu*. Inaba (1998) states that “*Onsetsu* is often translated as ‘syllables’ in some of Japanese literature, but this is a mistranslation.” Consider examples given in (5):

(5) Inaba (1998: 106)

a. *Onsetsu* = Mora = Syllable

fu ru i ke ya ‘an old pond’

ka wa zu to bi ko mu ‘a frog hopped into’

mi zu no o to ‘ the sound of water’

b. *Onsetsu* = Mora ≠ Syllable

ka ki ku e ba	'eating persimmon'
ka ne ga na ur na ru	'the bell rings'
hoo ryuu ji	'at the Horyuji temple'

In (5a), all syllables are light, consisting of a single mora. Thus the syllable and mora count is identical to the *onstsu*. As seen in (5b), however, in the case of heavy syllables that consist of two moras, the mora count coincides with the *onsetsu*, but the syllable count differs.

In Japanese, a glottal stop [ʔ] occurs in several cases: in accented speech, between a vowel and either a semivowel, or a consonant, or following a vowel in prepausal position. Noting that vowel sequence consisting of two moras reduces into a single mora when a glottal stop comes after word endings in /Vi/, as in an emphatic word such as /hái/ 'yes', Vance (1987) suggests that mora is an indispensable phonological unit. Consider examples, as in (6):

(6) Glottal Stop Compensation (Vance, 1987)

	μ	μ			μ	μ
	|	|	→		|	|
h	a	i		h	ai	ʔ

As seen in (6), after the two vowels become a diphthong consisting of a single mora, a glottal stop fills in the stranded mora to maintain its physical duration.

4.2 Phonological evidence

4.2.1 Onset/rhyme asymmetries

Segments in the onset and segments in the rhyme show different behaviors. One of the examples is that the deletion of a consonant in the onset does not result in compensatory lengthening while the loss of consonants in the rhyme does. Hayes (1989) argues that a timing tier approach cannot explain the asymmetry between the onset and the rhyme. Let us consider the example presented by Hayes (1989), as shown in (7):

(7) Latin compensatory lengthening (Hayes, 1989: 260-261)

a.

*kasnus	→	ka:nus	'gray'
*kosmis	→	ko:mis	'courteous'

b.

*smereo:	→	mereo:	'deserve-1 sg.-res.'
*snurus	→	nurus	'daughter-in-law'

In both cases of (7a) and (7b), the consonant /s/ is deleted before an anterior sonorant. What is notable is that, as you can see in (7), the loss of /s/ in coda position as in (7a) brings about compensatory lengthening while the loss of /s/ in onset position as in (7b) causes no change.

A similar example can be found in Middle English. Consider the example as shown in (8):

(8) The loss of [k, g] in the onsets [kn-, gn-] in Middle English

	knot	gnat
a.	[nɔt]	[næt]
b.	*[n:ɔt]	*[n:æt]
	*[nɔ:t]	*[næ:t]

When the onsets [kn-, gn-] in Middle English experienced the loss of their segments [k, g], no compensatory lengthening occurred. Words like *knot* and *gnat* as shown in (8) are now pronounced as in (8a), not as in (8b). The loss of [k, g] in *knot* and *gnat* did not allow *[n:ɔt], *[n:æt], *[nɔ:t], or *[næ:t].

This onset-rhyme asymmetry suggests that elements in the rhyme have something that elements in the onset do not have. The difference is that the elements in the rhyme are moraic while the elements in the onset are not moraic. A moraic approach can account for this asymmetry by making the rhyme segments dominated by moras but leaving the onset segments not dominated by moras.

With few exceptions, in many languages, stress assignment is sensitive to the segmental composition of the rhyme while it is insensitive to that of the onset. Consider the example presented by Jeanne (1982), as in (9):

(9) Hopi stress assignment (Jeanne, 1982: 252, 254-255)

a.	ˈqøq.tø.som.pi	‘headbands’
	ˈso:.ja	‘planting stick’
b.	qø.ˈtø.som.pi	‘headband’
	ko.ˈjo.ŋo	‘turkey’

In Hopi, stress falls on the first syllable if the rhyme contains a long vowel or a short vowel followed by a consonant as shown in (9a). On the other hand, stress falls on the second syllable if the rhyme in the initial syllable contains a short vowel (9b). Here again, stress assignment is irrelevant to the components in the onset.

In English, lax vowels cannot occur in open syllables of monosyllabic lexical words. Therefore, *[pɪ] is an ill-formed word. Adding consonants to the rhyme can improve the ill-formedness of *[pɪ]. For example, *[pɪ] becomes well-formed monosyllabic content words [pɪg, pɪt] if [g, t] are added to the rhyme. However, adding consonants to the onset does not help because forms such as *[spɪ], *[plɪ], and *[splɪ] are still ill-formed, which is called *minimality* effects. The ill-formedness of *[pɪ] in English will discussed in more detail in the next section.

4.2.2 Mora and syllable weight

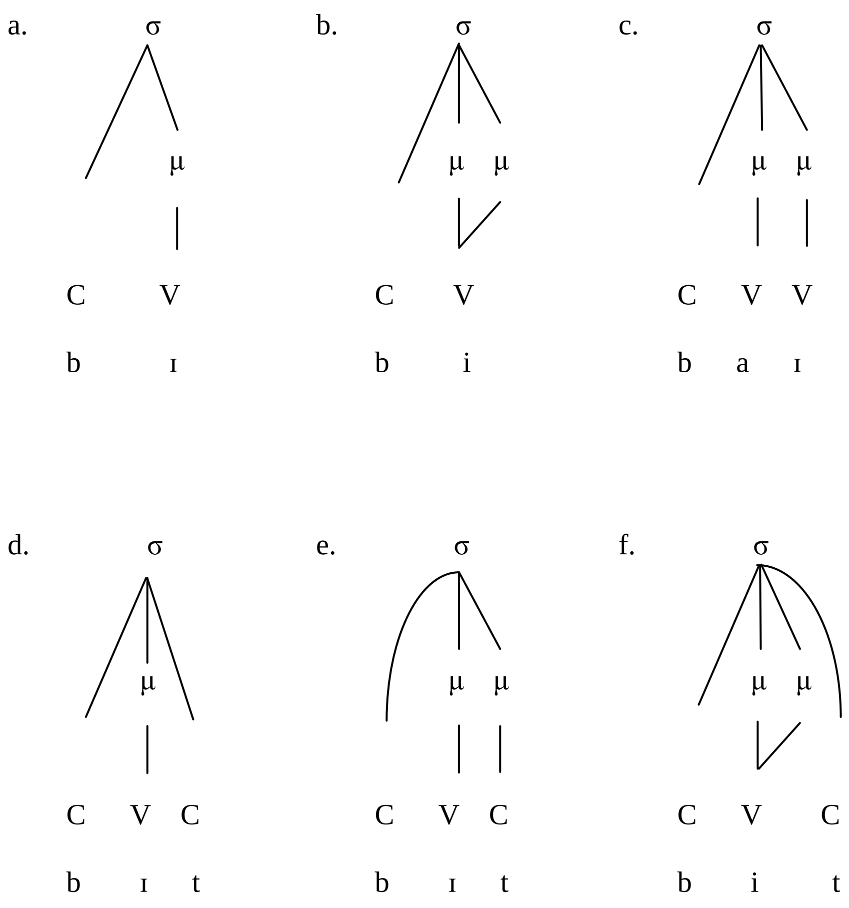
The mora serves as the intermediate level of structure that links segmental and prosodic information, as sketched out in (10):

(10)

```
  σ
  |
  μ
  |
[cons]
```

Root nodes are segmental units and moras are prosodic units. Therefore, moras capture the prosodic aspects of weight, whereas root nodes capture the segmental aspects of timing. It is not surprising to see that there is no one-to-one correspondence between them because root nodes are segmental and moras are prosodic. Moraic status is given to prosodically active segments. As considered in the previous section, segments in the rhyme are prosodically active while segments in the onset are inactive. Therefore, segments in the rhyme are given moras. Syllable weight is dependent on both vowel length and the presence of the coda. In a language with no vowel-length distinction and no coda, syllables are monomoraic. In a language with a vowel-length distinction, syllables are monomoraic or bimoraic. Onset consonants are nonmoraic because they are prosodically inactive. The moraic status of postvocalic consonants is language-specific while vowels are universally moraic. Hayes (1989) suggests the rule of Weight-by-Position. In a language where Weight-by-Position adjunction is applied to a coda, a mora is assigned to a postvocalic consonant. Let us consider the possible structures illustrated in (11):

(11) Moraic representation of different syllable types



No mora is assigned to consonants in the onset because they do not contribute to weight. One mora is given to a short vowel as in (11a) resulting in a light syllable while two moras are assigned to a long vowel or a diphthong as in (11b, c), resulting in a heavy syllable. The moraic representations of syllable structure shown in (11d, e) are language-specific. In a language without Weight-by-Position, like Khalkha Mongolian, a postvocalic consonant is treated as weightless as shown in (11d). On the other hand, in a language with Weight-by-Position, like Yana, a postvocalic consonant following a short vowel is considered moraic as shown in (11e). No mora is assigned to a postvocalic consonant following a long vowel or a diphthong as in (11f).

In many languages, a continuum of phonological weight properties is divided into two categories: light and heavy,[19] as sketched out in (12):

(12)		light	heavy
	a.	CV	CVC, CVV
	b.	CV, CVC	CVV

As mentioned earlier, syllables with one mora are treated as light and syllables with two moras are treated as heavy. As seen in (12a, b), CV syllables are intrinsically light and CVV syllables are intrinsically heavy. However, CVC syllables language-specifically pattern with CV or CVV syllables. In other words, the assignment of mora to coda consonants is optional, depending on languages, by the rule of Weight-by-Position (Hayes, 1989). For example, in Khalkha and Lardil, CV syllables and CVC syllables count as light and only CVV syllables are heavy. Moras are not assigned to coda consonants because those languages do not have Weight-by-Position. On the other hand, in Latin and Makilese, CVC syllables pattern with CVV syllables, treated as heavy, and only CV syllables are light. In this case, coda consonants have moras assigned by Weight-by-Position adjunction. Consider the examples presented by Ahn (2000), as shown in (13):

[19] The issue of "superheavy" will be considered later. For now, it will be left aside.

(13) Ahn (2000: 15)

	Khalkha	Lardil	Latin	Makilese
CVV	Heavy	Heavy	Heavy	Heavy
CVC	Light	Light	Heavy	Heavy
CV	Light	Light	Light	Light

In addition, the CV tier cannot explain minimality effect. Now, let us consider briefly how small a word could be. There are some languages that disallow light monosyllabic content words. For example, in English, there is a restriction, related to vowel quality, on the formation of monosyllabic content words: monosyllabic lexical words should consist of two moras. In other words, all open monosyllabic content worlds should consist of a tense vowel or a diphthong. A monosyllabic content word with a lax vowel without a consonant in the coda is not allowed. Therefore, lax vowels cannot appear in open monosyllabic lexical words in English, as illustrated in (14):

(14) English monosyllabic content words (Cohn, 2003)

a. tense vowels: pea, pay, Pooh, Po, paw

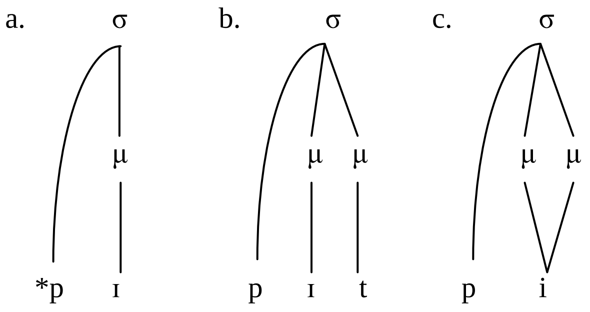
b. diphthongs: pie, pow, poy

but:

c. lax vowels: *[pɪ], *[pɛ], *[pæ], *[pʌ], *[pʊ]

Now, let us consider the ill-formed or well-formed structures of monosyllabic content words, as sketched out in (15):

(15)

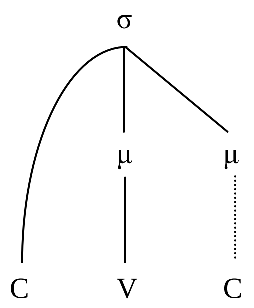


English disallows the moraic representation of monosyllabic content words like (15a). In sum, English monosyllabic content words should consist of two moras. It is also notable that the moraic view is more effective to account for minimality effects than the timing unit approach. It is more complex to account for minimal word effects with CV-tier theory because CVC syllables pattern with CV or CVV on a language-specific basis. Some languages (e.g., English) disallow only CV monosyllabic content words while other languages (e.g., Lardil) disallow CV and CVC monosyllabic content words. Note that, in English, CV syllables count as light while CVC syllables count as heavy, and in Lardil, both CV and CVC syllables count as heavy. Therefore, the moraic view, more effectively, captures the phonological phenomenon of minimality effects: some languages do not allow monosyllabic content words consisting of one mora.[20]

So far, with respect to the weight of coda, we have dealt with the case of a single consonant in the coda. Now, let us consider Weight-by-Position in a little bit more detail.

[20] Hayes (1995: 88) lists forty languages that show minimality effects.

(16) Weight-by-Position (Hayes, 1989)

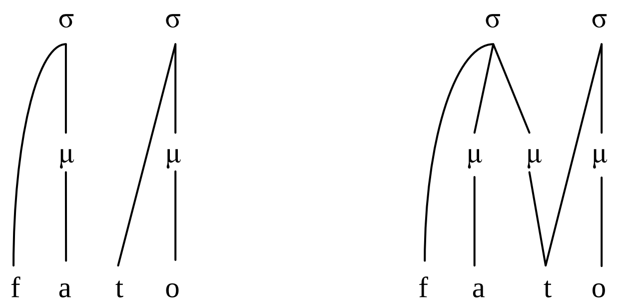


According to moraic theory, consonants in the onset do not contribute to syllable weight. So moras are not assigned to segments in the onset, C directly linked to syllable. On the other hand, vowels are automatically assigned a mora. The assignment of mora to consonants in the coda is language-specific and dependent on Weight-by-Position adjunction. However, why Weight-by-Position is language-specifically active is not accounted for. Gordon (2002b) argues, providing phonetic evidence, that the activation of Weight-by-Position adjunction is largely dependent on the proportion of high sonority codas. This will be discussed later. In languages with Weight-by-Position activated, a mora is assigned to a consonant in the coda, making CVC syllables heavy. In languages with Weight-by-Position inactivated, a mora is not assigned to a consonant in the coda, making CVC syllables light. With few exceptions, rhymes can have a maximum of two moras.[21] Therefore, a postvocalic consonant after a long vowel cannot be moraic. The first consonant after a short vowel can be assigned a mora. On the other hand, geminate consonants in the coda are always treated as moraic, Consider the example by Gussenhoven and Jacobs (1998) that shows the Italian distinction between nongeminate [fato] and geminate [fat:o] as illustrated in (17):

[21] It is assumed that the last syllable of the word can have three moras. The last syllable of the word behaves differently than other syllables. This will be discussed later.

(17) Italian (Gussenhoven & Jacobs, 1998)

a. [fato] ‘fate’ b. [fat:o] ‘fact’



As schematized above in (17a), a single consonant [t] in [fato] ‘fate’ is directly linked to the second syllable, treated as a weightless consonant in the onset of the second syllable. On the other hand, as in (17b), a geminate consonant [t:] in [fat:o] ‘fact’ is shared by a moraic consonant in the coda of the first syllable and a nonmoraic consonant in the onset of the second syllable. In order to express duration, geminate consonants are always assigned a mora. In fact, there exist weight-bearing geminates and non-weight-bearing geminates. This will be discussed in more detail in the next section.

4.2.3 Geminates vs. doubled consonants

There has been much debate on how to distinguish a geminate consonant from its singleton counterpart. Geminate consonants show a longer duration than its singleton counterparts. In the previous section, geminates are treated as moraic to express their duration. There exists a structural difference between CV-tier theory and moraic theory. In a timing unit approach, both geminates and long vowels contain two units (C/V or X), representing the same structure, as in (18):

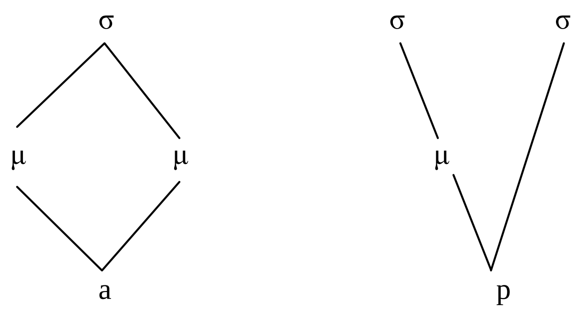
(18)

a. Long vowel b. Geminate consonant

As in (18), a long vowel is shared by the same positional units (VV), and a geminate consonant is also linked to the same positional units (CC). However, under the moraic view, the representation of geminates and long vowels is structurally different, as illustrated in (19):

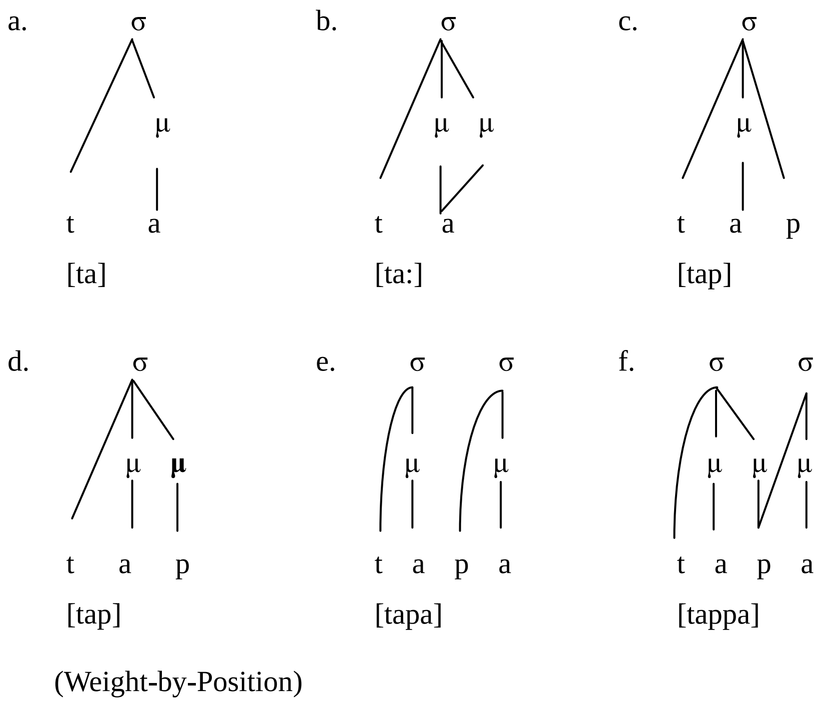
(19)

a. Long vowel b. Geminate consonant



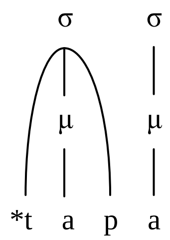
As we can see in (19), in moraic theory, a long vowel is linked to two moras which are dominated by one syllable while a geminate consonant is linked to two different positions: a mora which is dominated by the first syllable and the second syllable. Now, turn to the basic syllable types again, as illustrated in (20):

(20)



As discussed earlier, all consonants in the onset are never assigned a mora because they do not contribute to syllable weight. On the other hand, all vowels are intrinsically moraic, therefore all vowels, short or long, are legitimate to be assigned a mora. A short vowel, as in (20a), is assigned a single mora while a long vowel, as in (20b), is assigned to two moras to represent its duration. In a language whose coda consonants do not contribute to syllable weight, the moraic representation is illustrated as in (20c). The consonant in the coda is directly linked to syllable without being dominated by mora because it is not licensed to be assigned a mora. The diagram in (20d) illustrates Weight-by-Position proposed by Hayes (1989). In a language with weight-bearing coda consonants, a mora with a strikethrough is applied by Weight-by-Position to a coda consonant. In (20e), the consonant [p] is a simple intervocalic singleton, linked to the onset of the second syllable. Onset First Principle (or Maximum Onset Principle) disallows it to be linked to the coda of the first syllable, making a diagram sketched out in (21) ill-formed.

(21)

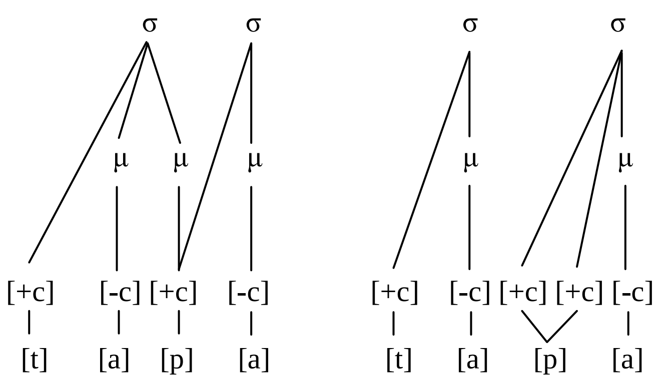


In (20f), the moraic representation of a geminate consonant is illustrated. An underlying moraic consonant is shared by both the coda of the first syllable and the onset of the second syllable, being assigned by a mora.

Now, let us turn to the issue of weight-bearing geminates and non-weight-bearing singletons. Geminates are underlyingly moraic while singletons are not. Following Cohn (2003) and Ham (2001), I refer to singletons that are not underlyingly moraic as “doubled consonants”.[22]

(22)

a. moraic geminate b. doubled consonant



[tappa] [tappa]

[22] Some (Davis 2011 among others) treat geminates and doubled consonants as the same term, referring to geminates as long or “doubled” consonants in contrast to short or singleton counterparts.

As seen in (22a, b), notable differences between geminate consonants and doubled consonants are weight contribution and syllable affiliation. With reference to weight contribution, a geminate consonant, as in (22a), contributes to weight, being assigned a mora while a doubled consonant, as in (22b), is not assigned a mora because it is weightless. In the case of syllable affiliation, as in (22a), a geminate consonant is shared by the coda of the first syllable and the onset of the second syllable while a doubled consonant is linked only to the onset of the second syllable, as in (22b). It is not that such contrasts are found in all languages. Nevertheless, there is strong evidence for the need of both representations. In some languages like Japanese and Italian, both representations co-exist. Consider the example, shown in (23) and (24):

(23) Japanese geminate contrast

a. [saka] ‘hill’ b. [sakka] ‘author’

(24) Italian geminate contrast

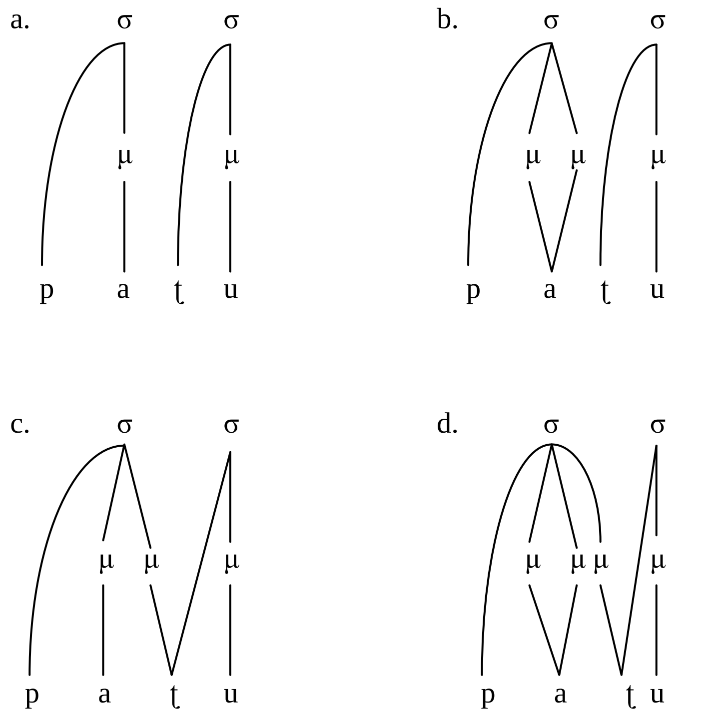
a. [fato] ‘fate’ b. [fatto] ‘fact’

Therefore, geminates and doubled consonants should be differently treated. Again, the CV tier fails to explain the difference between them. In the moraic structure, the difference is evidently revealed.

4.2.4 Superheavy syllable

Many languages restrict the number of moras in the rhyme to two, showing a two-way contrast: light and heavy. Languages with a two-way contrast disallow long vowels to appear before geminates. However, there are also, albeit rare, some languages that have three moraic syllables, which is called “superheavy” by allowing long vowels before geminates. There seem to be two means by which superheavy syllables are formed: The first one appears in languages that have three degrees of vowel length, like Dinka, and the second one appears in languages that allow long vowels before geminates, as mentioned above, like Tamil, as illustrated in (25):

(25)



The first syllable in (25a) has a single mora, counting as light. The first syllable in (25b, c) has two moras, counting as heavy. In Tamil, as seen in (25d), a long vowel with two moras is allowed before a geminate consonant with an underlying mora, making the rhyme trimoraic, counting as “superheavy”.

In many languages, long vowels appear before simple coda consonants, and short vowels appear before geminates without any restrictions. Consider the examples of long vowels before coda consonants in Koya, as shown in (26):

(26) Long vowels before coda consonants

[a:nd]	'female power'
[mansu:rku]	'men'
[me:ndu:li]	'back'

In many languages, complex coda consonant clusters are not necessarily considered geminate consonants. Therefore, long vowels are not banned before simple complex coda consonant clusters. In English, for example, *sixth* [sɪksθs] with four coda consonants is not considered heavier than *sick* [sɪk] with a single coda consonant. The example of short vowels before geminates in Koya is shown in (27):

(27) Short vowels before geminates

a. [pɪk:a]	'cup'
b. *[pu:t:i]	ill-formed

In Koya, as seen in (27a), short vowels are allowed to appear before geminates. However, as in (27b), long vowels before geminates are considered ill-formed. Superheavy, trimoraic, languages are rare. Therefore, when syllables in morphologically concatenated words have structures of long vowels before geminates, long vowels are shortened to avoid more restrictions, as illustrated in (28):

(28) Vowel shortening before geminates in Koya

ke: t: o:ɳɖa	[ket:o:ɳɖa]	'he told'
o: – t: – o:ɳɖu	[ot:o:ɳɖu]	'he brought'

Koya, as seen in (28), restricts long vowels to occur before geminates through vowel shortening. However, some languages such as Tamil as seen in (25), Sinhalese, and Hungarian allow the occurrence of long vowels before geminates. These languages violate, across the board, the ban on trimoraic syllables. Consider (29) below:

(29) Hungarian syllable types

a. μ

i.	CV	ma	'today'
		fa	'tree'
ii.	CVC	bot	'stick' (N)
		ɲom	'trail'

b. μμ

i.	CV:	lo:	'horse'
		fy:	'grass'
ii.	CV:C	po:k	'spider'
		ka:d	'tub'
iii.	CVC:/CVCC	kɛd:	'Tuesday'
		ʃylt	'baked' (adj.)

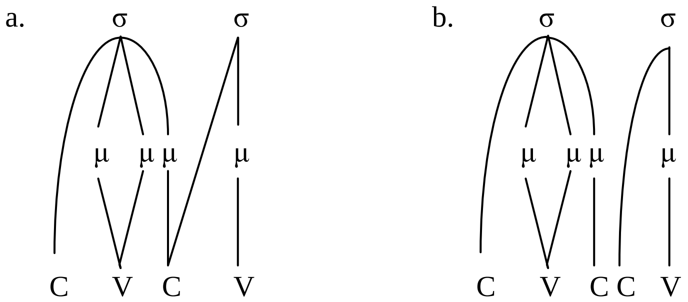
c. μμμ

CV:C:/CV:CC	ro:t:	'notched' (adj.)
	hy:lt	'cooled' (adj.)

d. *CVCCC, *CV:CCC

In Hungarian, final consonants are extrametrical. Thus, as seen in (29a), CV and CVC count as monomoraic. As seen in (29b), CV:, CV:C, and CVC:/CVCC count as bimoraic because a long vowel is assigned two moras, and a final geminate or a final consonant cluster is assigned a mora while a final consonant is not. As seen in (29c), syllables with a long vowel before a geminate or a consonant cluster are acceptable and count as superheavy. However, syllables with three final consonants are not acceptable. In moraic terms, the acceptable sequence of vowels and consonants can be better accounted for. Consider the representation of trimoraic syllables in Sinhalese, presented by Letterman (1994), as illustrated in (30):

(30) Trimoraic syllables in Sinhalese (Letterman, 1994: 175)



$CVVC_1C_1V$ $CVVC_1C_2V$

As seen in (30a), a long vowel is followed by a weight-bearing geminate, allowing the first syllable to have three moras because a long vowel has two moras and a weight-bearing geminate has one mora. Of interest here is in Sinhalese, Letterman (1994) argues, non-geminate coda consonants contribute to weight. Therefore, in Sinhalese, trimoraic syllables may be closed by a non-geminate as in (30b).

As discussed so far, the weight properties are defined by sequences of vowels and consonants. However, interestingly, Cohn (2003) argues, taking an example of liquid rhymes in English, that sonority, in some cases, also plays a role in defining the weight properties of a subclass of syllable types. Syllables with a liquid (/l/ or /r/) in the rhyme after certain vowels or diphthongs are superheavy,[23] as shown in (31):

[23] Lavie and Cohn (1999) refer to these as the sesquisyllalbes, which Cohn (2003) terms the “superheavy” syllables. Hereafter, I will use the term, superheavy syllables, following Cohn (2003).

(31) Cohn (2003)

/l/-rhymes: file, foul, foil, fool, fail

/r/-rhymes: fire, flour (coir)

Cohn (2003) argues that the distinction of syllable forms in (31) is not clear because many speakers intuitionally conceive these forms as something that falls between monosyllables and disyllables, summarizing the phonological distribution of these kinds of liquid rhymes, as illustrated in (32):

(32) Phonological distribution of r/l rhymes (Cohn, 2003: 82)

Key:

merged vowels	superheavy	– non-occurring

	r	l	n	ø
i	fear	feel	seen	fee
ɪ		fill	fin	–
e	fair	fail	rain	Fay
ɛ		fell	Ben	–
æ		pal	fan	–
a	far	doll	Don	fa
ʌ	(fur)	dull	fun	–
ər	–	curl	fern	fur
u	poor	fool	soon	Pooh
ʊ		full	–	–
o	four	sole	phone	foe
ɔ		fall	fawn	paw
aj	fire	file	fine	fie
aw	flour	foul	down	paw
oj	(coir)	foil	coin	poi

Cohn (2003) judges superheavy syllables based on evidence form speaker intuition, metrical evidence, and morphophonology.[24] With respect to metrical evidence, Lavoie and Cohn (1999: 111) find evidence from chanting and verse. Superheavy syllables[25] with a liquid rhyme "can be chanted in a manner similar to disyllabic words."[26] As can be seen in the table (32), Cohn (2003) points out differences of /r/ and /l/ rhymes from others consonants in the rhyme. First, despite slight different behaviors based on the qualities of preceding vowels, only /r/ and /l/ rhymes show this property. Second, this property occurs in both /r/ and /l/ rhymes following the true diphthongs such as /aj/, /aw/, and /oj/. Third, before /l/ rhymes, the vowel quality, tense or lax, is relevant for this property. When tense vowels are followed by /l/ rhymes, this property occurs while lax vowels do not bring about this property, as seen in the example *feel* /fil/ vs. *fill* /fɪl/. Fourth, for the /l/ rhymes, vowel height is relevant. Only when non-low vowels are followed, does this property occur. Consider the example *fail* /fel/ vs. *fall* /fɔl/. Finally, for the /r/ rhymes, the neutralization of the tense-lax vowels is relevant.

Cohn and Lavoie (2003) argue that the property of being heavy results from "the requirement that a liquid in the rhyme bear a mora." In many languages, *μμμ is highly ranked and inviolable. However, there are, albeit rare, languages that allow trimoraic syllables such as Hungarian and Sinhalese.

(33) Constraints

a. RIMER/L: Liquids in the rime must bear a mora.

b. *μμμ: No trimoraic syllables are allowed.

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24 See Lavoie and Cohn (1999) for details.

25 Again, Lavoie and Cohn (1999) call these sesquisyllables. Following Cohn (2003), "superheavy" is used in this dissertation.

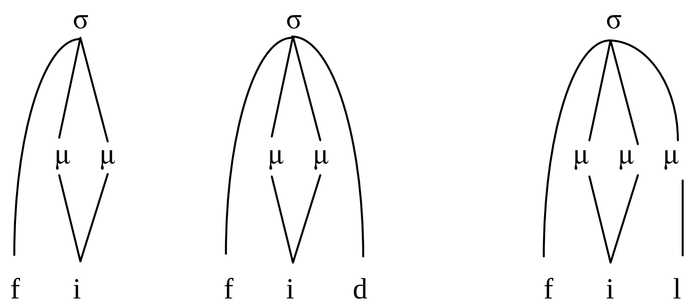
26 Consider the following examples and see Lavoie and Cohn (1999) for a detailed explanation

disyllabic	*table*	te-bl
sesquisyllabic	*peel*	pi-jl
	fire	faj-jr
	owl	aw-wl
monosyllabic	*pill*	pɪ -ɪl, *pɪ-jl
	far	fa-ar, *fa-jr
	all	a-al, *a-jl, *a-wl

In English, although the constraint *μμμ is not violated across the board like Hungarian and Sinhalese, the constraint RIMER/L outranks *μμμ. Therefore, trimoraic syllables are limited to liquids in the rhyme, and possible moraic representations are as illustrated in (34):

(34)

a. b. c.



bimoraic trimoraic

The bimoraic syllables are composed of a tense vowel or diphthong, as in (34a), or a vowel followed by a non-liquid consonant, as in (34b). On the other hand, the trimoraic syllables always consist of liquid rhyme and, at the same time, depend on the vowel property, as in (34c). Therefore, the number of segments in the rhyme does not decide the number of moras. In addition, the mora count is not influenced by the presence of additional consonants in the coda. Let us consider examples presented by Cohn (2003: 84), as in (35):

(35)

heavy rhyme		superheavy rhyme
will	pine	while
wilt	pint	whiled
wilts	pints	whilst

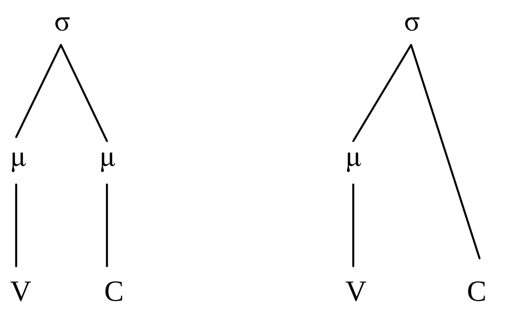
As seen in (35), whether the rhyme is heavy or superheavy cannot be predictable from the number of coda consonants. Here, we can see again that a timing slot approach is not sufficient to account for syllable weight, and that a moraic view can better account for it.

4.2.5 Mora-sharing representation

Broselow *et al.* (1997) explore three patterns of coda weight that occur in three distinct languages: Hindi, Malayalam, and Levantine Arabic. In Hindi, codas always add weight to syllables. In contrast, in Malayalam, coda consonants always do not contribute to syllable weight. On the other hand, in Levantine Arabic, coda consonants following a short vowel contribute to syllable weight while those following a long vowel are weightless. Given the representation discussed so far, coda consonants that do not contribute to syllable weight are linked directly to the syllable node. Consider (36):

(36)

a. Hindi b. Malayalam

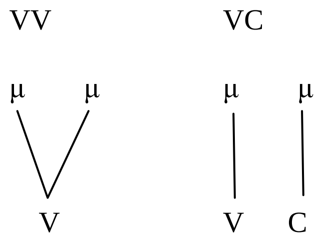


As seen in (36a), in Hindi, a coda consonant is assigned a mora because it always contributes to syllable weight. On the other hand, in Malayalam, a coda consonant attaches directly to the syllable node without being assigned a mora because a coda consonant is always weightless. However, as opposed to this moraic representation, Broselow *et al.* (1997) classify segments into mora-sharing segments and mora-occupying segments. Of interest is that Broselow *et al.* (1997) regard weightless coda consonants as mora-sharing. Thus, in their view, weightless coda consonants do not attach directly to the syllable node, but share a mora with a preceding vowel. Consider the structures of mora-sharing representation proposed by Broselow *et al.* (1997: 49), as illustrated in (37) and (38):

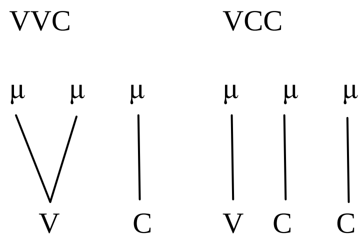
(37) Hindi syllable rhyme structures

a. light

b. heavy

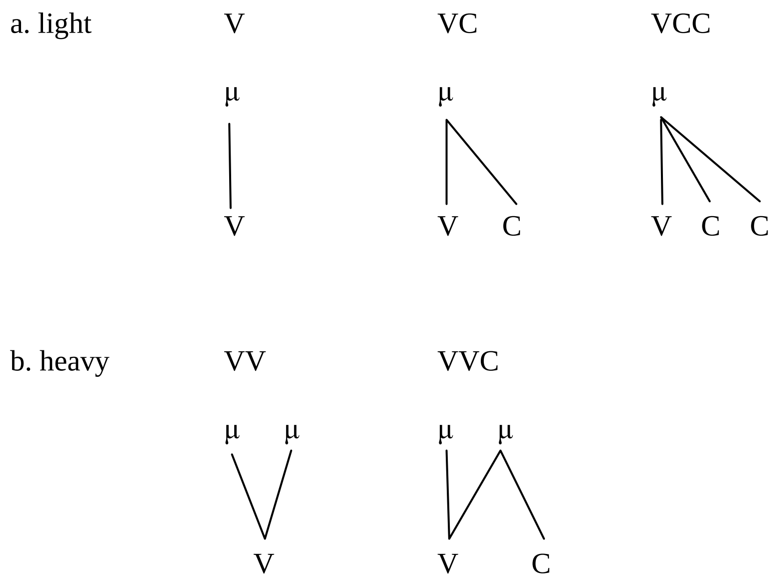


c. superheavy



As seen in (37a, b, c), in Hindi, coda consonants always add weight to syllables and have their own moras, making syllables monomoraic, bimoraic, or trimoraic.

(38) Malayalam syllable rhyme structures



As opposed to Hindi, in Malayalam, weight depends solely on vowel length because coda consonants are always weightless. What is notable is that, although coda consonants are weightless, they are linked to the mora node. Compare the previous moraic representation that attaches a weightless consonant directly to the syllable node, as in (36b). Broselow *et al.* (1997) argue that phonetic evidence provides an argument to support the distinction between representations like (36b) and the mora-sharing representations in (38) while it is difficult to find phonological arguments. This will be discussed in detail in the following section.

To summarize, in this section, we have discussed several phonological arguments. We also have seen that a moraic representation better accounts for syllable weight than a timing slot approach. To support these arguments in favor of a moraic representation of weight, we have seen evidence from onset/rhyme asymmetries, geminates vs. doubled consonants, and English liquid rhymes. Finally, we have considered the mora-sharing representation which is hardly supported by phonological arguments but possibly argued by phonetic evidence.

4.3 Phonetic evidence

4.3.1 Phonetic duration

It has shown in the recent literature that phonetic duration reflects the presence of moras. Broselow *et al.* (1997), for example, find the relation between phonetic duration and moraic presence by examining three phonological patterns of coda weight and compare them to the durations of vowels and coda consonants. Broselow *et al.* (1997) assume that weightless coda consonants share a mora with preceding vowels while vowels and weight-contributing consonants have their own mora. They also argue that it is difficult to find phonological arguments to prove the fact that non-weight-contributing coda consonants share a mora with preceding vowels, but that it is possible to prove it by representing phonetic data. They choose three distinct languages (Hindi, Malayalam, and Levantine Arabic), conduct an experiment, and provide a phonetic analysis. We have already discussed the phonological representation of Hindi and Malayalam. Now, let us turn to the phonetic aspects of those two languages.

In Hindi, both vowels and coda consonants have their own moras, and moraic content of the vowel does not change, depending on the presence of a coda consonant, because a coda consonant has its own mora and does not share a mora with the preceding vowel. In other words, vowel length does not change with the presence of a coda consonant. Thus, we can predict vowel duration patterns for Hindi as in (39):

(39) Predicted vowel duration patterns for Hindi (Broselow *et al.*, 1997: 51)

μ μ		μ μ		μ		μ
VV	=	VVC	>	V	=	VC

As seen in (39), vowel durations should not vary in both open and closed syllables because coda consonants do not affect the vowel durations. Thus, VV = VVC, and all VV > all V. Now, consider a shared mora as illustrated in (40):

(40) Predicted vowel duration patterns for Malayalam (Broselow *et al*., 1997: 51)

μ μ		μ + shared μ		μ		shared μ
VV	>	VVC	>	V	>	VC

As seen in (40), phonemically long vowels are longer than phonemically short vowels. What is notable is that vowels in closed syllables are shorter than their counterparts in open syllables, which is convincing evidence for the argument of shared-moraic representation. Finally, consider the predicted consonant duration patterns, as shown in (41):

(41) Predicted consonant duration patterns (Broselow *et al*., 1997: 51)

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

As in (41), in Hindi, coda consonants are always assigned a mora, while in Malayalam, a coda consonant is assigned a shared mora because it always shares a mora with the preceding vowel.

Now, let us consider whether the statistical results are comparable with the predicted patterns.[27] If our assumption is borne out, the statistical results will be comparable as theoretically predicted before. Consider statistical results for Hindi, as in (42):

(42) Statistical results for Hindi (Broselow *et al*., 1997: 53)

Vowel duration:	μ μ		μ μ		μ		μ
	VV	=	VVC	>	V	=	VC
		$p = .91$		$p < .0001$		$p = .98$	
Consonant duration:			μ		μ		
			VVC	=	VC		
				$p = .54$			

In (42), no significant differences are found between vowels in open syllables and those in closed syllables. Also, there is no difference in coda consonants following long vs. short vowels. Note that a highly significant difference ($p < .0001$) is found between long and short vowels. The statistical results confirm the assumption that in Hindi, coda consonants have their own mora without sharing a mora with the preceding vowel. In Malayalam, a coda consonant always shares a coda with the preceding vowel, regardless of whether it is long or short. Thus, we can predict that in Malayalam, phonetic shortening will occur in both long and short vowels in closed syllables. Now, take a look at the statistical results for Malayalam, as in (43):

(43) Statistical results for Malayalam (Broselow *et al*., 1997: 55)

Vowel duration:	μ μ		μ + shared μ		μ		shared μ
	VV	>	VVC	>	V	>	VC

[27] For detailed methodology and analysis, see Broselow *et al*. (1997: 52-62)

p = .0001 p = .0001 p = .003

Consonant duration: shared μ shared μ

VVC = VC

p = .677

The statistical results, as in (43), show that phonetic shortening occur in both long and short vowels in closed syllables, while the duration of coda consonants following both long and short vowels remains almost the same. The results support moraic representations proposed above: a weightless coda consonant does not attach directly to the syllable node, but it shares a mora with the preceding vowels regardless of whether it is long or short.

Now, let us turn to the case of Levantine Arabic,[28] in which coda consonants are weight-bearing or non-weight-bearing, depending on the property of preceding vowels: If a short vowel precedes, coda consonants bear weight, occupying their own mora, while if a long vowel precedes, coda consonants do not contribute to weight, sharing a mora with the preceding vowels. Thus, duration patterns for Levantine Arabic can be predicted as in (44):

(44) Predicted duration patterns for Levantine Arabic (Broselow *et al*., 1997: 58)

Vowel duration: μ μ μ + shared μ μ μ

VV > VVC > V = VC

Consonant duration: shared μ μ

VVC < VC

Now, let us consider whether predicted duration patterns accord well with statistical results. Statistical results are shown in (45):

[28] "A cover term for (mainly) urban dialects of Syria, Lebanon, Jordan and historical Palestine" Broselow *et al.* (1997: 55-56).

(45) Statistical results for Jordanian[29] (Broselow *et al.*, 1997: 59)

Vowel duration:	μ μ		μ + shared μ		μ		μ
	VV	>	VVC	>	V	=	VC
		p < .00001		p < .00001		p = .94	

Consonant duration:	shared μ		μ
	VVC	<	VC
		p < .0002	

As seen in (45), both long vowels and coda consonants following long vowels are significantly shortened in closed syllables, while the duration of short vowels and coda consonants after short vowels are maintained. Thus, predicted duration patterns are consistent with statistical results, showing that the mora-sharing assumption is borne out.

We now turn to the question of how we know the shortening of coda duration after long vowels results from the moraic structure, not from a phonetic effect of long vowels on the following consonants, having nothing to do with syllable affiliation. If the shortening of coda duration results from a phonetic effect, having nothing to do with moraic structure, onset consonants following long vowels are also shorter than those after short vowels. Consider the data, shown in (46):

(46) Mean onset C duration (msec)

	VV.C	V.C
Jordanian	51.6	54.5
Syrian	66.7	62.7
Lebanese	78.0	81.2

[29] Broselow *et al.* (1997: 59), "Specific probabilities for the Syrian and Lebanese speakers were similar."

As seen in (46), there is no significant difference in mean onset consonant duration after long and short vowels, showing that this is not the result of a phonetic effect of long vowels on the following consonants. Therefore, it is concluded that the shortening of long vowels is the result of an effect of sharing a vocalic mora with the following coda consonants.

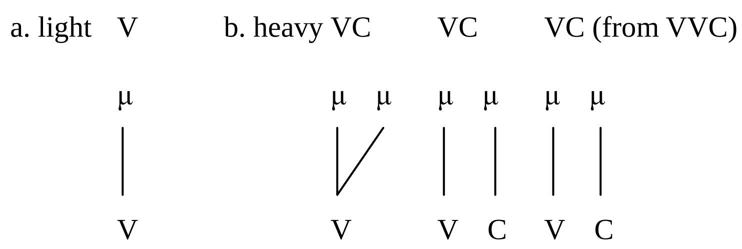
There are some Arabic dialects that show the opposite pattern of vowel shortening as described above. In Cairene and Alexandrian, the shortening of long vowels, as opposed to Jordanian, occur in closed syllables. Consider the data, shown in (47):

(47) Vowel and consonant duration comparison (msec)

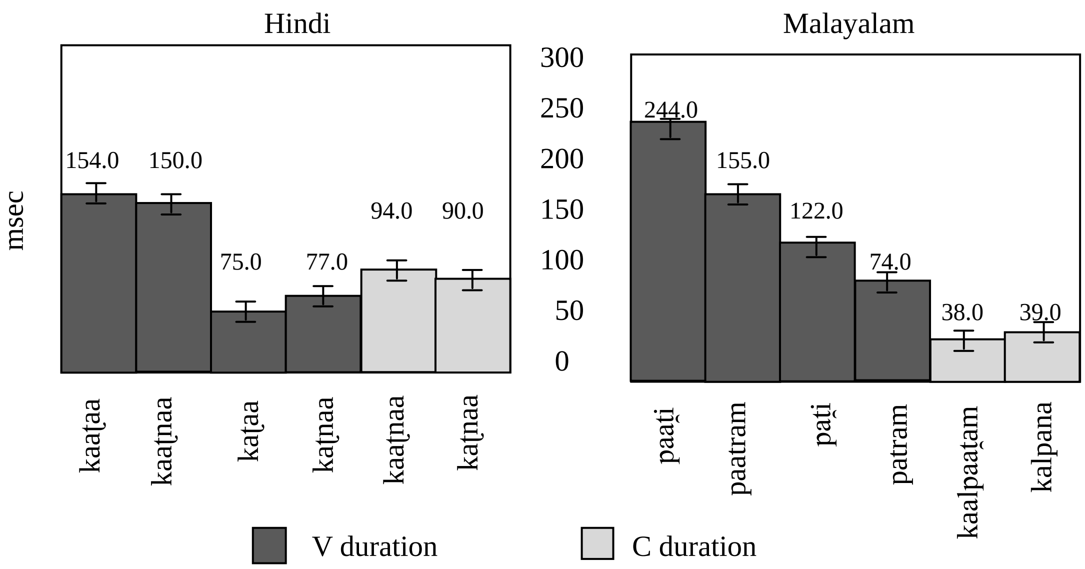
	t**aa**.bV	**ta(a)b**.CV		n**ab**.CV	
		V	C	V	C
Jordanian	161	131.6	67.6	79.9	88.4
Alexandrian	129.3	55.6	72.6	75.8	83.7
Cairene	115.4	78.1	85.5	81.2	85.9

As shown in (47), in Jordanian, as discussed above, the long vowel followed by a coda consonant is notably shorter than that in an open syllable, showing that the following non-weight-bearing coda consonant shares a vocalic mora with the preceding vowel. And the long vowel before a coda consonant is significantly longer than a short vowel in an open syllable. On the other hand, Egyptian shows a different pattern: The lexically long vowel in a closed syllable is shorter than the lexically short vowel in a closed syllable. Broselow *et al.* (1997: 61) assume that mora loss, rather than mora sharing, occurs in this case, proposing the following structure, as illustrated in (48):

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



Broselow *et al.* (1997) suggest four patterns of moraic structure, presenting the phonetic data of long and short vowels in open and closed syllables. The durational patterns accord well with the posited phonological structures: segments with two moras are longer than those with a single mora, and segments with their own mora are longer than those with a sharing mora. Their arguments well support that phonetic duration is closely related to the presence of mora. Rhyme segment duration comparisons are demonstrated in Figure 1:



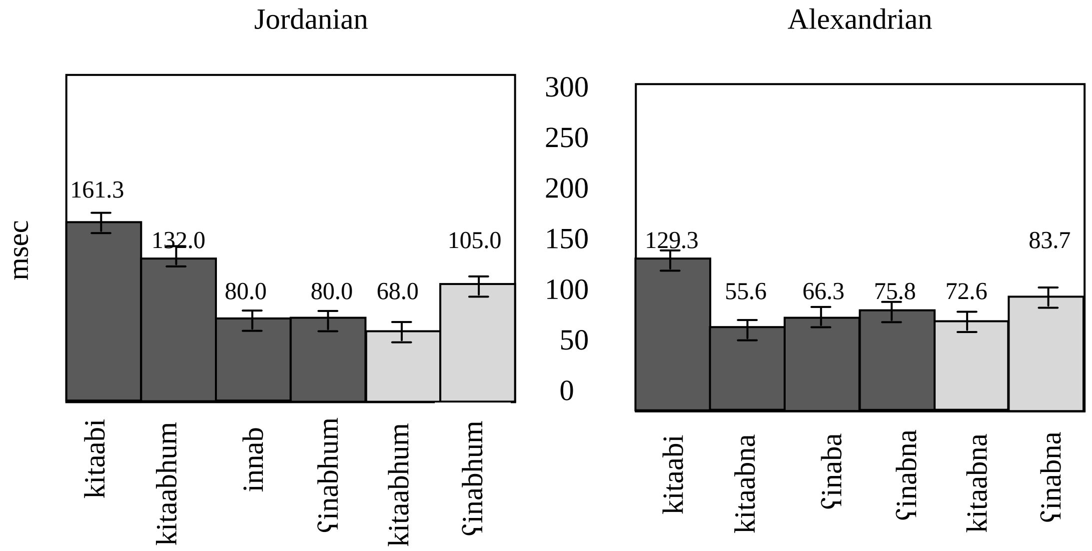


Figure 1: Rhyme segment duration comparisons (Broselow *et al*., 1997)

Others (Hubbard, 1995; Ham, 2001) also have argued that there is a strong correlation between phonetic duration and the presence of mora. Consider phonetic durations of Hungarian monosyllabic words, presented by Ham (2001) as in Figure 2:

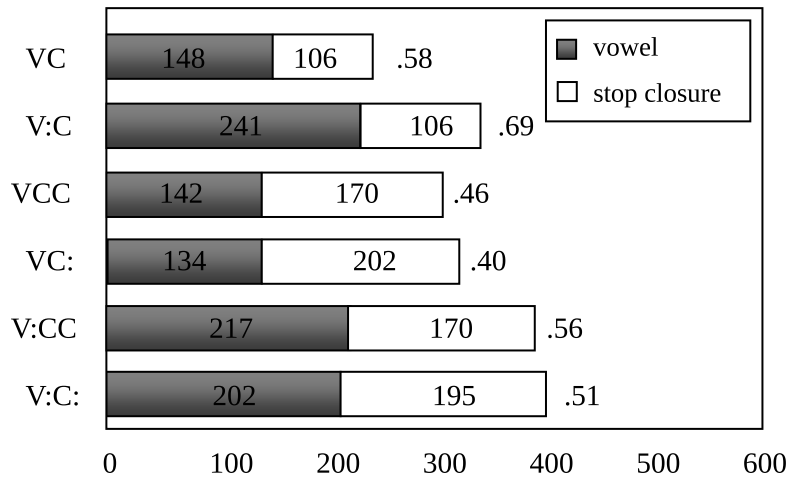


Figure 2: Duration patterns in Hungarian (Ham, 2001: 195)

As discussed earlier, Hungarian has a three-way distinction of syllable weight: monomoraic, bimoraic, and trimoraic. VC counts as monomoraic, V:C/VCC/VC: as bimoraic, and

V:CC/V:C: as trimoraic. As observed in (Figure 2), the shortest is the case of a monomoraic syllable consisting of a short vowel followed by a coda consonant (CV). Bimoraic syllables, consisting of a long vowel before a single coda consonant (V:C) or a short vowel followed by a coda consonant cluster or geminate (VCC or CV:), are longer than a monomoraic syllable. Finally, trimoraic syllables, consisting of a long vowel followed by a coda consonant cluster (V:CC) or a long vowel followed by a geminate (V:C:) are longer than bimoraic syllables. We can see that the number of mora is systematically consistent with the phonetic duration of syllables.

Evidence from Broselow *et al.* (1997) and Ham (2001) provides convincing arguments that phonetic duration and moraic presence are strongly correlated. Ham (2001) also argues that segmental duration is also important because non-moraic consonants also occupy duration. That is, physical duration consists of segmental and prosodic duration. Thus, when mora is not playing a contrastive role, there exist subtle differences in duration.

In this section, we have seen that phonetic duration provides convincing arguments in favor of moraic structure. In the next section, more complicated issues regarding mora and duration will be discussed.

4.3.2 Vowel height and duration

So far, we have seen that there is a strong correlation between phonetic duration and the presence of mora. The duration of segments with two moras is approximately twice longer than that of segments with a single mora. Now, let us consider a more complex issue of height-related vowel duration: tense vs. lax vowels in English. As has been discussed, all vowels are intrinsically moraic, and that tense vowels and diphthongs are bimoraic and lax vowels are monomoraic. Thus, for example, tense /i/ and /e/ are assigned two moras while lax /ɪ/ and /ɛ/ are given a single mora. Let us take a look at the data recorded (45 men, 48 women, and 46 children) and analyzed by Hillenbrand, Getty, Clark, and Wheeler (1995), as shown in Table 1:

Table 1: Part of average durations, fundamental frequencies and formant frequencies of vowels (Hillenbrand *et al.*, 1995)[30]

		/i/	/ɪ/	/e/	/ɛ/	/æ/	/ɑ/	/ɔ/	/o/	/ʊ/	/u/	/ʌ/	/ɝ/
Dur	M	243	192	267	189	278	267	283	265	192	237	188	263
	W	306	237	320	254	332	323	353	326	249	303	226	321
	C	297	248	314	235	322	311	319	310	247	278	234	307
*F*0	M	138	135	129	127	123	123	121	129	133	143	133	130
	W	227	224	219	214	215	215	210	217	230	235	218	217
	C	246	241	237	230	228	229	225	236	243	249	236	237
*F*1	M	342	427	476	580	588	768	652	497	469	378	623	474
	W	437	483	536	731	669	936	781	555	519	459	753	523
	C	452	511	564	749	717	1002	803	597	568	494	749	586

Table 1 shows vowel durations and formant values from /hVd/ context measured by Hillenbrand *et al.* (1995). Durational differences exist between men, women, and children. However, they have no explanations for this. For convenience, let us compare the data from men because proportional differences are comparable between men, women, and children regardless of actual differences in duration. Compare the phonetic duration of /i/ (243ms) with that of /ɪ/ (192ms) and /e/ (267ms) with /ɛ/ (189ms). This correctly shows a correlation between phonetic duration and the presence of mora. The duration of tense vowels are longer but not twice longer than that of short vowels. It is assumed that this is because in English a coda consonant following a short vowel shares a vocalic mora with the preceding vowel, as explained by Broselow *et al.* (1997), while a coda consonant following a long vowel has its own mora.

However, a problem arises from height-related vowel duration, which is a universal tendency: higher vowels are shorter than lower vowels. Consider the case in which a high tense vowel is compared with a low lax vowel. Compare, for example, high tense /i/, taken to be bimoraic, with low lax /æ/, taken to be monomoraic. The phonetic duration of high tense

30 See Appendix B for the full data.

/i/ (243ms) is shorter than that of low lax /æ/ (273ms), which contradicts what is predicted by the mora count. Then, how do we know that the moraic structure is still consistent with the case of tense-lax contrast in English?

Cohn (2003: 91) argues, "the effect of intrinsic duration on vowel height, whereby low vowels are longer than high ones (Peterson & Lehiste, 1960), has a more robust effect on duration than the mora count." Gussenhoven (2007) suggests the following conclusion:

> "It is suggested that, paradoxically, the negative correlation between vowel height and acoustic duration explains why vowel height and *perceived* duration are *positively* correlated. The hearer knows that low vowels require more time and are therefore inherently longer than high vowels… By way of compensation, the hearer reduces the acoustic duration when estimating the perceived duration." (Gussenhoven, 2007)

Of particular interest among others are the findings by Arvaniti and Ladd. (1998), Ladd, Mennen, and Schepman (2000), and Ladd (2005). It is worth summarizing those findings first.

A tone or similar phonological object is realized as tonal targets in the fundamental frequency (f_0) contour. The phonetic variation of tonal targets occurs along two dimensions: alignment and scaling. Alignment is the phonetic property corresponding to the "horizontal" time dimension, while scaling is the phonetic property corresponding to the "vertical" f_0 dimension. Consider Figure 3 shown below:

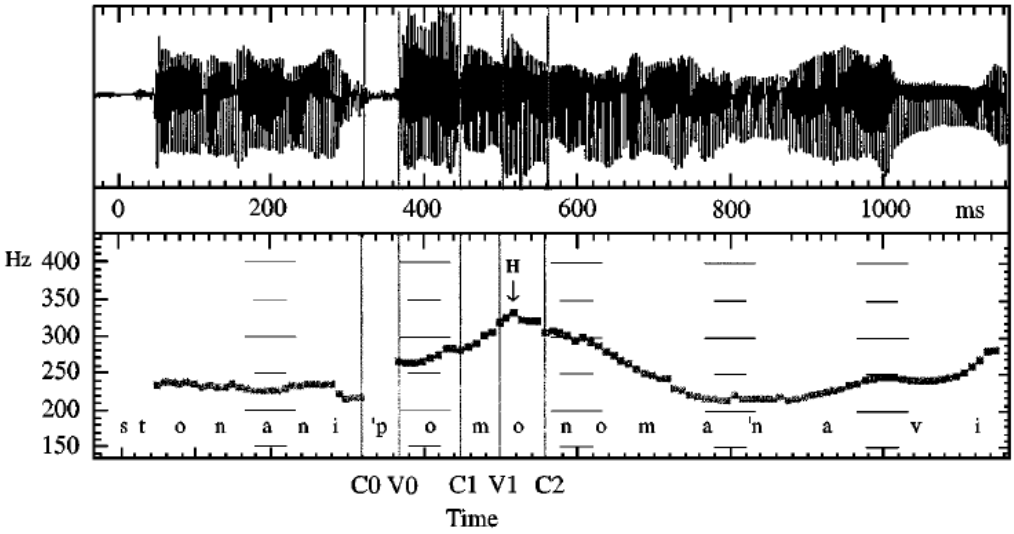


Figure 3. Waveform and f_0 trace (Arvaniti *et al.*, 1998: 10)

As can be seen in Figure 3, waveform and f_0 trace show how the duration and the point of the H target are measured.

Arvaniti *et al.* (1998: 5) examined Modern Greek prenuclear accents and found that "the initial f_0 minimum is very stable in terms of both scaling and alignment: it occurs approximately 5ms before the onset of the accented syllable, and its scaling is not affected by the number of unaccented syllables intervening between accents." The distribution of the H target of Greek prenuclear accents is fixed in distance (on average 17ms) from the onset of the first postaccentual vowel.

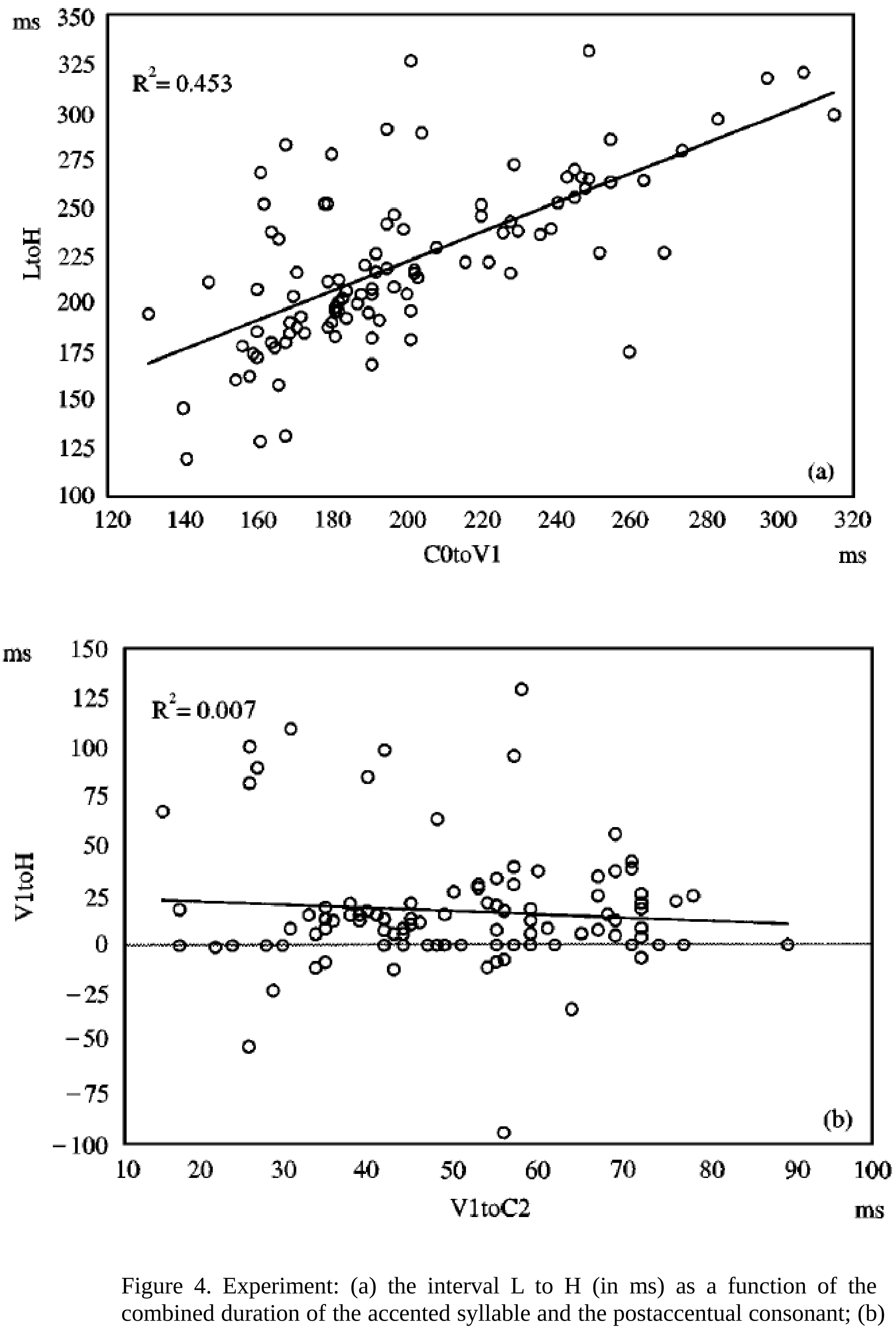
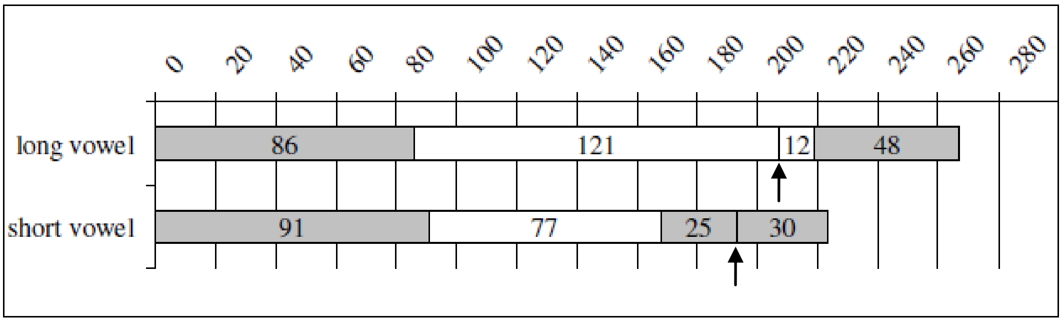


Figure 4. Experiment: (a) the interval L to H (in ms) as a function of the combined duration of the accented syllable and the postaccentual consonant; (b) the interval V1 to H as a function of the duration of the postaccentual vowel; data from all speakers together. (Arvaniti *et al.*, 1998: 18)

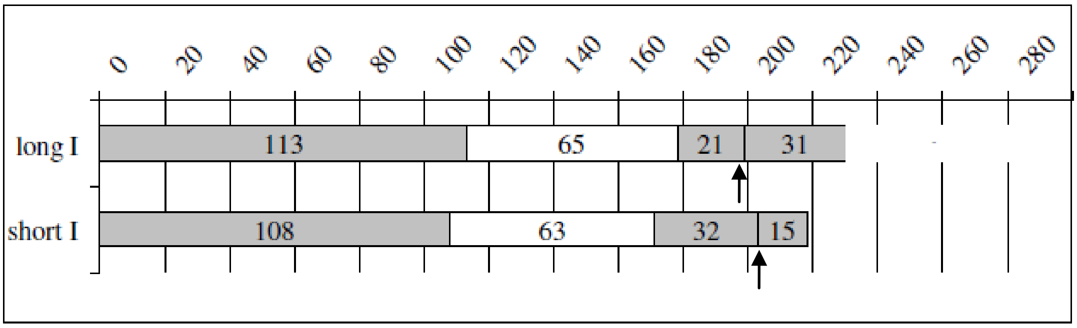
As can be seen in Figure 4, a significant correlation can be found between the distance from the L to the H target and the interval C0 to V1. On the other hand, no correlation can be found between the distance of the H from the beginning of the unaccented vowel and the duration of that vowel. The contour begins at the end of the preaccentual vowel and ends at the beginning of the postaccentual vowel. In addition, Ladd (2005) provides intriguing results about the effect of vowel length on prenuclear pitch peak alignment in Duch and English (RP and SSE). The relative length of the CVC sequence with the accented vowel in Dutch is shown in the graphs, as illustrated in (49):

(49)

a. Results for all vowels:



b. Results for “long” /i/ and “short” /ɪ/:



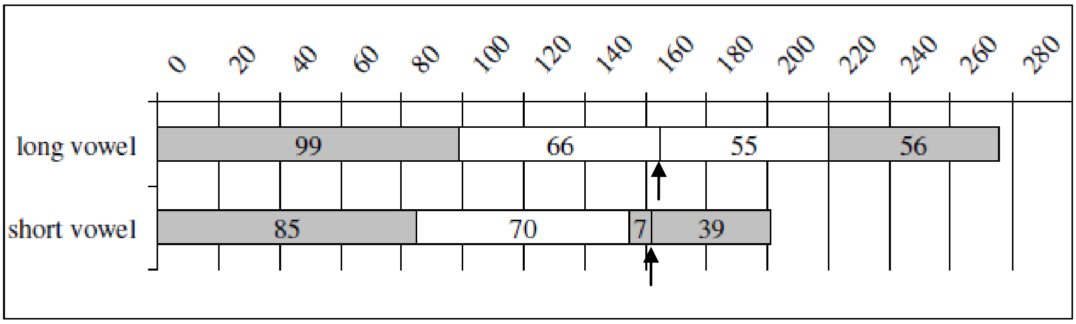
As seen in (49a), there is a notable difference between long vowels and short vowels in terms of the peak alignment (the alignment of the accentual pitch peak is marked by a vertical arrow). In the case of long vowels, the peak is aligned in the latter part of the vowel. In contrast, the alignment is marked well into the consonant following short vowels.

The durational difference between long vowels and short vowels in (49a) is marked. Thus, a possible explanation for this could come from the durational difference. Then, now consider the case of "long" /i/ and "short" /ɪ/ that show similar duration.

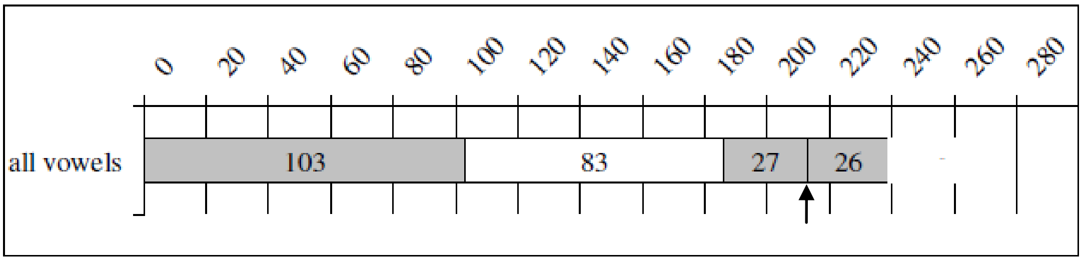
As (49b) shows, despite the similar duration that "long" /i/ and "short" /ɪ/ show, there is a significant difference between the peak alignments of those vowels. This suggests that the different peak alignment is not caused by vowel duration. Ladd found the same results from the data in English (both RP and SSE). Consider the data presented in (50):

(50)

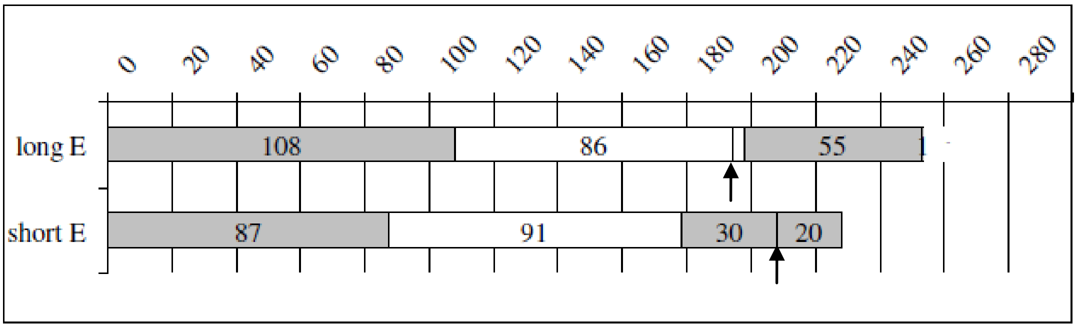
a(i). Results for all vowels in RP



a(ii). Results for all vowels in SSE



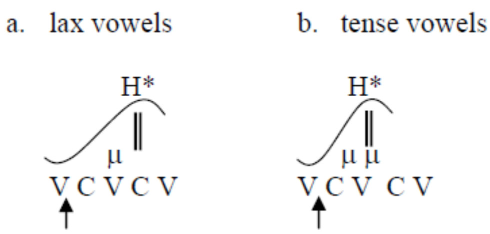
b. Results for “long” /e/ and “short” /ɛ/ in SSE



From the data shown in (50a), it can be observed that as in Dutch, the peak alignment is marked in the consonant following short vowels, while it is marked in long vowels. Again, so as to see if it is caused by vowel length or syllable structure, compare two long and short vowels of similar duration, “long” /e/ and “short” /ɛ/ in SSE, as in (50b). “Long” /e/ and “short” /ɛ/ have similar duration. However, they show a significant difference in alignment. This, again, suggests that the difference in alignment is influenced by syllable structure, not by vowel length.

The anchoring of tone to segments provides convincing evidence that the alignment of the pitch contour is influenced by syllable structure, irrespective of intrinsic duration, strongly supporting the mora count difference. Consider the explanation by Cohn (2003), as illustrated in (51):

(51)



‖ = peak alignment

↑ = beginning/end of pitch contour

In the case of lax vowels as in (44a), the peak is aligned in the following consonant, while in the case of tense vowels as in (44b), the peak is aligned within the later part of the vowel. This can be accounted by the mora count irrespective of intrinsic duration.

4.3.3 Weight-by-position

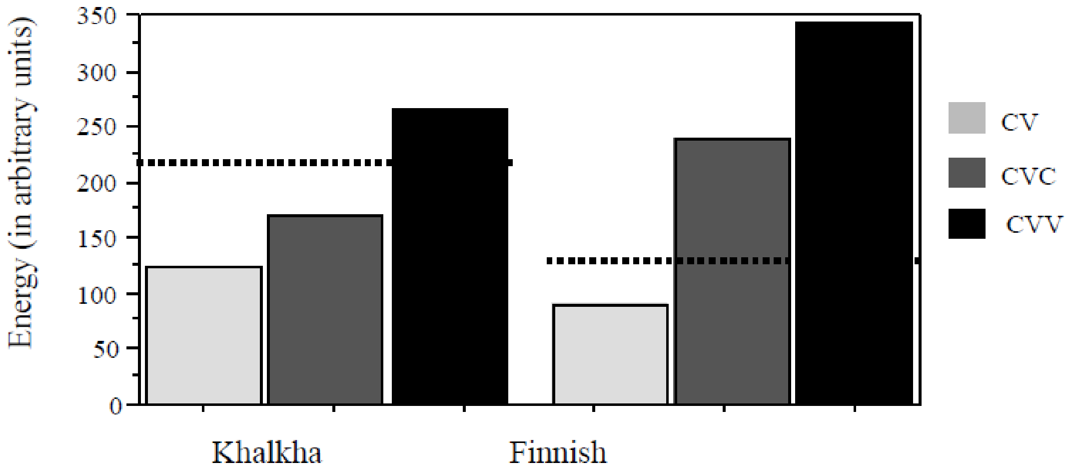
As discussed earlier, in all languages, CVV syllables are treated as heavy while CV syllables count as light. On the other hand, the weight of CVC syllables is dependent on a language-specific basis. Hayes (1989) argues that in languages with Weight-by-Position activated, coda consonants contribute to syllable weight, being assigned a mora, and that in languages with Weight-by-Position inactivated, coda consonants do not contribute to syllable weight without being assigned a mora. The presence of Weight-by-Position adjunction is arbitrary and language-specifically determined. Thus, it remains unexplained whether the presence of Weight-by-Position in specific languages is predictable from distinct properties of those languages.

Duanmu (1994), Broselow *et al.* (1997), and Gordon (2002a, 2002b) and others find evidence for a phonetic correlate for the phonological argument. Duanmu (1994) conducted a phonetic analysis on Mandarin and Shanghai: all full Mandarin rhymes are considered heavy and all Shanghai rhymes are considered underlyingly light. He found that the average syllable duration in Mandarin (215 ms) is longer than that in Shanghai (162 ms), showing the significant difference in duration. In addition, Broselow *et al.* (1997), as discussed in subsection 4.3.1, claim that non-weight-bearing codas share a mora with the preceding vowels, and that weight-bearing codas have their own mora assigned by Weight-by-Position. They phonetically examine three patterns of coda weight in three languages: Hindi (codas always add weight to syllable), Malayalam (codas never contribute to syllable weight), and Levantine Arabic (codas are assigned a mora by Weight-by-Position). They find that non-weight-bearing coda consonants that share a more with the preceding vowels are shorter than weight-bearing coda consonants that are assigned a mora by Weight-by-Position. Finally, Gordon (2002b) claims that Weight-by-Position adjunction is not an arbitrary one, but it is reliably predictable on the basis of syllable structure as well as moraic structure. In languages with a preponderance of codas that are phonetically prominent, CVC syllables are more likely to be heavy. In contrast, in languages with less prominent codas, CVC syllables tend to be light. Gorden (2002b: 4) argues, "these differences between languages in coda prominence lead to differences in the overall phonetic prominence of CVC and ultimately to differences in the phonological weight of CVC."

Heavy syllables are phonetically more prominent than light syllables, where prominence is dependent largely on the phonetic properties of intensity and duration.[31] Those phonetic properties of intensity and duration are comparable with the phonological notions of sonority and timing, respectively. Gordon (2002b) argues that CVC syllables in languages that have a large proportion of sonorant codas will have more energy than those in languages that have a large proportion of obstruent codas, and that these differences in energy of coda inventory contribute to the phonological weight of CVC. He examined the phonetic link between coda inventory and weight using data from two languages (Khalkha that treats CVC as light and Finnish that treats CVC as heavy), and then extended it to other languages. Consider the average energy values, presented by Gordon (2002a: 26, 2002b: 7), for CV, CVC, and CVV in Khalkha and Finnish, as shown in (52):

[31] Gordon (2002b) terms it as "total rimal energy".

(52) Average energy values for CV, CVC, and CVV in Khalkha and Finnish (Gordon, 2002a: 26, 2002b: 7)

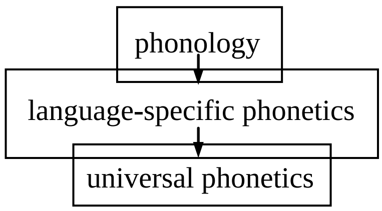


The measurement units of the energy of CVC in Khalkha and Finnish are arbitrary because the goal is to compare differences in coda inventory with those in the energy of CVC. As can be seen in (52), the energy of CVC in Khalkha is closer to that of CV than to that of CVV. Thus, it is more reasonable to group CVC with CV in terms of energy than to group CVC with CVV. Likewise, in energy, CVC in Finnish is closer to CVV than to CV, grouping CVC with CVV, rather than with CV. Gordon (2002b: 7) argues, "languages prefer to rely on weight distinctions based on the largest phonetic differences, since distinctions based on larger phonetic differences are easier to perceive than distinctions based on smaller differences." It is noted that these phonetic distinctions are consistent with the phonological distinctions in the two languages: as discussed above, Khalkha treats only CVV as heavy, but CV and CVC as light, Finnish, on the other hand, treats both CVV and CVC as heavy, but only CV as light.

4.3.4 Geminates vs. doubled consonants

Ham (2001), by extending Hubbard's (1994) proposal of moraic primacy, looks for the phonetic evidence for distinguishing weight-bearing geminates from non-weight-bearing doubled consonants. Ham (2001), based on Hubbard's (1994) findings, claim that moras are allocated a minimum target duration, and that the implementation of this target in terms of timing takes precedence over anticipated segment-specific effects. This view is called 'the moraic primacy.' Hubbard (1994), adopting Cohn's (1990) model of the phonology-phonetics interface, suggest that moraic structure is preserved through the top-down timing model proposed by Cohn (1990), as schematized in (53):

(53)



underlying weight contrast
implementation of weight as length
segment-level effects subordinated

Weight-bearing geminates should be less influenced by segment-level timing effects than non-weight-bearing doubled consonants since only weight-bearing geminates are moraic. And the interpretation of moraic duration is language-specific. Ham (2001) compares segment-level timing influences in doubled consonants and geminates by investigating the effects of place of articulation and voicing on closure duration. He analyzes the data from four different languages: Bernese (syllable-timed, featuring the phonological characteristics of mora), Hungarian (mora-timed), Levantine (mora-timed), and Madurese (syllable-timed).

Ham (2001), beginning with the place of articulation, notes that it is a widely observed cross-linguistic tendency that closure duration decreases as the point of oral constriction along the vocal tract becomes less anterior. He also predicts that if moraic primacy is valid, the place effect on closure duration should be smaller in geminates than in doubled consonants. Ham (2001) measured the percentage differences in the values of mean closure duration between stops in adjacent places of articulation in order to set off differences in speaking rate, and averaged the absolute values of differences. Consider Figure 5, below:

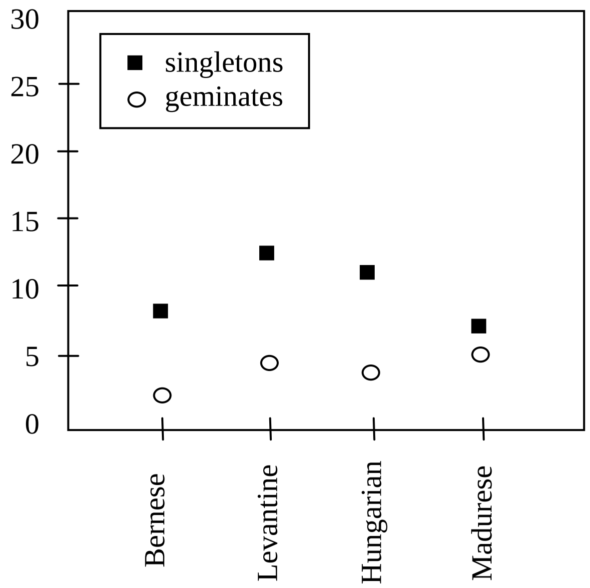


Figure 5. Mean absolute percentage differences in singleton and geminate stop closure duration conditioned by place of articulation (Ham, 2001: 216).

The size of the effect for place of articulation was measured in terms of the value F and percentage of variability in closure duration coupled with place of articulation was measured in terms of the value r^2. The regression analysis, as seen in Figure 5, shows that there is a large percentage difference between geminates and doubled consonants: geminates systematically show much less effect than doubled consonants. He also notes that Madurese which is a syllable-timed language[32] shows less prominence in the asymmetry. The moraic representation of geminates is least robust in Madurese (The reason will be discussed later).

With respect to the effect of voicing on closure duration, a widely observed cross-

[32] Note that Madurese is the only "true" syllable-timed language, while Bernese is syllable-timed but featuring the phonological characteristics of mora, Hungarian and Levantine are mora-timed languages.

linguistic tendency is that voiced stops are shorter than their voiceless counterparts. Ham (2001) again predicts, following moraic primacy, that the mean percentage differences in voiced and voiceless geminate stops will be smaller than those in voiced and voiceless doubled consonant stops. In this case, Bernese is excluded since voiced stops do not exist in this language. Consider the result, shown in Figure 6:

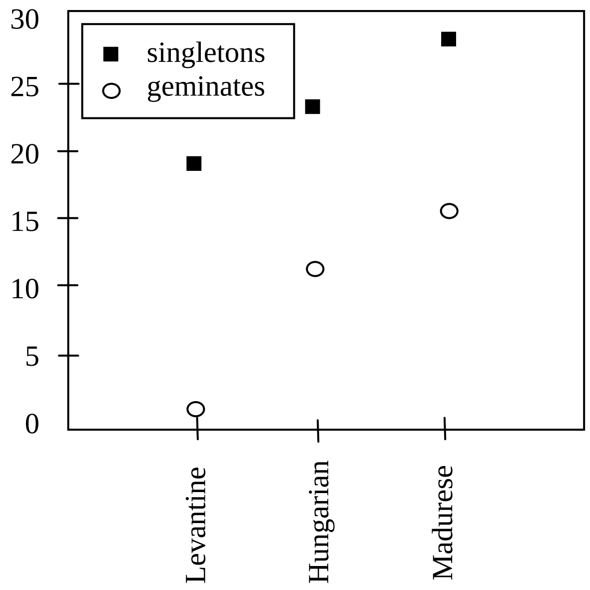
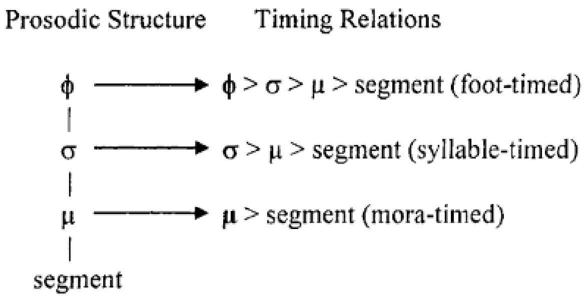


Figure 6. Mean absolute percentage differences in singleton and geminate stop closure duration conditioned by voicing (Ham, 2001: 217).

As identified in Figure 6, geminates systematically show much less difference than doubled consonants, supporting the hypothesis. In both cases of place of articulation and voicing on closure duration, geminates show smaller differences than doubled consonants in support of moraic primacy blended with a moraic view of geminates.

Ham (2001) also asserts that the durational stability effects are least robust in Madurese compared to the other three languages (Bernese, Levantine and Hungarian) because the role of mora is the most minimal in Madurese. In syllable-timed Madurese, mora does not play a central role in phonological processes. On the other hand, in Madurese, phonological processes are mostly relevant to syllable: the temporal distance is equal between syllable peaks, and other phonological processes such as minimum word requirements and stress assignment are tied to syllable. Geminates in Madurese are also underlyingly moraic, but compared with other mora-timed languages, the relationship between mora and timing is less prominent. Consider the schematic illustration, as shown in (54):

(54)



As (54) shows, in syllable-timed Madurese, syllables take precedence over moras in phonological processes, resulting in the less direct relationship between mora in the phonology and timing in the phonetics. Moras, on the other hand, take precedence over segments, showing the durational stability effects. In contrast, mora-timed languages give priority to mora timing. Thus, syllable duration can be adjusted to mora count.

4.3.5 English /l/-rhymes

In order to provide additional phonetic evidence that supports the analysis of liquid rhymes in American English as trimoraic, Lavoie and Cohn (1999) compared the phonetic realization of heavy and superheavy syllable and tested the prediction that the duration of trimoraic rhymes will be longer than that of similar bimoraic ones. Results are summarized in Figure 7:

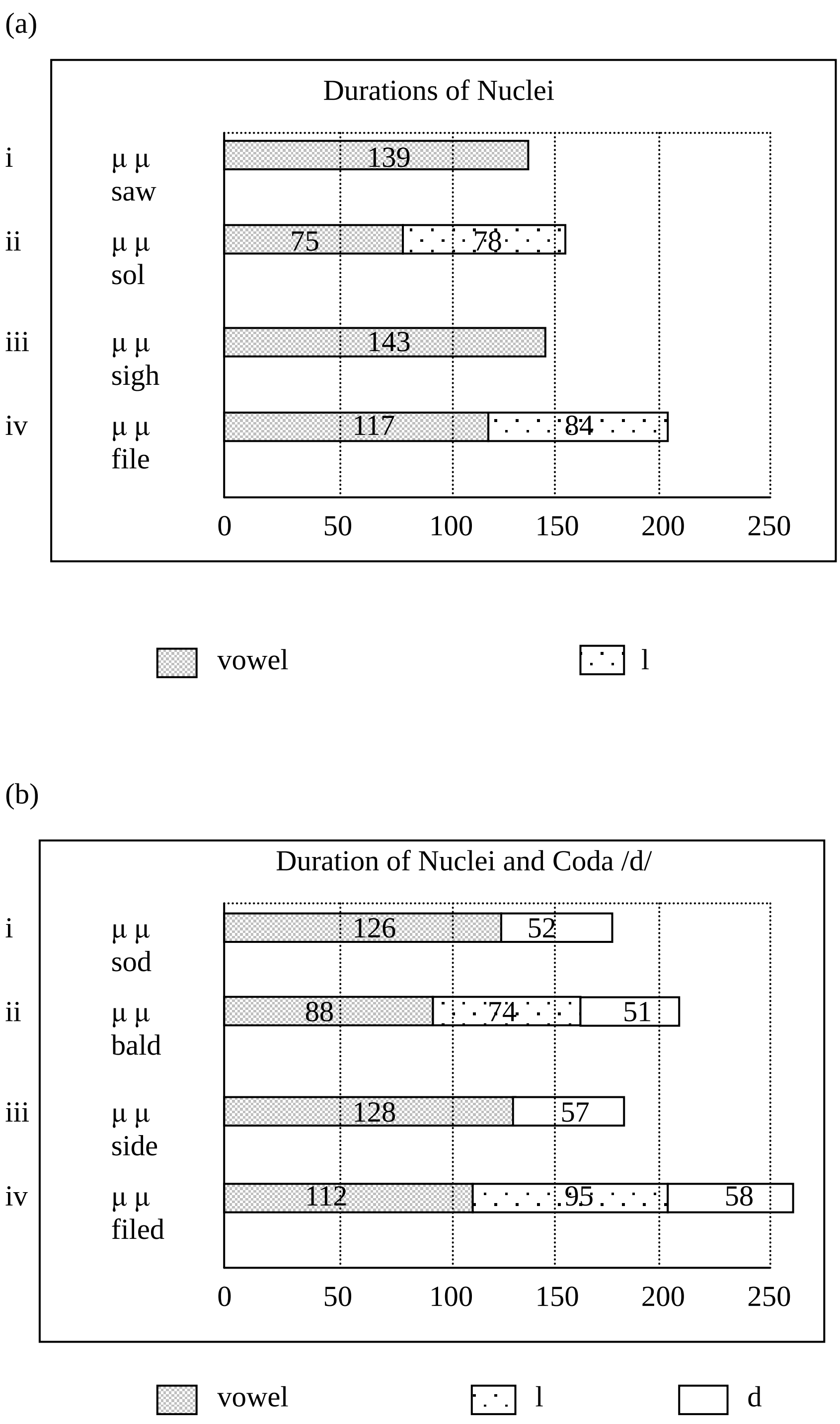


Figure 7. Results for rhyme duration of /l/ rhymes (a) vowel + /l/ and (b) vowel + /l/ + /d/ (Cohn, 2003: 95)

As illustrated in Figure 7(a), rhymes consisting of a diphthong + /l/ are systematically longer than those consisting of a low vowel, a low vowel + /l/, or a diphthong. The bar (i) indicating a low vowel exemplified by *saw* shows that its rhyme duration is 139 ms. The bar (ii) indicating a low vowel + /l/ exemplified by *Sol* shows that its rhyme duration is about 153 ms. The bar (iii) indicating a diphthong exemplified by *sigh* shows that its rhyme duration is 143 ms. Finally, The bar (iv) indicating a diphthong + /l/ shows that its rhyme duration is 201 ms. No significant differences in the rhyme durations are observed in the cases of the rhymes consisting of a low vowel, a low vowel +/l/, or a diphthong which are all considered to be bimoraic. In contrast, significant differences are observed in the case of a diphthong + /l/ which is argued to be trimoraic, compared to the other bimoraic rhyme durations. As can be seen in Figure 7(b), a /d/ is added to the rhymes in order to compare the effect of a liquid /l/ with that of a non-liquid consonant /d/. Unlike a liquid /l/, a non-liquid /d/ contributes constant duration (about 55 ms) to the rhymes, showing the duration of /d/ is irrelevant of moraic structure. These results provide support to the view that moraic structure in the phonology is systematically manifested in the phonetics.

So far, syllable weight has been discussed focused on mora. First, phonological arguments have been reviewed and then phonetic evidence has been shown. Among them, I have focused on the mora-sharing representation. Again, in Chapter 5, I will focus on the mora-sharing word-final consonant because this is very important to analyze the results of the experiments I have conducted in Chapter 6 and support my conclusion in Chapter 7.

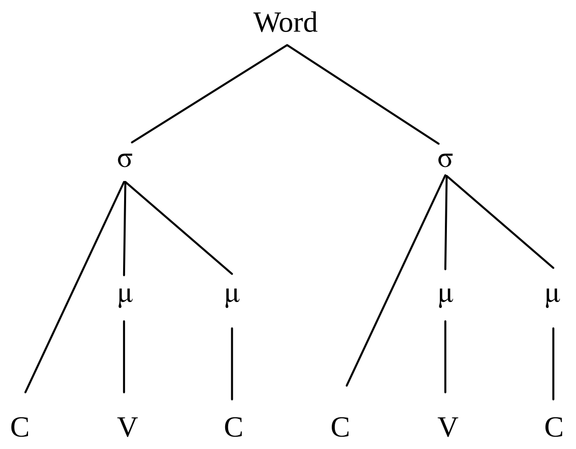
Chapter 5

The Weight of Word-final Syllables

5.1 CVC weight asymmetry

There are many languages, including English, that exhibit an asymmetrical status of CVC syllables: CVC is considered heavy in non-word-final position but light in word-final position. In these languages, non-word-final CVC attracts stress, while word-final CVC does not, showing asymmetrical stress assignment. In moraic theory, codas are treated as weight-bearing. Thus, it needs to be modified to account for the weight difference between a non-word-final CVC syllable and a word-final CVC syllable. In addition to this, there is some more evidence against the final-coda view. The first evidence can be found in syllable typology. In languages which allow a word-final consonant to occupy a syllable coda, a coda is expected to be found in word-internal position. However, some languages such as Luo and Yucatec Maya allow the CVC sequence word-finally but do not allow word-internal consonants. Conversely, there are some languages such as Italian and Telugu in which the CVC sequence appears only word-internally, disallowing word-final coda (Harris & Gussmann, 1998). Second, a word-internal consonant plays a certain role in a preceding vowel, while a word-final consonant does not. In English, for example, closed-syllable shortening only occurs word-internally, not word-finally. In other words, the preceding vowel of a word-internal coda is shortened, while a vowel preceding a word-final counterpart is not. Thus, the view of syllable structure as in (1) below does not provide a satisfactory explanation because it cannot account for the asymmetry between the word-internal coda and the word-final consonant:

(1)

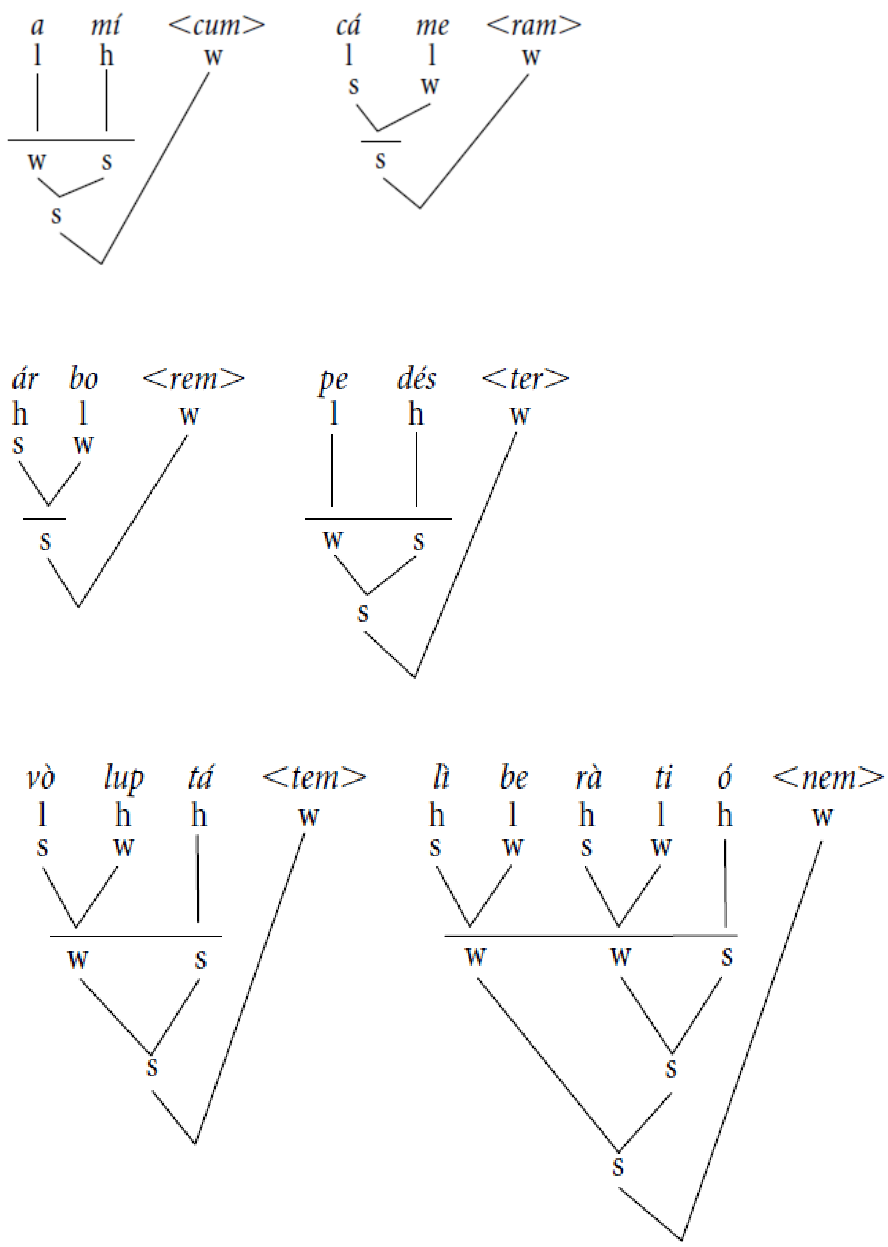


In this section, three possible solutions will be discussed: word-final C extrametricality, catalectic final syllable, and word-final mora-sharing C. Word-final C extrametricality (Hayes, 1995), and catalectic final syllable (Kiparsky, 1991) are based on phonological solutions, while word-final mora-sharing C (Lunden, 2011, 2013) is based on phonetic motivations. In this section, word-final mora-sharing C will be briefly introduced and more about phonetic motivations will be discussed in section 5.2.

5.1.1 Word-final C extrametricality

One possible phonological solution to a CVC weight asymmetry is to treat the word-final consonant as extrametrical (Hayes, 1995). In Latin polysyllabic words, the final syllable is completely discounted for metrical structure, rejecting stress on the final syllable, as illustrated in (2), where *l* and *h* stand for light and heavy, *s* and *w* for strong and weak, respectively, and extrametrical syllables are indicated by angled brackets:

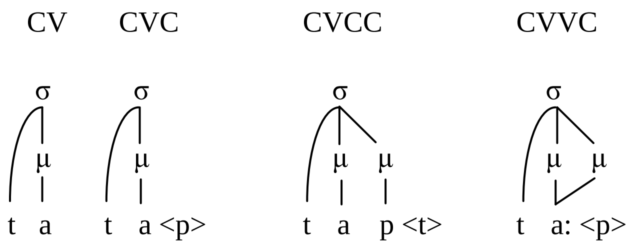
(2)



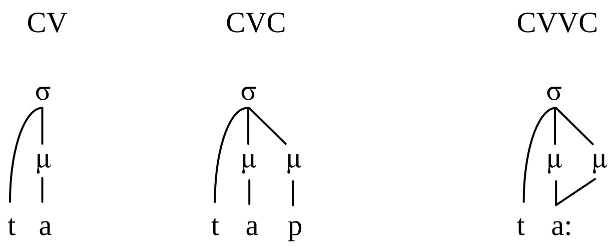
In moraic theory, CVC behaves as heavy (bimoraic) in non-final position but as light (monomoraic) in final position. Only consonants are treated as extrametrical. Thus, final syllables with a long vowel are always bimoraic and heavy. Now, let us compare the structures of final syllables and non-final syllables, as sketched out in (3):

(3)

a. Final Syllables

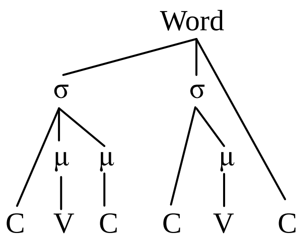


b. Non-final Syllables



As illustrated in (3a, b), CV is treated as light in both final and non-final position. In contrast, a final CVC syllable as seen in (3a) is treated as monomoraic and thus light since the final consonant is not assigned a mora, being treated as extrametrical, while a non-final CVC syllable as seen in (3b) is bimoraic, the final consonant being assigned a mora by Weight-by-Position, and thus heavy. In the case of CVV, CVCC, CVVC, they are always bimoraic and thus heavy. In word-final C extrametricality, the final consonant is not treated as the coda of the final syllable, but directly linked to the word level, as illustrated in (4):

(4)

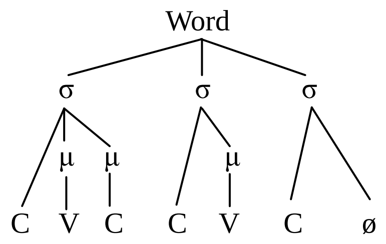


Extrametricality supports the argument that a word-final consonant cannot be treated as a coda because it behaves differently from a word-internal coda. In English, for example, a non-word-final consonant is treated as a coda, contributing to the syllable weight, while a word-final consonant is treated as extrametrical, not as a coda, thus not contributing to the syllable weight.

5.1.2 Catalectic final syllable

As the opposite of extrametricality, Kiparsky (1991), Harris and Gussmann (1998, 2002) among others propose the notion catalexis, treating the word-final consonant as the onset of a final catalectic syllable which is an abstract syllable at the end of a word. Though the final consonant is not treated as extrametrical, the syllable does not attract stress because the consonant is treated as an onset, not a coda, and its nucleus is empty. The structure can be illustrated as in (5):

(5)



As seen in (5), the final consonant is treated as an onset of the abstract syllable whose nucleus is empty. The degenerate syllable does not play a role in any metrical structure within a word domain.

5.1.2.1 Arguments against the final-coda view

Harris and Gussmann (1998, 2002) claim that the consonant of word-internal VV･C and that of word-final VVC] do not have the same status. Closed syllable shortening also provides evidence that a vowel and a following word-final consonant do not occupy the same syllable, and that thus word-final consonant is not a coda. Word-internal consonants have a preceding vowel shortened, while word-final consonants do not. It can be translated into the fact that a word-internal consonant and a preceding vowel occupy the same syllable, but a word-final consonant and a preceding vowel do not occupy the same syllable. Harris and Gussmann (1998, 2002) present the relevant evidence from English and Icelandic.

First, let us turn to the case of English. In English, a length distinction of a syllable nucleus depends partially on the status of a following consonant. This distinction is observed in word-internal consonants, but not in word-final consonants, presenting convincing evidence that word-final consonants are not codas.

In English, VV･C can appear without restrictions, but VVC･ is strictly restricted by the nature of consonants. Restrictions are as follows (Harris & Gussmann, 1998: 144, 2002: 7):

(6)

a. the C must be a fricative or a sonorant, e.g. pastry, oyster, danger, council, boulder, ancient (**beypti*, **aːkmi*);

b. if sonorant, C must be homorganic with the following onset, e.g. council, paltry (**kawnbəl*, **pɔːlbri*);

c. in the case of (b), the place is (almost) invariably coronal (**kaymbəl*, **iːmpri*).

In contrast, word-final VVC] can appear without those restrictions on the characteristic of the consonant, proving that the consonant of word-internal VV･C and that of word-final VVC] are different in status.

More evidence that word-final consonants are not codas can be found in Modern Icelandic. In Icelandic, stressed syllables must be heavy, (C)VC or (C)VV, restricting a stressed open syllable to contain a long vowel. Consider examples (Harris & Gussmann, 1998, 2002) shown in (7):

(7)

a.	**fela**	*fɛ:la*	‘hide’	**tala**	*t^{h}a:la*	‘speak’
	ráða	*rau:ða*	‘advise’	**éta**	*jɛ:t^{h}a*	‘devour’
	þola	*θɔ:la*	‘tolerate’	**yfir**	*ɪ:vɪr*	‘over’
	sími	*si:mɪ*	‘telephone’			
b.	**betri**	*bɛ:t^{h}rɪ*	‘better’	**nepja**	*nɛ:p^{h}ja*	‘cold weather’
	vökva	*vø:k^{h}va*				
c.	**panta**	*panta*	‘order (vb.)’	**senda**	*senda*	‘send’
	mæ lti	*ma^{y}ltɪ*	‘speak (pret.)’			

As seen in (7a), long stressed vowels are observed before single consonants word-internally. Note that single consonants following long vowels belong to the following syllable, thus they are not codas. As in (7b), long stressed vowels appear just before clusters of two consonants. Note again that clusters of the two consonants following long vowels are branching onsets of the following syllable. In contrast, as can be seen in (7c), vowels must be short before codas word-internally.

5.1.2.2 Arguments for the final-onset view

Harris and Gusmann (1998, 2002) argue that if a word-final consonant is considered a coda, the fact explained in (7c) becomes problematic. According to the generalization accounted for above in (7c), monosyllabic words consisting of a closed syllable is expected to contain short vowels. However, there are cases in which monosyllabic words contain long vowels before word-final consonants as in (8):

(8)

tal	t^h*a:l*	'number'	**von**	*vɔ:n*	'hope'
hæ ð	*hai:ð*	'height'	**þjóð**	*θjou:ð*	'nation'
rök	*rø:*k^h	'cause'	**bil**	*bɪ:l*	'moment'
fet	*fɛ:*t^h	'step'			

Taking the data as shown in (8) for example, Harris and Gussmann underline the need for the generalization to account for the long vowels of both t^h*a:l* and t^h*a:la*.

Despite some differences in metrical lengthening between English and Icelandic, it is clear that unlike word-internal codas, word-final consonants are not relevant to the quantity of the preceding nucleus, making more convincing the argument that word-final consonants are not codas.

Harris and Gussmann (1998, 2002) argue that word-final consonants in English should be treated as an onset, not as a coda, providing phonotactics of word-final consonant clusters and preconsonantal vowel length as convincing evidence.

Harris and Gussmann (1998, 2002) also claim that final CC] clusters are identical to internal C·C clusters based on English examples as in (9):

(9)

	Medial	Final		Medial	Final
a.	Stop-Stop		b.	Sonorant-Stop	
	chapter	**apt**		**pamper**	**damp**
	vector	**sect**		**winter**	**flint**
				wrinkle	**rink**
				filter	**guilt**
				scalpel	**scalp**
c.	Fricative-Stop		d.	Sonorant-Fricative	
	minister	**mist**		**cancer**	**manse**
	after	**raft**		**dolphin**	**golf**
	whisper	**wisp**		**whisker**	**whisk**

The final-coda and extrasyllabicity approaches view the parallel between domain-internal C・C and domain-final CC] as totally accidental. Thus, the same phonotactic regularities have to be stated twice: word-internally for internal coda-onset clusters and word finally either for double consonant codas (the final-coda view) or for a coda followed by an unsyllabified C (the extrasyllabicity view).

The same examples can be found in Modern Irish, too. Consider Irish examples as shown in (10):

(10)

	Medial		Final	
Sonorant-stop				
rp	**torpa**	'clod'	**corp**	'body'
rt	**gorta**	'hunger'	**gort**	'field'
lt	**rialta**	'regular'	**oscailt**	'open'
lk	**folca**	'flood (n. pl.)'	**folc**	'flood (n. sg.)'
rd	**garda**	'police'	**bord**	'table'
ŋg	**rangaigh**	'classify'	**long**	'ship'
Fricative-stop				
χt	**donachta**	'badness (gen.)'	**donacht**	'badness (nom.)'
st	**postaire**	'messenger'	**post**	'post'
sk	**taoscach**	'gushing'	**taosc**	'drain'

Based on the parallel between the phonotactics of internal C·C clusters and final CC] clusters in both English and Irish, Harris and Gussmann (1998, 2002) argue that a final C] is an onset of the following abstract syllable. From the viewpoint of the final-onset, the parallel between internal C·C clusters and final CC] clusters is not accidental but entirely expected. Thus, the phonotactic generalizations need to be stated only once because word-internal C·C clusters and word-final CC] clusters are syllabically identical. Then, the same syllabic representations are valid for both English and Irish. Consider the syllabic representations exemplified for the English pair *mister-mist* and Irish *gorta-gort* as illustrated in (11):

(11)

a. Internal coda-onset C•C
mister, gorta

```
     R
     |\
 O   N \      O   N
 |   |   \    |   |
[x   x     x  x   x]
 |   |     |  |   |
 m   ɪ     s  t   ɚ
 g   o     r  t   ə
```

b. Final coda-onset C•C]
mist, gort

```
     R
     |\
 O   N \      O   N
 |   |   \    |   |
[x   x     x  x   x]
 |   |     |  |
 m   ɪ     s  t
 g   o     r  t
```

5.1.2.3 Empty nucleus

In the previous subsection, it has been argued that word-final consonants are onsets, not codas. Then one question arises: Whose onsets are they? A nucleus is obligatory in a syllable, thus an onset is required to be followed by a nucleus. A possible solution is that a word-final consonant is followed by an empty nucleus which is metrically inactive.

Two arguments in favor of empty nuclei will be introduced from now on. First, the introduction of empty nuclei makes it possible to more straightforwardly analyze the word-stress assignment of many languages. For example, in Spanish, stress is typically assigned to the penultimate or the final vowel in a word, as illustrated in (12):

(12)

a.	**patáta**	'potato'	b.	**Madríd**	
	palóma	'pretty'		**jamón**	'ham'
	camísa	'shirt'		**papél**	'paper'

This observation can be generalized as follows: stress falls on the last syllable if it contains a final consonant, as in (12b); otherwise it falls on the penult, as in (12a). If we introduce a degenerate syllable that contains an empty nucleus, the C-final context in (12b) can reduce to the V-final context in (12a), making the generalization simpler: regular stress in Spanish consists in a final trochaic foot. Another example can also be found in English. Consider examples as shown in (13):

(13)

a.	**agénda**	b.	**tormént**
	magénta		**lamént**
	aróma		**cajóle**

To account for the stress assignment observed in (13), it is required to distinguish between heavy and superheavy syllables: [33] non-final stress falls on a heavy syllable as in (13a) and final stress falls on a superheavy syllable as in (13b). In contrast, the introduction of empty nuclei also makes it possible to treat a superheavy syllable as a heavy syllable followed by a light syllable. Then the generalization becomes simpler: trochaic stress falls at the right edge, irrespective of whether the weak nucleus is sounded as in *ma(génta)* or silent as in *la(méntø)*.

The other argument countenancing empty nuclei comes from epenthesis. Under a final-coda analysis, resyllabication is always required when the suffixation of -*(e)s* or -*ed* in English adds to words that end with sibilants or alveolar plosives, respectively. For example, the sibilant -*(e)s* marking the plural is not permitted in English to appear after sibilants. Thus, it must be incorporated into an epenthetically vocalized syllable by inserting a vowel between sibilants as in *kisses*, causing a stem-final consonant to be resyllabified from a coda to an onset of the following syllable. By the same token, the alveolar plosive -*ed* must also be organized into an epenthetically vocalized syllable by inserting a vowel between alveolar plosives as in *wedded*. This process compromises theoretical restrictiveness of structure

[33] Harris and Gussmann (1998, 2002) treat a syllable containing a two-consonant coda as superheavy.

preservation between input and output forms (Harris, 1994) by transforming the stem-final consonant from coda to onset and leaving the lexical source of the epenthetic position unidentified.

In contrast, under a final-onset view, resyllabification is not required because stem-final consonants are onsets of the following degenerate syllable with an empty nucleus. Consider the illustration below as in (14):

(14)

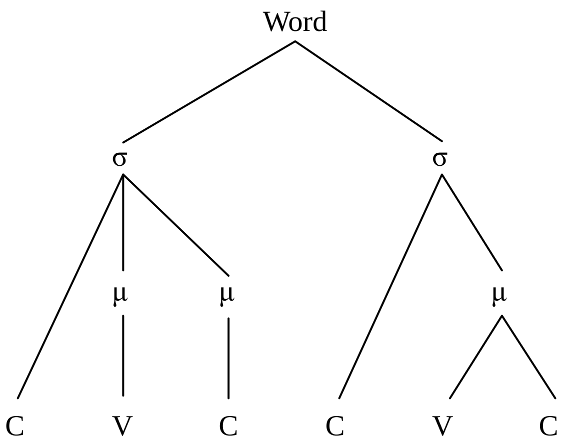
```
a.   kisses                      b.   wedded
     O N O N  O N                     O N O N  O N
     | | | |  | |                     | | | |  | |
   [[x x x x] x x]                  [[x x x x] x x]
     | | |    |                       | | |    |
     k ɪ s ɨ  z                       w e d ɨ  d
```

As can be seen in (14), no insertion of syllabic positions is required and no resyllabification is involved.

5.1.3 Word-final mora-sharing C

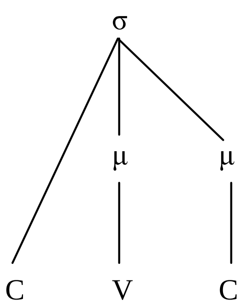
Both word-final C extrametricality and catalectic final syllable approaches treat a word-final consonant as structurally different from a word-internal coda. In other words, a word-final consonant is not included in the final non-degenerate syllable in both cases. Despite the fact that both views provide formal solutions which are very convincing, under a phonetic and perceptual point of view, the word-final consonant is pronounced as part of the final non-degenerate syllable. In order to reflect the speaker’s perception that the word-final consonant is part of the final syllable albeit it behaves differently from its counterpart of a word-internal syllable, we need to find another solution to reflect the difference in behavior between final consonants in word-final syllables and those in word-internal syllables, still keeping word-final consonant as part of the final syllable. One possible solution might be to allow the final consonant to share a mora with the preceding vowel, as sketched out in (15):

(15) Word-final mora-sharing C



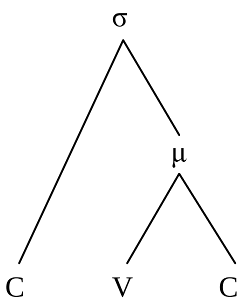
As can be seen in (15), the hierarchical structure of a word-internal CVC syllable is different from that of a word-final CVC syllable albeit they are linearly the same CVC syllables. If we look at the hierarchical structure of the word-internal CVC syllable as in (16), the syllable is treated as heavy, being assigned two moras:

(16) Word-internal syllable



This is a typical syllable structure as discussed in Chapter 4. In contrast, if we take a closer look at the hierarchical structure of the word-final CVC syllable as in (17), the syllable is treated as light, being assigned a single mora shared by the final consonant and its preceding vowel:

(17) Word-final syllable



As can be seen in (17), the word-final CVC syllable is treated as light, and the final consonant still constitutes the word-final syllable.

As discussed in 4.3, Broselow *et al.* (1997) explored three patterns of coda weight that occur in three distinct languages (Hindi, Malayalam, and Jordanian Arabic) and found a significant correlation between the weight of a syllable and the duration of its segments. Let us briefly review the result. In Hindi, the duration of a long vowel measured in an open syllable and a closed syllable is statistically the same. Thus, a VVC rhyme is significantly longer than a VC rhyme, allowing Hindi to have a three-way weight distinction. In contrast, in Jordanian Arabic with a two-way weight distinction, the duration of a long vowel in an open syllable and a closed syllable shows asymmetry: a long vowel in an open syllable is significantly longer than that in a closed syllable. Broselow *et al.* (1997) argue that a VVC rhyme in Hindi has three moras, while a VVC rhyme in Jordanian Arabic has only two moras with the second mora shared by the coda and the preceding vowel. We assume that a VC rhyme of a word-final syllable has a single mora shared by the coda and the preceding vowel as in (17). Then, a CCV rhyme of a word-final syllable is expected to be shorter than that of a word-internal syllable.

However, phonetic analysis of syllable duration by position shows that word-final rhymes have longer durations than non-final rhymes. Final lengthening explains the longer durations of word-final rhymes. Then, if final lengthening makes word-final syllables longer, how can we judge whether final syllables are originally light or heavy without the effects of final lengthening? Lunden (2006, 2011) proposes proportional increase theory of weight based on Weber's law. This will be analyzed in the next section.

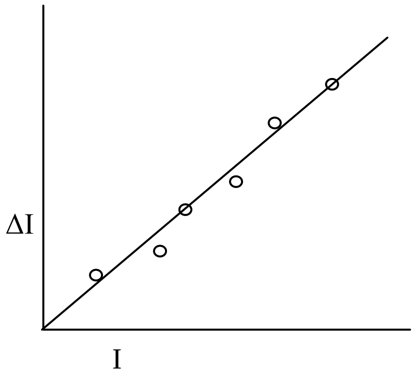
5.2 Phonetic analysis of word-final rhyme

5.2.1 Weber's law

It is worth taking a brief look at Weber's law before Lunden's proportional increase theory of weight is introduced because Lunden's proposal is based on the extended application of Weber's law to perceived syllable durations.

Weber found in 1834 that there exists the increment threshold for detecting perceived changes and that the just noticeable difference between two stimuli is proportional. For example, if you are holding a weight of 2.0 lbs and the two-pound weight is taken out of your hand and replaced with a new 2.1-pound weight, you would not notice an additional weight of 0.1 lb despite the change in a physical stimulus. However, if a two-pound weight is replaced with a new weight of 2.2 lbs, an additional weight of 0.2 lb will make you notice the change in weight. Now if you are holding a weight of 5.0 lbs, an additional weight of 0.2 lb, the weight that makes you detect the change when you hold a weight of 2.0 lbs, won't make you realize the physical change in weight. In order to make you detect any change in weight, the weight difference should be at least 0.5 lb, which is called the just noticeable difference. According to Weber's law, the ratio of the increment threshold to the back ground intensity is constant, as illustrated in (18):

(18)



ΔI: difference threshold

I: background intensity

As seen in (18), delta I over I is constant.[34] This also applies to auditory stimuli. For example, when we are in the quiet library, we are able to hear the flipping sound of books. However, when we are in the rock concert, it is quite difficult to hear even the yelling voices of people.

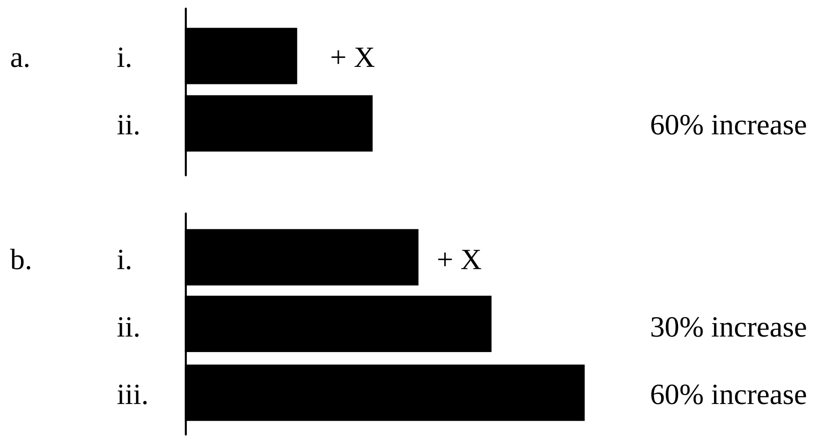
5.2.2 Lunden's proportional increase theory of weight

Lunden (2006, 2011) proposes, based on Weber's law, that a minimum proportional increase threshold is related to syllable weight. Lunden (ibid.) shows that in Norwegian, the rhymes of heavy syllables over the rhyme of a CV syllable in the same position have a consistent proportional increase. In her research, she used highly-controlled nonce words in a carrier phrase, measured rhyme durations, and compared them to a shorter, unstressed V rhyme in the same position of the word. Word-final lengthening affects raw durations,

[34] To reflect reality, the fraction is adjusted to ΔI over I+α = k. α is a constant.

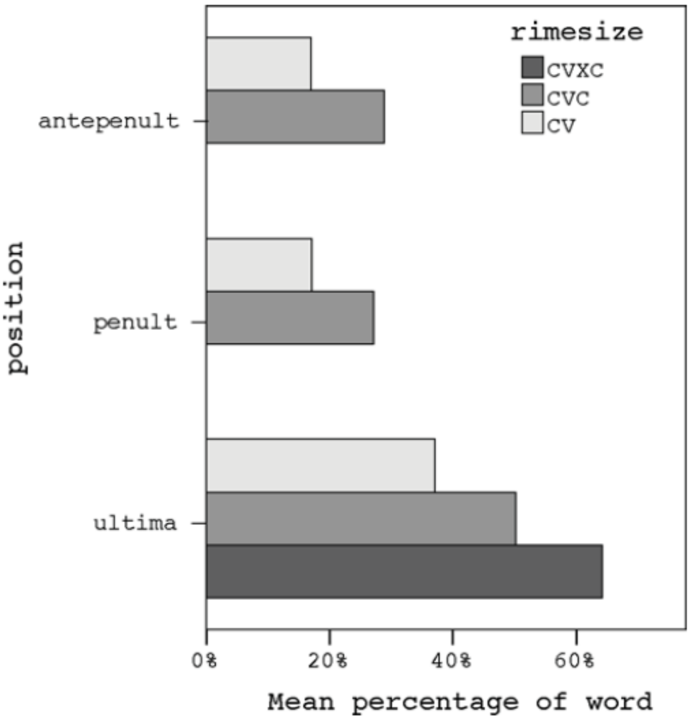
making all word-final durations longer than non-word-final counterparts. One question which arises here is whether it is possible to measure durations not affected by word position. Lunden (2006, 2011) finds that with the exception of VC rhymes, the average proportional increase of a larger rhyme over a V rhyme shows significant consistency in all positions. Word-final lengthening makes a word-final V rhyme significantly longer, resulting in a notably longer word-final syllable by applying the same proportional non-final increase. Lunden's (2006, 2011) finding is consistent with Weber's law: perceptual increase follows a scale of proportional increase, not a scale of raw increase. Consider the difference between a consistent proportional increase and a consistent raw increase, as illustrated schematically in (19):

(19) The same raw increase has a lesser effect on larger amounts (Weber's law)



As illustrated in (19), x (the same raw increase) is added to (a-i) and (b-i), resulting in (a-ii) and (b-ii), respectively. Notably, the difference between (a-i) and (a-ii) is much greater than the difference between (b-i) and (b-ii). The raw increase is the same but the proportional increase is twice as great: (a-ii) shows 60% increase compared to (a-i) while (b-ii) shows only 30% increase from (b-i). To reach the same proportional increase of (a-ii) over (a-i), (b-i) needs more raw increase. If the same proportional increase of (a-ii) over (a-i) applies to (b-i), the result should be (b-iii), not (b-ii). Lunden (ibid.) notes that this law applies to Norwegian rhyme durations. Consider rhyme/word percentage by syllable position and size, as illustrated schematically in (20):

(20) Rhyme/word percentage by syllable position and size (Lunden, 2011: 155)

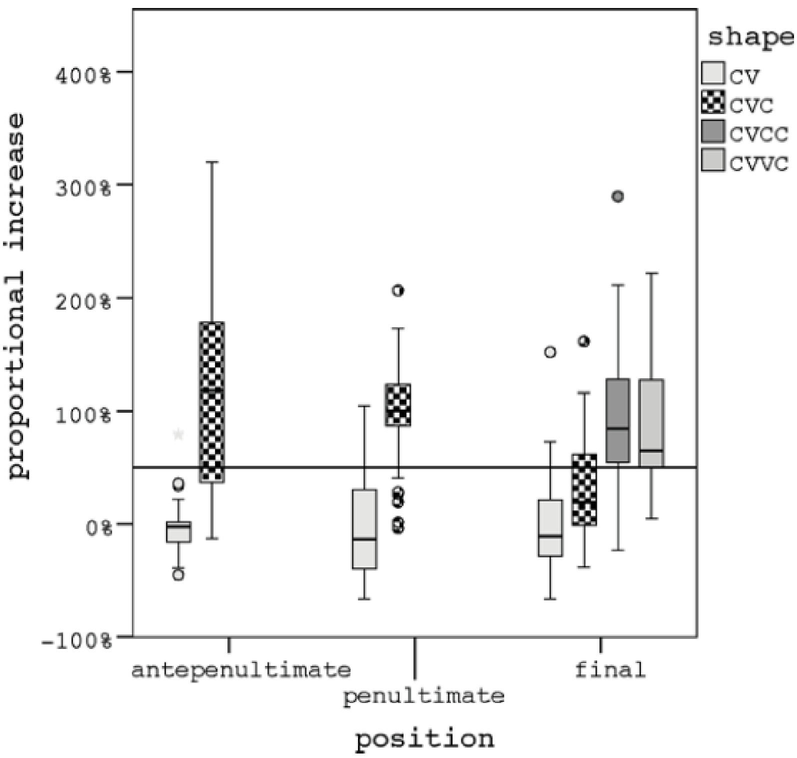


As (20) shows, a VC rhyme is strikingly different from a V rhyme in the two non-final positions (the antepenult and penult). A similar raw increase is found in the word-final position (the ultima), which fails to reach the proportional increase, so perceptional increase is much less. On the other hand, it is noted that a VXC rhyme shows a similar proportional increase over a final V rhyme that can be found between non-final VC and V.

Lunden (2011: 155) argues that "If we take the classification of weight within a language to follow Weber's law, we require that in order to be classified as heavy a syllable's rhyme to regularly reach a minimum proportional increase threshold over the rhyme of a CV syllable in the same position." Her proposal makes the correct prediction that CVC syllables will pattern as light word-finally and heavy non-finally. She also argues that if weight classifications follow a proportional increase threshold, word-final syllables are not required to be differently treated because the same weight criterion is applied across all positions.

Lunden (2011) shows that the proportional increase threshold theory of weight makes the correct prediction for word-final syllables in English: CVC syllables pattern as heavy non-finally and light word-finally like Norwegian, but CVV syllables pattern as heavy across all positions. Consider the CVC proportional increase asymmetry in English that Lunden (2011) found, as illustrated schematically in (21):

(21) CVC proportional increase asymmetry (Lunden, 2011: 156)

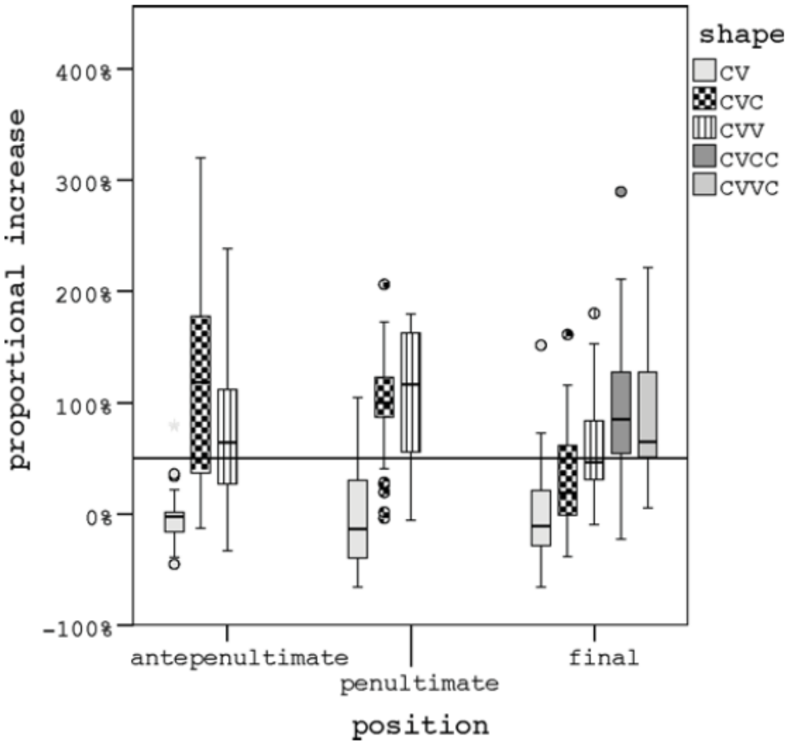


In (21), V, VC, VCC, and VVC rhyme durations are shown as a proportional increase over a V rhyme in the same position of the word. A rough estimate of the proportional increase threshold is 50 %. Notably, the proportional increase of VC rhymes shows a significant difference word-finally. The proportional increase of an antepenultimate VC rhyme is 120% on average. The proportional increase of a penultimate VC rhyme is 102%. Note that a word-final VC rhyme shows only a 36% increase.

Now, let us consider the addition of the diphthongs (CVV) in all positions, as illustrated schematically in (22):

(22) Diphthongs and the proportional increase categorization of weight

(Lunden, 2011: 157)



As seen in (22), although the proportional increase of the diphthongs over a V rhyme shows some variety, they pattern with the heavy syllables.

The proportional increase theory of weight consistently and correctly predicts for weight across all positions: Final CVC syllables pattern as light syllables and final diphthongs as heavy in English.

In Chapter 5, theories to explain the CVC weight asymmetry have been reviewed. In the next chapter, I will show and analyze the results of the experiments I have conducted to support the word-final mora-sharing consonant.

Chapter 6

The Mora-sharing Word-final Consonant and Prelexical Classification

This chapter argues that the final coda shares a mora with the preceding vowel (Broselow *et al.*, 1997; Lunden, 2006, 2011) by analyzing the results of the two experiments, and shows that the syllable plays a vital role in prelexical classification even in non-syllable timed languages like English.

As discussed in Chapter 5, the catalectic final syllable proposed by Harris and Gussmann (1998, 2002) phonologically well explains some linguistic phenomena by treating the word-final consonant as the onset of the abstract syllable. Still, it seems that if the word-final consonant is the onset of the abstract syllable with its nucleus being empty, the abstract syllable should occupy some duration, making it longer. At least, its duration should be the same as the onset. Even though phonological rules well explain some phenomena, if it is short of being impressionistic and corpus-internal, it is considered incomplete.

Lunden (2006, 2011) measures rhyme durations by using highly-controlled nonce words in a carrier phrase. The finding is that word-final lengthening affects raw durations, making all word-final durations longer than non-word-final counterparts. She proposes the proportional increase theory to explain durations not affected by word position.

Instead of Lunden's proportional increase theory, I have used pairs of words that sound like one word to hide the word-final effect and at the same time to compare the differences in the word boundary and the syllable boundary.

As discussed so far, if the word-final consonant shares a mora with the preceding vowel, the duration of the word-final consonant (coda) will be shorter than that of the onset counterpart.

In Experiment 2, prelexical classification is discussed. In a hierarchical prosodic structure, segments are at the lowest level. Therefore, segments should be the first unit to recognize the lexical representation (e.g., word). Interestingly, the syllable, rather than the segment, is important for prelexical classification (Cutler & Norris, 1988; Mehler, Dommergues, Frauenfelder & Segui, 1981; Norris & Cutler, 1988). I have also concluded by using the results of Experiments that the syllable plays a vital role in prelexical classification even in non-syllable timed languages like English.

The speech recognition process involves receiving the acoustic signals and deriving the meaning by matching the acoustic signals to lexical representations. A set of discrete meanings are stored in memory and the meanings that correspond to each acoustic signal are located in memory. However, the number of potential utterances is infinite. Therefore, complete utterances cannot be stored in memory. Instead, discrete units are stored and utterances may be constructed from the lexical unit.

In order to access the meaning of any lexical unit, a recognizer must be aware of where the unit begins because speech signals are continuous. There are two possible solutions to deciding where the lexical unit begins: matching the arbitrary speech signals to stored acoustic templates and undertaking prelexical classification.

The first solution is mostly adopted by machine recognition systems. In this approach, exhaustive search of all representations are required, which makes accessing lexical representations cumbersome. For simplicity's sake, as its details are not relevant here, I will ignore details and turn to the second solution (see Holmes, 1984 for more information).

The second solution is adopted by psychological models of speech recognition. In this approach, to achieve greater efficiency, a recognizer undertakes a prexical classification of the speech signal, using a relatively small set of units of which any lexical units will be composed. For example, the speech could be analyzed into phonetic segments, syllables, feet, or words. If the speech is classified into phonetic segments, then the phonetic segments are used to decide where the lexical unit initiates. This process is still cumbersome but much simpler than attempting to match all the arbitrary speech signals to stored acoustic templates, and access attempts can be ruled out when the sequence of segments postulated to initiate the lexical unit, say, word, is phonetically illegal in the language (e.g., [vn]).

A more efficient classification would be based on syllables. The experimental evidence seems to favor the syllable as the smallest spoken unit (Norris & Cutler, 1988: 541). This procedure will considerably reduce wasted access attempts.

In this chapter, I conducted research and analyzed the acoustic sounds to find out how a recognizer or listener psychologically and cognitively identifies the inputs. In Experiment 1, I showed a native speaker of English the list of eight sets of words that consist of two words that sound like one word (e.g., *rock it*), and required him to read them at a normal speed. I did not explain the purpose of the experiment because the explanation might affect the speaker. After that, I showed the list of eight words that sound the same as two words (e.g., *rocket*). I phonetically analyzed the difference between the word boundary and the syllable boundary.

In Experiment 2, thirty six participants were asked to listen to the recording of eight sets of words that sound like one word and required them to identify the acoustic sounds. For example, participants are asked to listen to *let us*, and I documented how they identify the acoustic sound: *let us* or *lettuce*. The list of words is shown in (1):

(1)

a.	list 1	b.	list 2
	rock it		rocket
	let us		lettuce
	two lips		tulips
	kill her		killer
	I scream		ice-cream
	catch up		ketchup
	sand witch		sandwich
	mark it		market

6.1 Experiment 1

Experiment 1 has been conducted to shed light on the status of the word-final consonant. Through this experiment, I will show the duration of the word-final consonant is shorter than that of the onset, supporting the word-final mora-sharing consonant (coda).

6.1.1 Method

Eight pairs of words were chosen as shown in (1). An English native speaker was asked to read them at a normal and natural speed. The list 1 (1a) was first given to the participant because if the list 1 is given after the list 2 (1b), the probability that he recognizes the two sets sound the same is higher, and the speaker's psychology might be affected, resulting in unnatural readings. For example, if the participant reads *let us* after reading *lettuce*, he might recognize *let us* and *lettuce* sound the same. Thus, it is more likely that he might put pause between words or try to pronounce more clearly to distinguish *let us* from *lettuce*.

Praat (version 6.1.04 released on September 28th in 2019) was used to analyze the acoustic sounds.[35] The proportional duration of the final consonants of the first word of the pair of two words (for example the /t/ of *let* in *let us*) in (1a) was measured and compared with that of the initial consonants of the second syllable of words in (1b).

6.1.2 Results

All C/TD's are shorter than the O/TD counterparts (here, C/TD stands for the duration of the coda over the total duration and O/TD stands for the duration of the onset over the total duration) and there is no significant difference between O/TD and O/TD in the case of *two lips* and *tulips*, as shown in (2):

(2)

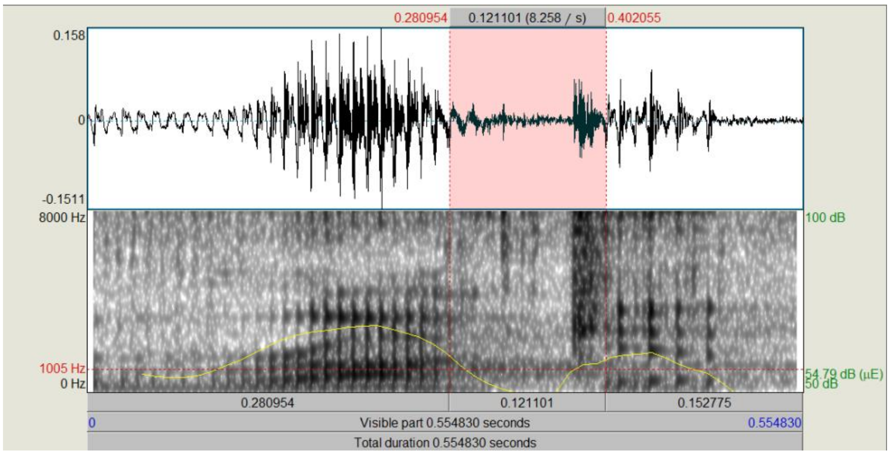
Rock it vs. rocket	C/TD = 0.218	O/TD = 0.259
Let us vs. lettuce	C/TD = 0.040	O/TD = 0.049
Two lips vs. tulips	O/TD = 0.057	O/TD = 0.056
Kill her vs. killer	C/TD = 0.111	O/TD = 0.159
I scream vs. ice-cream	O/TD = 0.307	O/TD = 0.356
Catch up vs. ketchup	C/TD = 0.155	O/TD = 0.184
Sand witch vs. sandwich	C/TD = 0.154	O/TD = 0.182
Mark it vs. market	C/TD = 0.042	O/TD = 0.056

[35] Praat is a free phonetic analyzing software and available at http://www.fon.hum.uva.nl/praat/.

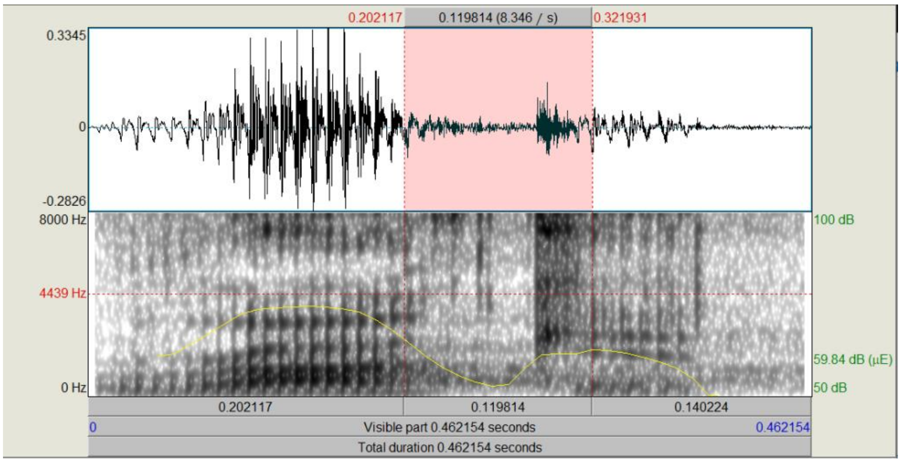
Consider the spectrograms and wave forms analyzed by Praat in detail, as shown in (3):

(3) rock it vs. rocket

a. rock it



b. rocket

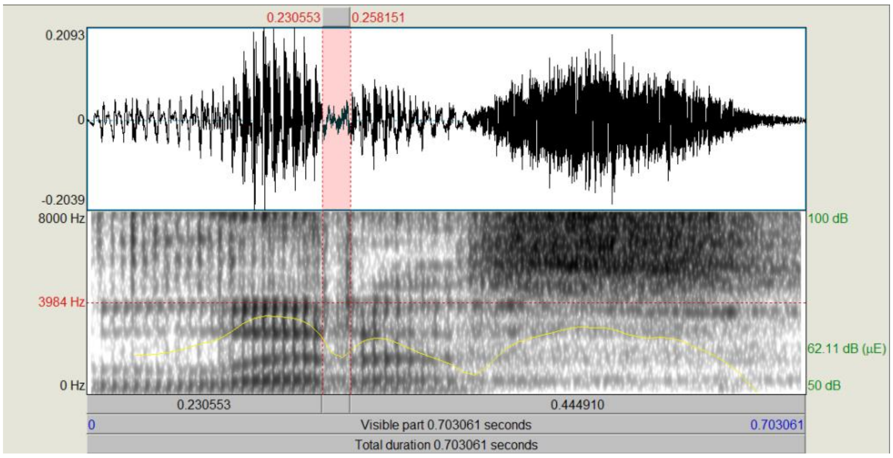


The total duration of *rock it* is 0.555 seconds and the duration of the coda (/k/) of the first word is 0.121 seconds as seen in (3a). Thus, the ratio of the total duration to that of the coda of the first word is 0.555:0.121. C/TD = 0.218.

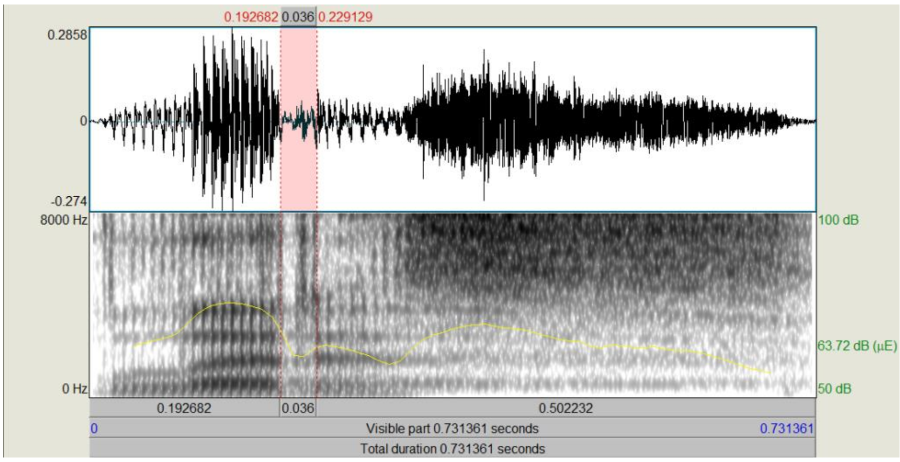
The total duration of *rocket* is 0.462 seconds and the duration of the onset (/k/) of the second syllable is 0.120, resulting in the ration of the total duration to that of the onset of the second syllable is 0.462:0.120. O/TD = 0.259.

(4) let us vs. lettuce

a. let us



b. lettuce

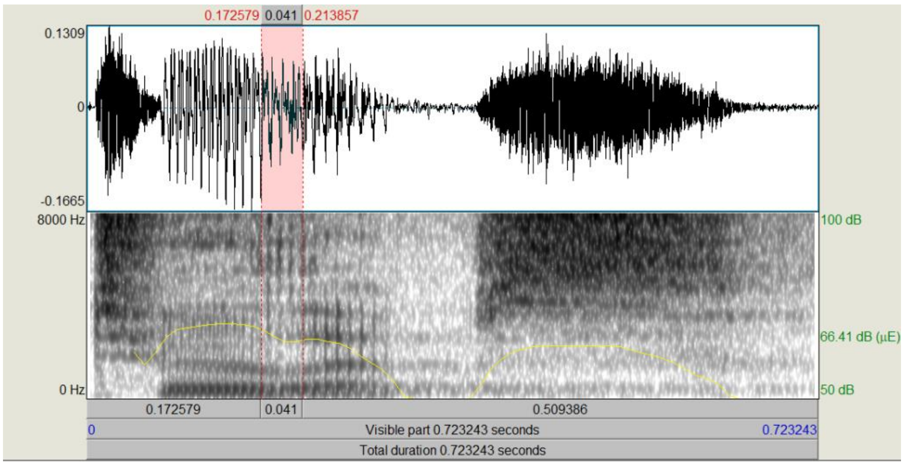


The total duration of *let us* is 0.703 seconds and the duration of the coda (/t/) of the first word is 0.028 seconds as seen in (4a). Thus, the ratio of the total duration to that of the coda of the first word is 0.703:0.028. C/TD = 0.040.

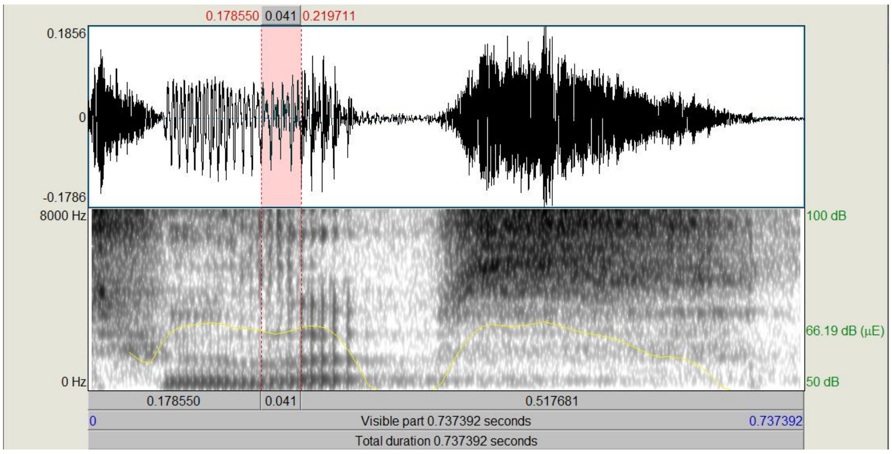
As seen in (4b), the total duration of *lettuce* is 0.731 seconds and the duration of the onset (/t/) of the second syllable is 0.036, resulting in the ration of the total duration to that of the onset of the second syllable is 0.731:0.036. O/TD = 0.049.

(5) two lips vs. tulips

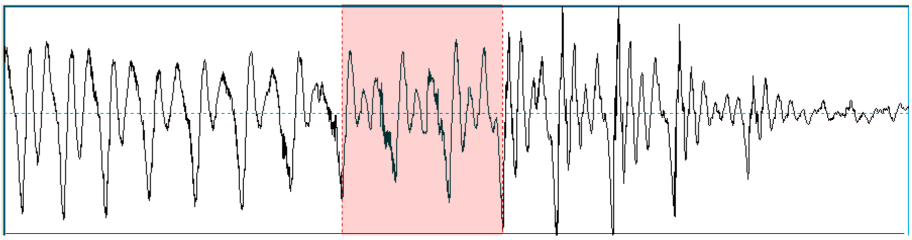
a. two lips



b. tulips



c. liquid /l/ in two lips



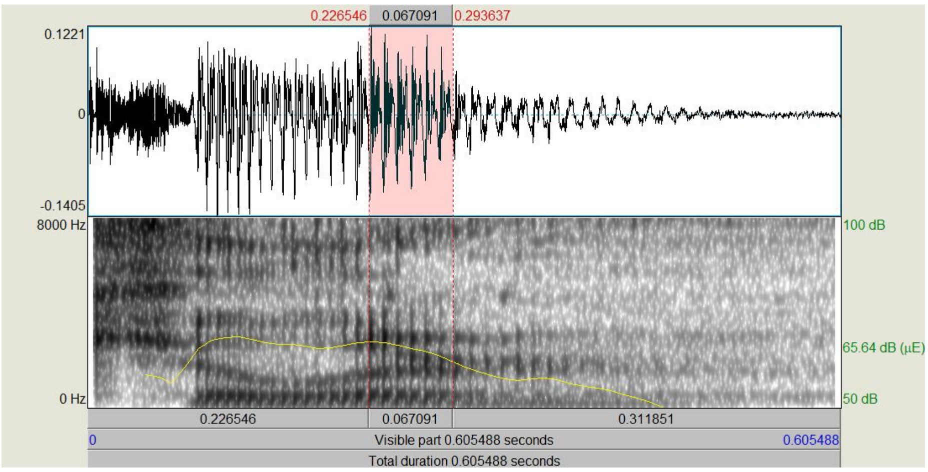
In this case different from other cases, /l/ in both *two lips* and *tulips* is the onset. The total duration of *two lips* is 0.723 seconds while the duration of the onset (/l/) of the second word is 0.041 seconds as seen in (5a). Thus, the ratio of the total duration to that of the coda of the first word is 0.723:0.041. O/TD = 0.057.

The total duration of *tulips* is 0.737 seconds and the duration of the onset (/l/) of the second syllable is 0.041, resulting in the ration of the total duration to that of the onset of the second syllable is 0.737:0.041. O/TD = 0.056.

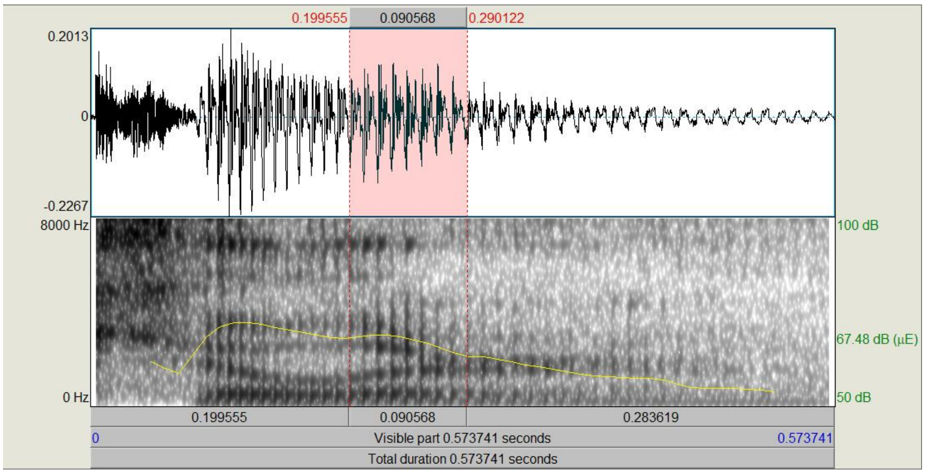
Interestingly, unlike other consonants, liquid /l/ shows a similar pattern as vowels. As seen in (5a,b), liquid /l/ shows formants like vowels. In addition, as seen in (5c), the sound wave of liquid /l/ looks like that of vowels.

(6) kill her vs. killer

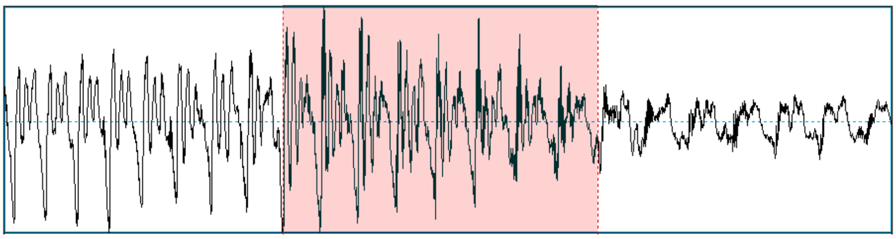
a. kill her



b. killer



c. liquid /l/ in kill her



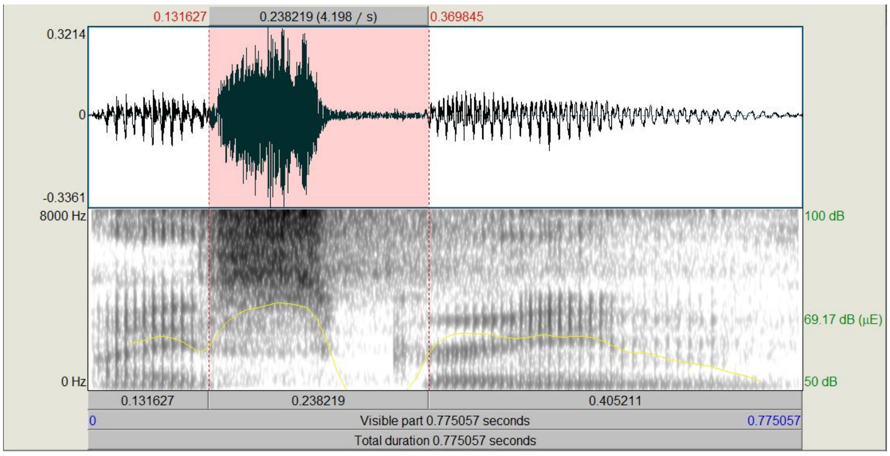
The total duration of *kill her* is 0.605 seconds and the duration of the coda (/l/) of the first word is 0.067 seconds as seen in (6a). Thus, the ratio of the total duration to that of the coda of the first word is 0.605:0.067. C/TD = 0.111.

The total duration of *killer* is 0.574 seconds and the duration of the onset (/l/) of the second syllable is 0.091, resulting in the ration of the total duration to that of the onset of the second syllable is 0.574:0.091. O/TD = 0.159.

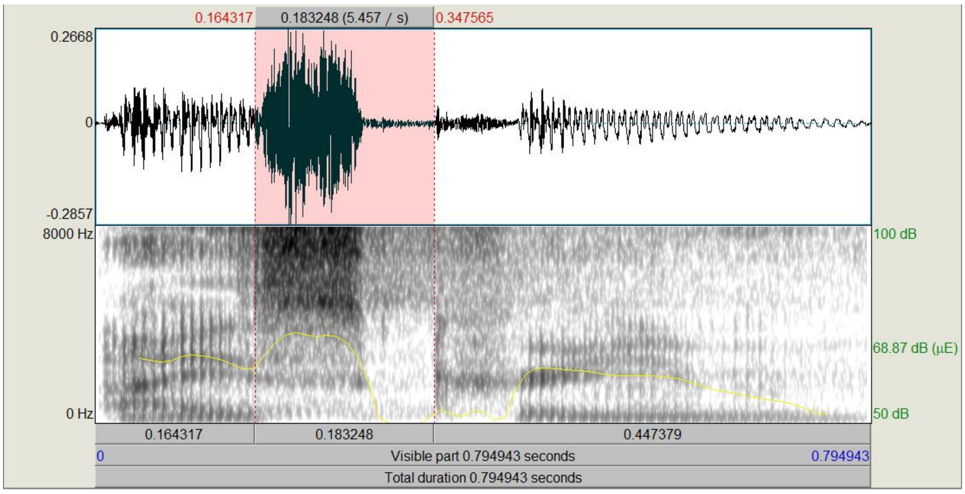
Consider the sound wave of the liquid /l/ as in (6c). As explained before in (5c), its pattern looks similar to that of vowels. This means that liquid /l/ has the feature of vowels.

(7) I scream vs. ice-cream

a. I scream



b. ice-cream

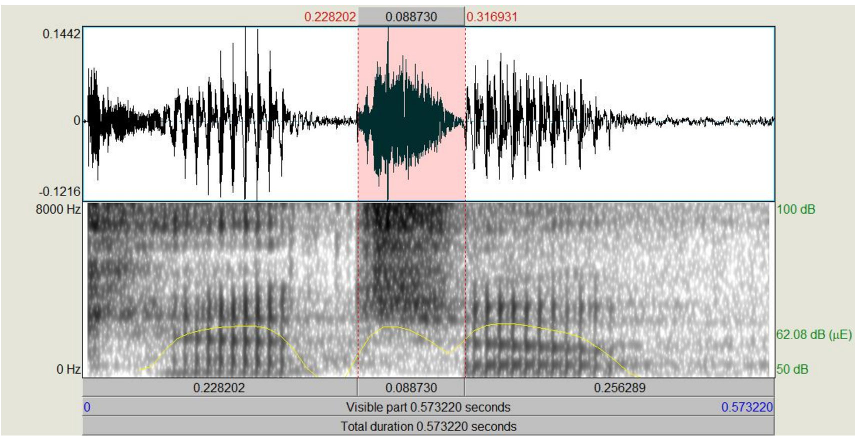


The total duration of *I scream* is 0.775 seconds and the duration of the onset (/s/) of the second word is 0.238 seconds as seen in (7a). Thus, the ratio of the total duration to that of the coda of the first word is 0.775:0.238. O/TD = 0.307.

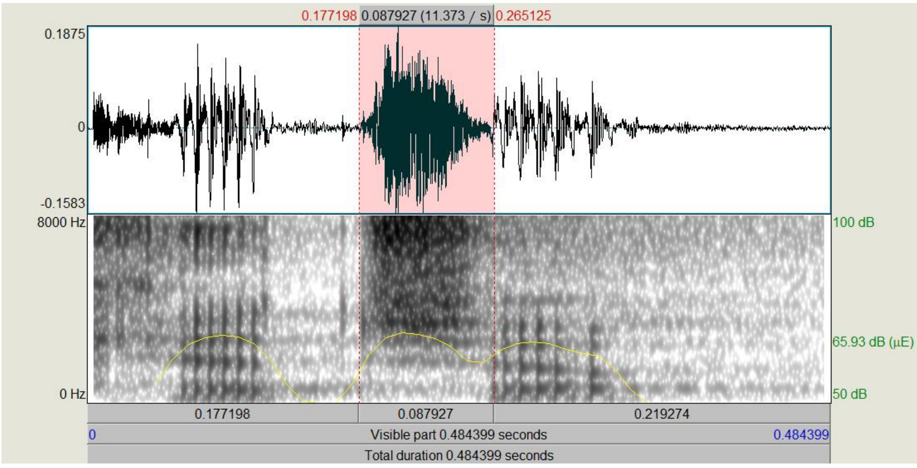
The total duration of *ice-cream* is 0.795 seconds and the duration of the coda (/s/) of the first syllable is 0.183, resulting in the ration of the total duration to that of the onset of the second syllable is 0.795:0.283. O/TD = 0.356.

(8) catch up vs. ketchup

a. catch up



b. ketchup

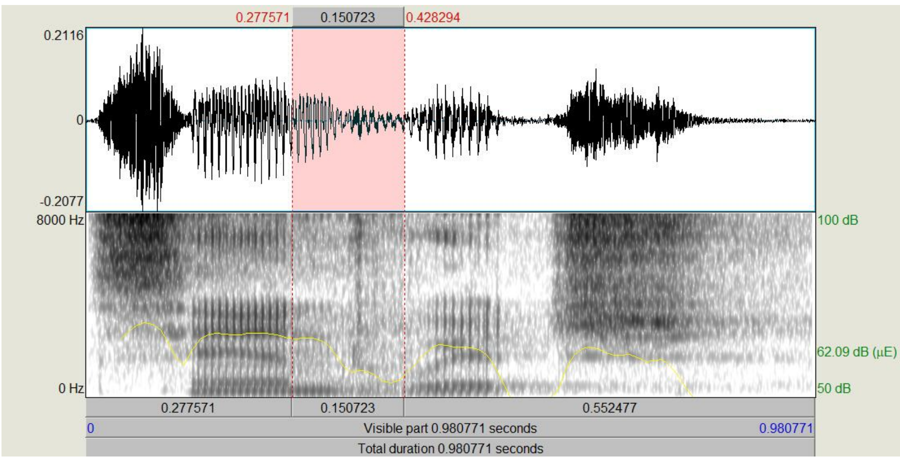


The total duration of *catch up* is 0.573 seconds and the duration of the coda (/ʧ/) of the first word is 0.089 seconds as seen in (8a). Thus, the ratio of the total duration to that of the coda of the first word is 0.573:0.089. C/TD = 0.155.

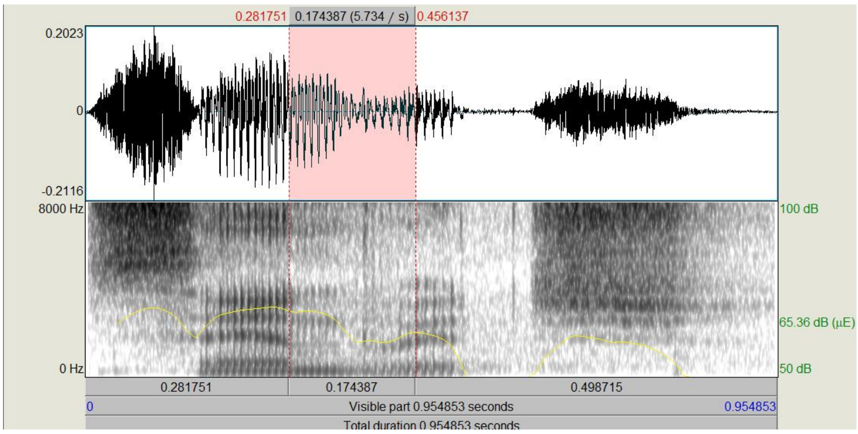
The total duration of *ketchup* is 0.484 seconds and the duration of the onset (/ʧ/) of the second syllable is 0.089, resulting in the ration of the total duration to that of the onset of the second syllable is 0.484:0.089. O/TD = 184.

(8) sand witch vs. sandwich

a. sand witch



b. sandwich

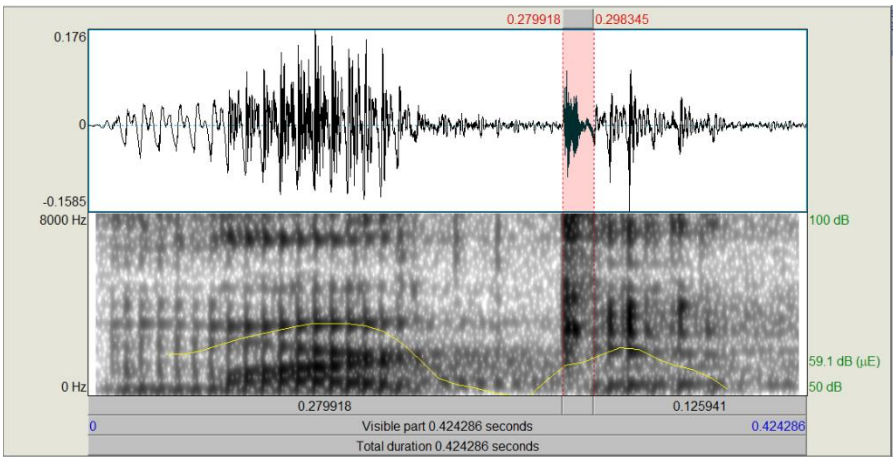


The total duration of *sand witch* is 0.981 seconds and the duration of the coda (/nd/) of the first word is 0.151 seconds as seen in (8a). Thus, the ratio of the total duration to that of the coda of the first word is 0.981:0.151. C/TD = 0.154.

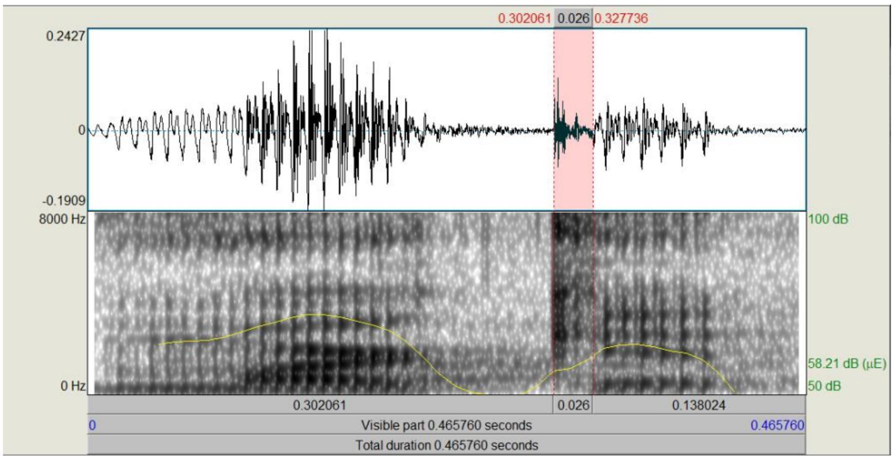
The total duration of *sandwich* is 0.955 seconds and the duration of the coda (/nd/) of the first syllable is 0.174, resulting in the ration of the total duration to that of the onset of the second syllable is 0.955:0.174. O/TD = 0.182.

(10) mark it vs. market

a. mark it



b. market



The total duration of *mark it* is 0.424 seconds and the duration of the coda (/k/) of the first word is 0.018 seconds as seen in (10a). Thus, the ratio of the total duration to that of the coda of the first word is 0.424:0.018. C/TD = 0.042.

The total duration of *market* is 0.466 seconds and the duration of the onset (/k/) of the second syllable is 0.026, resulting in the ration of the total duration to that of the onset of the second syllable is 0.466:0.026. O/TD = 0.056.

6.1.3 Discussion

In all cases, the onsets of the second syllables of one-word readings are longer than the codas of the first word-final syllables, and there is no significant difference between the duration of the onset of the second word and that of the onset of the second syllable.[36] . If shortened C/TD is the result of the phonetic effect, the /l/ in *two lips* should be shorter than the /l/ in *tulips*. This can be translated as the coda of the word-final syllable becomes longer by being affected by word-final lengthening. When two words combines, the coda of the first word-final syllable is no longer affected by final lengthening. This also means that the longer

[36] Note that in the case of *two lips* and *I scream*, the word-initial onsets are measured and compared to the onsets of the second syllables of one-word readings, *tulips* and *ice-cream*, respectively.

duration of the word-final coda is not derived from mora assignment but final lengthening. Therefore without the effect of final lengthening, the word-final syllable should be considered light with single mora assigned only to nucleus.

6.2 Experiment 2

6.2.1 Method

Thirty six English native speakers participated in Experiment 2. The responses to the test items were inspected first. They were requested to listen to the recording of list 1 (*rock it*, *let us*, *two lips*, *kill her*, *I scream*, *catch up*, *sand witch*, *mark it*) as in (1a) and write down as they recognize without any context. Then, statistics were shown.

6.2.2 Results

Most participants identified two-word readings as one-word readings. Consider the results below as shown in (11):

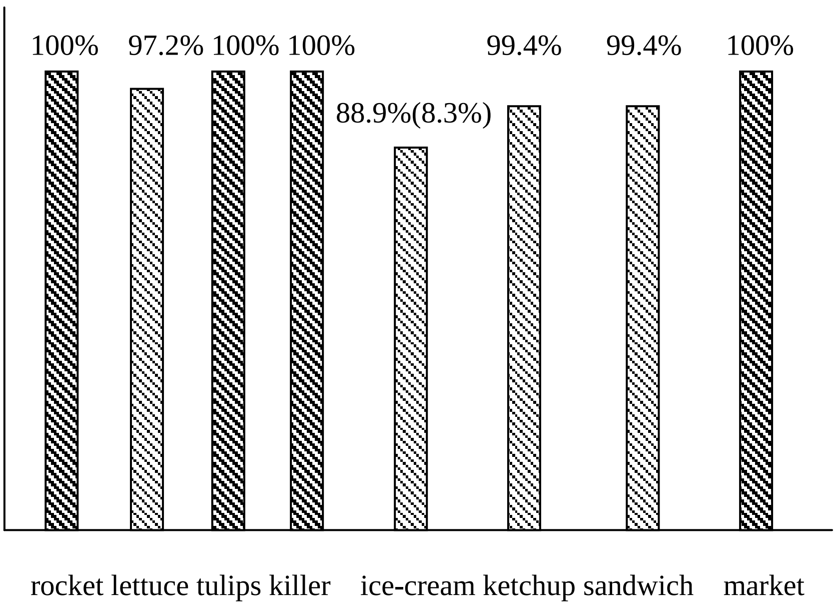
(11)

a.

No.	word list	the number of participants who perceived the item	percentage
1	rocket	36	100%
	rock it	0	0%
2	lettuce	35	97.2%
	let us	1	2.8%
3	tulips	36	100%

	two lips	0	0%
4	killer	36	100%
	kill her	0	0%
5	ice-cream	29	80.6%
	I scream	4	11.1%
	ice-cream (I scream)	3	8.3%
6	ketchup	34	94.4%
	catch up	2	5.6%
7	sandwich	34	94.4%
	sand witch	2	5.6%
8	market	36	100%
	mark it	0	0%

b.



One notable exception (still 80.6% of participants detected it as one-word reading) is that in the case of *I scream*, the greater number of participant identified it as the two-word reading compared with other two-word readings.

It can be noted that the wave forms of *I scream* and *ice-cream* are different, as seen in (7), compared to the wave forms of other pairs of words that show similar wave forms. The reason is that the stress falls on the second word (*scream*) whereas the stress falls on the first word of the pairs in other examples. I noticed that when recording the list 1, a speaker places the stress on the second word of *I scream*. I did not interrupt for mainly two reasons. First, spontaneity is important. Second, I wanted to see the result when the stress falls on the second words. This will be discussed in 6.2.3 below.

6.2.3 Discussion

There is some evidence that the syllable functions as a basic perceptual unit. Mehler *et al.* (1981) show that matching the target specification with the syllabification of the target word facilitates syllable-monitoring responses. Consider *balance* and *balcony*. They both begin with the same three segments, *bal-*. However, there exists the difference in the prosodic structure between the two words. The first syllable of *balance* is *ba-*, not *bal-*. On the other hand, *bal-* is the first syllable of *balcony*. The target *ba* is identified faster than the target *bal* in *balance* because the target *ba* constitutes the syllable. By the same token, the target *bal* is detected faster than the target *ba* in *balcony* because the target *bal* constitutes the syllable.

There is also evidence that listeners tend to consider strong syllables as word-initial and weak syllables not as word-initial (Taft, 1984). For example, when the first syllable is strong and the second syllable is weak, one-word readings like *lettuce* were chosen more often than two-word readings like *let us*. In contrast, when the first syllable is weak and followed by the strong syllable, two-word readings like *in vests* were identified faster than one-word readings like *invests*.

However, as the results of the experiments show, even when the weak syllable is followed by the strong syllable, one-word readings like *ice-cream* is detected faster than two readings like *I scream* (80.6 % chose *ice-cream* and 8.3% chose both *i-cream* and *I scream*. Only 11.1 % chose *I scream*).

Listeners identify the target faster when the target matches the syllabication (Mehler *et al.*, 1981). However, Cutler *et al.* (1983, 1986) argue that the syllabification effect does not hold in English, explaining the differences in the phonology of French and English. The syllabification effect is reliable in French because French is a syllable-timed language. In contrast, it is not reliable in English because English is a stress-timed language. Nevertheless, the results show that the syllable is the major unit of perception in English even though English is sensitive to stress.

Experiment 2 also shows that syllables tend to be detected and responded to faster than words when given two words that sound like one word. In other words, one-word readings (e.g., *killer*) are chosen much more often than two-word readings (e.g., *kill her*).

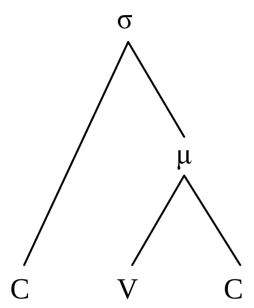
I postulate that if the word-final is treated as an onset of the abstract syllable with an empty nucleus, listeners identify words faster than syllables when analyzing the recording of a pair of two words because the final abstract syllable functions as a psychological and cognitive barrier that distinguishes words. Not only sparse abstract representations but also fine-grained phonetic information consists of lexical representations (Cohn, 2010). Therefore, phonetic information on the abstract syllable must be stored in memory and reflected in lexical representations in some ways.

The results of Experiment 2 show that the word-final coda and the word-initial onset are perceived as the same unit. For example, both *rock it* and *two lips* are identified as *rocket* and *tulips*, respectively. Consider the difference in the prosodic structure between *rock it* and *two lips*. The consonant /k/ of *rock it* is the coda of the first word whereas the consonant /l/ of *two lips* is the onset of the second word. However, listeners identified both consonants as the onset of the second syllable of *rocket* and *tulips*. This proves that the word-final coda functions differently from the word-internal coda.

6.3 General discussion

We now turn to the question of how the asymmetry between the word-internal coda and the word-final coda can be accounted for. Weightless coda consonants share a mora with preceding vowels while vowels and weight-contributing consonants have their own mora (Broselow *et al.*, 1997). As seen in Experiment 1, the durations of all word-final consonants are shorter than those of their counterpart onsets. This can be translated as the word-final consonants share a more with preceding vowels. Therefore, the hierarchical structure of the word-final CVC syllable should be diagrammed as in (12):

(13) Word-final syllable



As (13) illustrates, the word-final CVC syllable is treated as light, but the final consonant still constitute the word-final syllable, sharing a mora with a preceding vowels. As proposed by Broselow *et al.* (1997) and Lunden (2011), the syllable is treated as light, being assigned a single mora shared by the final consonant and its preceding vowel.

Mora contributes to syllable weight, and the presence or the number of moras can be counted by the length of segments. This dissertation asserts that the length of the word-final consonant is shortened because it shares a more with the preceding vowel. In other words, the word-final consonant's sharing a mora with the preceding vowel results in decreasing its weight. This argument reinforces weight sensitivity that links stress assignment to syllable weight. Weight sensitivity is constrained to the word-final syllable not only in English but also in many other languages. In other words, the word-final syllable is involved in stress assignment. This dissertation also indirectly supports the language-universal preference of the position of stressed syllables (word-initial > prefinal > final).[37] This is the language-universal preference of stress assignment, but it is meaningful that this dissertation supports the preference by analyzing the experimental data.

This dissertation also supports that in CVC.CVC, stress falls on the penult syllable, not on the ultimate syllable because syllable weight is different, showing the positional asymmetry discussed in this dissertation that syllable weight depends on the position of the syllable in the word. In addition, this weight difference explicitly shows Weight to Stress Principle (WSP).

The word-final syllable is the language-universally not preferred position for stress assignment in part because the word-final coda shares a mora with the preceding vowel, reducing the weight of the word-final syllable, and as a result, the word-final syllable is not heavy enough to attract stress.

The arguments in this dissertation serve as the justification of Non-finality (No foot is final in PrWd)[38] that has traditionally been argued. In order for stress to fall on the word-final syllable, the word-final syllable should be included in the foot. In this case, there is a possibility that the word-final syllable becomes metrically active, and that it can be assigned stress. However, the word-final syllable is not heavy enough to attract stress because the word-final coda shares a mora with the preceding vowel. Therefore, the word-final syllable cannot be parsed to the foot.

As the results of Experiment 2 show, even though English is considered a stress-timed language, syllables are still important for prelexical classification. In other words, stored representations would be in syllabic form. Mehler *et al.* (1981) present direct evidence

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[37] A > B means that A is preferred to B.
[38] It is used as a constraint in OT.

that humans detect syllable-sized targets significantly faster if the target is the same as the actual syllabification of human speech. However, Mehler *et al.* (1981) ran their experiment in French. French is a syllable-timed language while English is a stress-timed language. As a result, there exist differences in the phonology of French and English. Shown in this dissertation is that despite the differences in the phonology of syllable-timed languages and stress-timed languages, the syllable plays an important role as prelexical classification.

The results of the cognitive experiment of the so-called *mark it vs. market* uttered in casual speech mode show that listeners perceive is as one word with rare exception. This is because in casual speech mode, listeners cannot perceive the difference in the syllable length caused by the word-final consonant's sharing a mora with the preceding vowel. This result seems to derive from the fact that listeners perceive the speech signal as continuous. In other words, phonological hypothesis of mora sharing can be overridden in casual speech mode.

Prelexical classification also proves that the existence of syllable has been important in phonetics and phonology.

Chapter 7

Conclusion

In this dissertation, I have discussed the prosodic structure with special reference to syllable weight. Now, brief summaries of each chapter will be provided, and finally the conclusion will be drawn.

In Chapter 2, three different views on the relation between phonetics and phonology are discussed. The first view is that phonology is abstract and categorical while phonetics is concrete and continuous. Therefore, there exists the complete division between phonology and phonetics. In the abstract phonological analysis, phonetic facts are excluded. For example, Fudge (1967) phonologically analyzed the Hungarian vowels. In the Hungarian language, vowel harmony is important. There are no high back unrounded vowels in the vowel system of the Hungarian language. A front vowel /i/ can be attached to the stem with front vowels as in /keze-i/. In rare cases, however, a front vowel /i/ is attached to the stem with all back vowels as in /doboza-i/. Fudge (1967) phonologically argues that the corresponding high front unrounded vowels, /i/ and /i:/ fill the gap of the high back unrounded vowels. The second view is phonetics and phonology can be unified into one single module. For example, Flemming (2001) applies the constraint-based analyses to phenomena involving phonetic details. Flemming (2001) has found that the relation between F2(C) and F2(V) is highly linear. The third view is that phonetics and phonology are conditionally interfaced. Polarized view cannot be the best way to enhance our understanding of the nature of human language (Cohn, 2010). Experimental paradigms are required to control for details of phonological structure. Thus, a so-called hybrid methodology is required to explain the relationship between phonological components and phonetic components (Beckman & Kinstone, 1990). The post-nasal devoicing phenomenon is not consistent in languages (Hayes, 1999). English shows phonetic post-nasal voicing patterns but English speakers maintain the phonemic contrast of /p/ with /b/ after a post-nasal consonant, whereas in Ecuadorian Quechua, the post-nasal voicing effect is marked as phonological. In phonology, high vowels [i, u] are considered identical to glides [j, w], respectively. However, glides are phonetically different from high vowels in two ways: dynamics and constriction degree (Catford, 1988; Ladefoged & Maddieson, 1996; Padgett, 2008).

In Chapter 3, the syllabic structure is briefly reviewed by accepting the syllable as an essential phonological constituent. Phonological rules and constraints are sensitive to the syllable. First, the glottalization occurs in the syllable final position. The /t/ in *atlas* is glottalized, whereas the /t/ in *attraction* is not. Second, plosives are aspirated in the syllable-initial position. The /t/ in the second syllable of *potato* is aspirated as [t^h]. Third, phonotactic constraints are based on syllable phonotactics. The sequences of segments like /nstr/ in *instruct* is possible because the syllable boundary divides /nstr/ as /ɪn $ strʌkt/. Next, the theories on the syllabic structure are reviewed. The sonority theory has at least four unsolved problems: First, *hidden aims* consists of three syllables, whereas *hid names* two syllables. However, the sonority theory describes both as two syllables. Second, the sonority theory does not show the position of syllable boundaries (e.g., *aroma* and *phonology* as *a.ro.ma* and *pho.no.lo.gy*, not as **ar.om.a* and **phon.ol.og.y*). Third, the sonority theory cannot account for the maximum number of phonemes within a syllable or the possible string of phonemes (e.g., /pljaʊlmp/ is possible in the sonority theory). Finally, when /s/ is followed by a voiceless stop /p, t, k/, the sonority theory cannot correctly predict the number of syllable (e.g., *sticks* is a monosyllabic word, but the sonority theory shows that it contains three sonority peaks). The CV tier, a timing unit, better explains the phonological representation (Clements & Keysr, 1983). There are three types of argument for the CV tier: templates, unassociated slots, and compensatory lengthening. First, templates form independent morphemes in Arabic (McCarthy, 1985). In Arabic, vowels, as a conjugation and a verbal aspect, are inserted nonconcatenatively to the root of a verb that consists only of consonants.

Second, Clements and Keyser (1983) take liaison and *h-aspiré* in French as an example to support the need of unassociated slots. Finally, compensatory lengthening provides convincing evidence for the existence of the CV tier. If a segment is deleted, the time it took is still preserved. Nevertheless, there are two phenomena that the CV tier fails to account for. First, compensatory only occurs when segments in the rhyme are deleted, and never occurs when segments in the onset are deleted. Second, the location of the word stress is sensitive to segmental composition of the rhyme with segments in the onset being irrelevant. There is a need to introduce mora. In this chapter, mora is briefly introduced and will be discussed in detail in the next chapter.

In Chapter 4, syllable weight and the role of mora are discussed in detail through phonological arguments and phonetic evidence. Hyman (1984, 1985) and McCarthy and Prince (1986) propose moraic theory of prosodic tier structure. Katada (1990, 2014) provides evidence for mora, drawn the Japanese language game *Shiritori* 'hip-taking'. For example, [budo:] can be followed by [origami], whereas [budo:] cannot be followed by [do:butu]. Languages have different syllabic structures. Some languages, including English, have the onset-rhyme asymmetry. Elements in the rhyme have mora while those in the onset do not have mora. This asymmetry can be accounted for by moraic theory. No mora is assigned to the onset. One mora is assigned to a short vowel. Two moras are assigned to a long vowel or a diphthong. The moraic status of postvocalic consonants (coda) is language-specific. In languages with Wight-by-Position (Hayes, 1989) including English, single mora is given to the coda. Monomoraic syllables are treated as light and bimoraic syllables heavy. Phonological arguments and phonetic evidence are introduced with focus on mora.

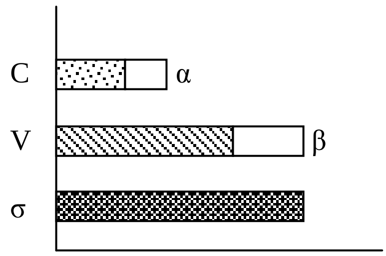
In Chapter 5, three main theories that explain the CVC weight asymmetry between word-internal and word-final syllables. Word-final C extrametricality (Hayes, 1995) does not treat a word-final consonant as a coda because it behaves differently from a word-internal coda. A word-final consonant is directly linked to the word. Catalectic final syllable (Kiparsky, 1991) treats a word-final coda as the onset of the abstract syllable. Word-final mora-sharing C (Broselow *et al.*, 1997; Lunden, 2011) views the word-final consonant sharing a mora with the preceding vowel.

In Chapter 6, the results of the experiments show that all word-final consonants are shorter than the onset counterparts of the second syllable, proving that the preceding vowel's mora is shared by the word-final coda. In addition, it is shown that listeners tend to use the syllable as prelexical classification.

Finally, two-fold conclusions are drawn in this dissertation: First, the word-final coda shares a mora with the preceding vowel, supporting the word-final mora-sharing consonant (Broselow *et al*., 1997; Lunden, 2011). Second, the syllable plays a vital role in prelexical classification even in non-syllable timed languages like English.

Phonetic duration is correlated with moraic presence. The duration of the segments with two moras is twice longer than that of the segments with single mora. Since no-moraic consonants also have their own duration, segmental duration is also important. In other words, segmental and prosodic durations amount to physical duration (Broselow *et al.*, 1997; Ham, 2001). Consider (1) below:

(1)



In (1), a preceding vowel is sharing a mora with a postvocalic consonant. Therefore, the duration of the mora should be the same as that of the vowel and the consonant. As can be seen in (1), the raw duration of the vowel and the consonant is much longer than that of the mora. In order to match the duration of the shared mora, proportional deletion occurs in both the vowel and the consonant. Consider the equation, as shown in (2):

(2)

a. $\sigma < C + V$

b. $\sigma = (C - \alpha) + (V - \beta)$

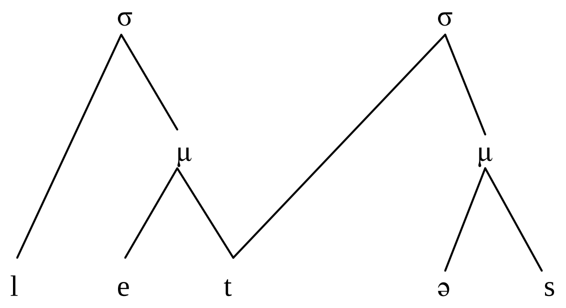
c. $\beta = C - \alpha$

Here, α and β stand for the deletion of duration. Since the total raw duration of C and V is longer than σ, the total raw duration of C and V should be deleted to some degree to match the duration of σ. Proportional deletion applies to C and V. Since V has one mora, V should be equal to σ. Therefore, $\beta = C - \alpha$. In sum, we can see that C becomes shorter as much as α and V becomes shorter as much as β or $C - \alpha$.

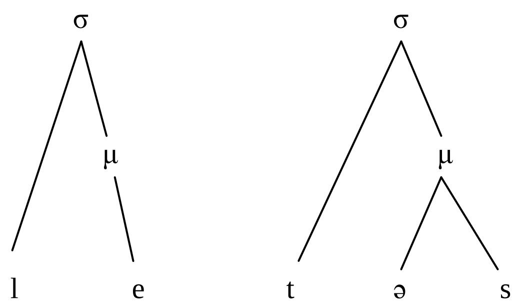
Now, let us compare the difference in the internal structure between *let us* and *lettuce*, as shown in (3):

(3) The difference in the hierarchical structure between *let us* and *lettuce*

a. let us



b. lettuce



As seen in (3a), since the postvocalic consonant /t/ is the coda of the word-final syllable, it shares a mora with the preceding vowel /e/. According to Onset First Principle, it is also linked to the onset of the second word. In (3b), on the other hand, the consonant /t/ is the onset of the second syllable. The onset /t/ of the second syllable preserves it own segmental duration, whereas the postvocalic consonant /t/ (the mora-sharing coda of the word-final syllable) experiences the shortening of duration.

The mora-sharing word-final syllable suggested in this dissertation well explains weight sensitivity that has been traditionally argued (preferred syllable for stress assignment: word-initial > prefinal > final), and indirectly supports the preferred position for stress assignment. In CVC.CVC, stress usually does not fall on the ultimate syllable due to the syllable weight. The word-final syllable is not heavy enough to attract stress. This difference in syllable weight explicitly shows WSP.

Even though there exist differences in the phonology of syllable-timed languages (French) and stress-timed languages (English), the syllable is important in terms of prelexical classification. It is true that English is very sensitive to the stress. For example, stress shift occurs in the foot level. Nevertheless, in terms of prelexical classification, most listeners tend to detect the syllable first without the word boundary being ignored.

Even in the case of *I scream* (note that the stress fell on the second syllable), 80.6% of the participants detected it as *ice-cream*, and only 11.1% recognized it as *I scream*. 8.3% chose both *I scream* and *ice-cream*. It can be concluded that even in stress-timed languages like English the syllable is more important than the stress in terms of prelexical classification.

Despite the difference in syllable weight, listeners tend to perceive two-word readings as one-word readings. This is because the difference in syllable is not big enough for listeners to perceive in casual speech mode. In addition, this result derives from the fact that listeners perceive speech sounds as continuous. Prelexical classification shows that the syllable is still important in both phonetics and phonology.

In sum, in English, the word-final coda shares a mora with the preceding vowel and the syllable plays a vital role in prelexical classification with the influence of the stress being limited.

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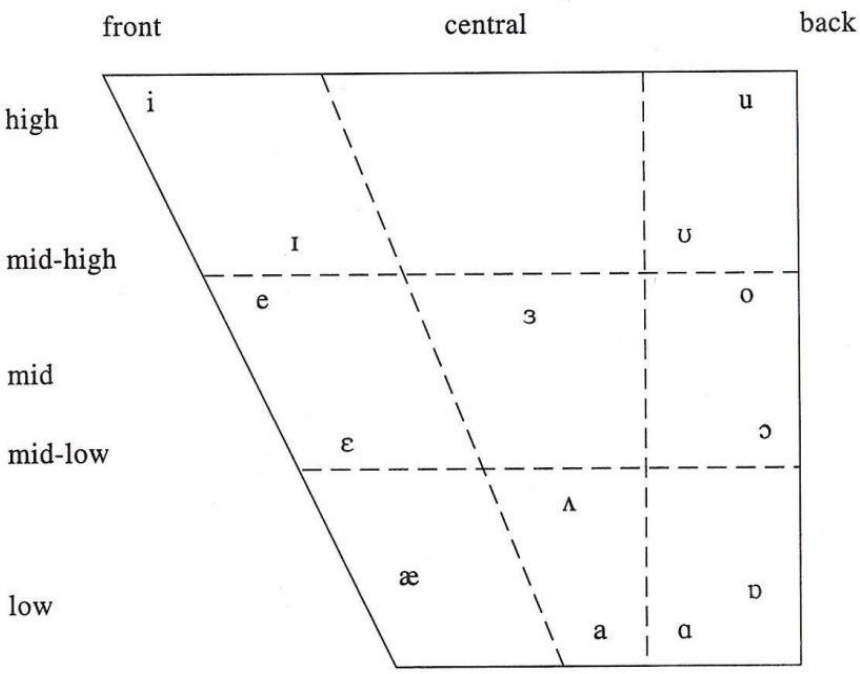
Appendix A: The English Vowel Chart (Ladefoged 2001: 36)



Appendix B: Average durations, fundamental frequencies, and formant frequencies of vowels (Hillenbrand *et al*., 1995)

		/i/	/ɪ/	/e/	/ɛ/	/æ/	/ɑ/	/ɔ/	/o/	/ʊ/	/u/	/ʌ/	/ɝ/
Dur	M	243	192	267	189	278	267	283	265	192	237	188	263
	W	306	237	320	254	332	323	353	326	249	303	226	321
	C	297	248	314	235	322	311	319	310	247	278	234	307
*F*0	M	138	135	129	127	123	123	121	129	133	143	133	130
	W	227	224	219	214	215	215	210	217	230	235	218	217
	C	246	241	237	230	228	229	225	236	243	249	236	237
*F*1	M	342	427	476	580	588	768	652	497	469	378	623	474
	W	437	483	536	731	669	936	781	555	519	459	753	523
	C	452	511	564	749	717	1002	803	597	568	494	749	586
*F*2	M	2322	2034	2089	1799	1952	1333	997	910	1122	997	1200	1379
	W	2761	2365	2530	2058	2349	1551	1136	1035	1225	1105	1426	1588
	C	3081	2552	2656	2267	2501	1688	1210	1137	1490	1345	1546	1719
*F*3	M	3000	2684	2691	2605	2601	2522	2538	2459	2434	2343	2550	1710
	W	3372	3053	3047	2979	2972	2815	2824	2828	2827	2735	2933	1929
	C	3702	3403	3323	3310	3289	2950	2982	2987	3072	2988	3145	2143
*F*4	M	3657	3618	3649	3677	3624	3687	3486	3384	3400	3357	3557	3334
	W	4352	4334	4319	4294	4290	4299	3923	3927	4052	4115	4092	3914
	C	4572	4575	4422	4671	4409	4307	3919	4167	4328	4276	4320	3788

Appendix C: Experiment 2 (Data 1)

No.	age	sex	perceived outcomes
1	30	F	rocket, lettuce, tulips, killer, ice-cream, ketchup, sandwich, market
2	40	M	rocket, let us, tulips, killer, I scream, ketchup, sand witch, market
3	28	F	rocket, lettuce, tulips, killer, ice-cream, ketchup, sandwich, market
4	36	M	rocket, lettuce, tulips, killer, ice-cream, ketchup, sandwich, market
5	43	F	rocket, lettuce, tulips, killer, ice-cream, ketchup, sandwich, market
6	28	M	rocket, lettuce, tulips, killer, ice-cream, ketchup, sandwich, market
7	37	M	rocket, lettuce, tulips, killer, ice-cream, ketchup, sandwich, market
8	36	M	rocket, lettuce, tulips, killer, ice-cream, ketchup, sandwich, market
9	33	F	rocket, lettuce, tulips, killer, ice-cream, ketchup, sandwich, market
10	37	M	rocket, lettuce, tulips, killer, ice-cream, ketchup, sandwich, market

No.	age	sex	perceived outcomes
11	38	M	rocket, lettuce, tulips, killer, I scream , catch up, sandwich, market
12	37	M	rocket, lettuce, tulips, killer, ice-cream, ketchup, sandwich, market
13	50	M	rocket, lettuce, tulips, killer, ice-cream (I scream), ketchup, sandwich, market
14	52	M	rocket, lettuce, tulips, killer, ice-cream, ketchup, sandwich, market
15	41	F	rocket, lettuce, tulips, killer, ice-cream, ketchup, sandwich, market
16	32	M	rocket, lettuce, tulips, killer, ice-cream, ketchup, sandwich, market
17	46	M	rocket, lettuce, tulips, killer, ice-cream (I scream), ketchup, sandwich, market
18	33	M	rocket, lettuce, tulips, killer, ice-cream, ketchup, sandwich, market
19	43	M	rocket, lettuce, tulips, killer, I scream, ketchup, sandwich, market
20	38	M	rocket, lettuce, tulips, killer, ice-cream, ketchup, sandwich, market

No.	age	sex	perceived outcomes
21	30	F	rocket, lettuce, tulips, killer, ice-cream, ketchup, sandwich, market
22	29	F	rocket, let us, tulips, killer, I scream, ketchup, sand witch, market
23	44	F	rocket, lettuce, tulips, killer, ice-cream, ketchup, sandwich, market
24	32	M	rocket, lettuce, tulips, killer, ice-cream, ketchup, sandwich, market
25	24	M	rocket, lettuce, tulips, killer, ice-cream, ketchup, sandwich, market
26	34	F	rocket, lettuce, tulips, killer, ice-cream, ketchup, sandwich, market
27	51	M	rocket, lettuce, tulips, killer, ice-cream, ketchup, sandwich, market
28	61	M	rocket, lettuce, tulips, killer, ice-cream, ketchup, sandwich, market
29	56	M	rocket, lettuce, tulips, killer, ice-cream, ketchup, sandwich, market
30	20	F	rocket, lettuce, tulips, killer, ice-cream (I scream), ketchup, sandwich, market

No.	age	sex	perceived outcomes
31	12	M	rocket, lettuce, tulips, killer, ice-cream, ketchup, sandwich, market
32	50	M	rocket, let us, tulips, killer, I scream, ketchup, sand witch, market
33	47	F	rocket, lettuce, tulips, killer, ice-cream, ketchup, sandwich, market
34	36	F	rocket, lettuce, tulips, killer, ice-cream, ketchup, sandwich, market
35	42	F	rocket, lettuce, tulips, killer, ice-cream, ketchup, sandwich, market
36	52	M	rocket, lettuce, tulips, killer, I scream, ketchup, sand witch, market

Appendix D: Experiment 2 (Data 2)

No.	word list	the number of participants who perceived the item	percentage
1	rocket	36	100%
	rock it	0	0%
2	lettuce	35	97.2%
	let us	1	2.8%
3	tulips	36	100%
	two lips	0	0%
4	killer	36	100%
	kill her	0	0%
5	ice-cream	29	80.6%
	I scream	4	11.1%
	ice-cream (I scream)	3	8.3%
6	ketchup	34	94.4%
	catch up	2	5.6%
7	sandwich	34	94.4%
	sand witch	2	5.6%
8	market	36	100%
	mark it	0	0%

Acknowledgements

It was a long journey.
Sometimes happy, sometimes frustrated.

When I was happy,
I saw you.
When I was frustrated,
I saw you.

When I was shivering,
When I was giving up,
You saw me, holding my hands.

You were always…
In my sight, and deep in my heart, pounding my old-aged heart.

Now, I can see, and feel,
And understand you.

I am sorry I was too late.
Please understand me.
Now, I am on the way to you.