TEL AVIV UNIVERSITY אוניברסיטת תל-אביב
The Lester and Sally Entin Faculty of Humanities
School of Philosophy, Linguistics and Science Studies
Department of Linguistics

POSITIONAL ALLOMORPHY

Pausal vs. Context forms in Tiberian Hebrew

MA thesis submitted by

ROMAN HIMMELREICH

Prepared under the guidance of

PROF. OUTI BAT-EL FOUX *Tel-Aviv University*

PROF. GEOFFREY KHAN *University of Cambridge*

September 2019

TABLE OF CONTENTS

Abstract

According to the Masoretic script, Tiberian Hebrew exhibits positional allomorphy, whereby a word has different surface structures: the *pausal* form – in phrase final position, and the *contextual* form – in phrase medial position (Revell 1981; 2012; Goerwitz 1993; Dresher 2009).

	Pausal form		*Contextual form*		
a.	kɔ.tɔ́v	כָּתָב	kɔ.táv	כָּתַב	'wrote 3MSG'
	ʔɔ.mɔ́r.tɔ	אָמָרְתָּ	ʔɔ.már.tɔ	אָמַרְתָּ	'said 2MSG'
b.	ʃɔ.mɔ́.ru	שָׁמָרוּ	ʃɔ.mə.rú	שָׁמְרוּ	'guarded 3PL'
	lé.xu	לֵכוּ	lə.xú	לְכוּ	'go! 2MPL'

In this study, the vowel alternation in these data is analyzed as vowel reduction. The main problem encountered with pause-context allomorphy is that, in some cases, the reduced vowel resides in a stressed syllable – which is typically a prominent prosodic position that resists reduction. Earlier studies have proposed different foot-types for each phenomenon – trochaic feet for stress and iambic feet for vowel reduction (Rappaport 1984). Conversely, the current analysis employs consistent trochaic foot-type for both phenomena. An elaborate scheme of phenomenon-specific syllable weight is developed, where syllable weight is grounded in a cross-linguistically attested hierarchy of positional prominence. Specifically, weight assignment varies, depending on syllable structure, the position of the vowel in the word, the position of the word in the phrase and the relevant phenomenon (stress vs. vowel reduction). Such phenomenon-specific syllable weight systems are found in numerous languages (Gordon 2006; Ryan 2019).

For the phenomenon of stress, weight assignment is sensitive only to syllable structure (CVC is heavy). Whereas for the phenomenon of vowel reduction, weight assignment is based on the following prominence hierarchy, which is grounded in perceptual and phonetic factors:

Stressed, Phrase-final > Word-final > Stressed > Unstressed, Non-final

The elevated prominence of domain-final syllables stems from cross-linguistically attested phenomena of phonetic lengthening which target the boundaries of prosodic domains (Berkovits 1994; Cambier-Langeveld 1997; Turk & Shattuck-Hufnagel 2007). Consequently, the lengthened state of vowels provides for the blocking of vowel reduction (Barnes 2006; Lindblom 1963), and ultimately to the emergence of pausal forms. The proposed analysis provides a metrically consistent account of Tiberian Hebrew stress and reduction patterns, while being based on cross-linguistically attested patterns of phonetic domain-final lengthening and vowel reduction. The presented formal analysis is couched in the framework of Optimality Theory (Prince & Smolensky 1993).

Acknowledgements

I start by expressing my deepest gratitude to Prof. Outi Bat-El Foux, for her boundless patience, wisdom, humor and keen interest in this study. For the countless hours of discussing and editing this paper, preparation for conferences and presentations, and warmhearted grooming into the academic world – my most sincere thanks. Not being a philologist, I could not have dwelt into the unfathomable diachronic knowledge so often required for the study of ancient languages like Tiberian Hebrew. For this, I want to extend my gratitude to Prof. Geoffrey Khan for his invaluable counsel and lifetime body of work on matters where my own hands were short of reach.

A special appreciation is due to those contributed both time and thought despite not having any official affiliation to this study. Many thanks to Dr. Evan-Gary Cohen, for reviews, comments, customary kindness and sharpness of mind. To Prof. Noam Mizrahi, Prof. Elan Dresher and Dr. Vincent DeCaen for insightful discussions and remarks on various occasions.

I was honored and excited to present this work, in different stages on its development, at the 2nd workshop of the Biblical Hebrew Linguistics and Philology network and the 2nd Brill's Journal of Afroasiatic Languages and Linguistics conference. I would like to extend my gratitude to both the organizers and the participants of these events for the opportunity to present and discuss my work.

A warm regard to my colleagues from the Linguistics department in Tel Aviv University Hadas Yeverechyahu, Si Berebi, Aviv Schoenfeld; and in particular to my coffee-shop writing pals Noa Handelsman and Mor Haim. To my dear language-enthusiastic friends, Jonathan Brown, Hallel Kula and Eli Asor and my mother Ella Himmelreich – thank you for listening to my ever-replenishing dilemmas and deliberations. Finally, to my beloved wife, Hava Rokhlin, thank you for your endless patience, and your soft, non-relenting support.

Morphological abbreviations

In support of the effort to standardize the linguistic annotation used to describe and transcribe Tiberian Hebrew, this paper follows the conventions suggested in Anstey (2005).

The majority of examples and glosses in this paper deal with verbal forms. The annotation scheme for marking person, gender and number is described hereby:

Person	Gender	Number
1 for 1st person	M for male	SG for singular
2 for 2nd person	F for female	DU for dual
3 for 3rd person		PL for plural

For example, 3rd person singular male is denoted by 3MSG, 2nd person plural female by 2FPL etc.

The following table lists the abbreviations used in for morphological properties other than person, gender and number.

NOM	Nominative
GEN	Genitive
IMP	Imperative
DIM	Diminutive
ADJ	Adjective
IMP	Imperative

For brevity, where the English gloss shares the same lexical category and morphological class – no explicit annotation is specified.

1 Introduction

Tiberian Hebrew exhibits positional allomorphy, whereby a word has different surface structures in different positions: the *pausal* form in phrase final position, and the *contextual* form in phrase medial position (Revell 1981, 2012; Goerwitz 1993; Dresher 2009; *inter alia*). As shown below, the alternation between these allomorphs is either in vowel quality only (1a) or in vowel quality and stress position (1b).[1]

(1) Positional allomorphy – pausal vs. context forms

	Pausal form		***Contextual form***		
a.	kɔ.ˈθ**ɔ**v	כָּתָב	kɔ.ˈθ**a**v	כָּתַב	'wrote $_{\text{3MSG}}$'
	ʔɔ.ˈm**ɔ**r.tɔ	אָמָרְתָּ	ʔɔ.ˈm**a**r.tɔ	אָמַרְתָּ	'said $_{\text{2MSG}}$'
b.	ʃɔ.ˈm**ɔ**.ru	שָׁמָרוּ	ʃɔ.m**ə**.ˈru	שָׁמְרוּ	'guarded $_{\text{3MPL}}$'
	ˈl**e**.χu	לֵכוּ	l**ə**.ˈχu	לְכוּ	'go! $_{\text{2MPL}}$'

In this study, I analyze pause-context allomorphy in the verbal system. The exhibited vowel (and stress) alternation which distinguishes the two allomorphs is attributed to different patterns of *vowel reduction* (Crosswhite 2001, 2004; Flemming 2005; Beckman 1997). This difference is attributed to differences in moraic structure, which in turn, is attributed to *phrase final lengthening* (Turk & Shattuck-Hufnagel 2007). The effect of phrase final lengthening is an increase in the phonetic duration of the final and stressed syllables of the last word in the phrase. The incurred lengthening of the stressed vowel of the phrase's rightmost word renders this vowel resistant to vowel reduction (Barnes 2006), thus producing the distinct surface form of the pausal allomorph.

The problem encountered in the study of pause-context allomorphy in Tiberian Hebrew is that in some cases, the reduced vowel resides in a stressed syllable. This is universally rare since a stressed syllable is a prominent prosodic position where segments typically resist alternation, let alone reduction. Previous studies have proposed different metrical foot-types for each phenomenon – trochaic feet for stress and iambic feet for vowel reduction (Rappaport 1984). In the present study, I employ a single foot-type for both phenomena – a trochaic foot, constructed within an elaborate system of *phenomenon-specific weight assignment* (Gordon 2006; Ryan 2019). The proposed analysis boils down to stress and vowel reduction employing different criteria for weight (*mora*)

[1] The examples provided in this study often include the following inflectional suffixes:

	1st person		2nd person		3rd person	
Singular	[-ti]	[ʔɔ.már-ti]	[-tɔ]	[ʔɔmár-tɔ]	– no affix –	
Plural	[-nu]	[ʔɔmár-nu]	[-tɛm]	[ʔɔmár-tɛm]	[-u]	[ʔɔmər-ú]

assignment. Consequently, the metrical parsing of words in phrase medial position differs from that in phrase final position – causing the different patterns of vowel reduction.

The advantage of the present analysis is that moraic weight assignment is grounded in universally attested phenomena of phonetic lengthening at prosodic domain boundaries (Wightman et al. 1992; Fougeron & Keating 1997). I propose a new account of vowel reduction and pausal allomorphy in Tiberian Hebrew, developed within the broad perspective of Generative Phonology and couched in the formal devices of the Optimality Theory (Prince & Smolensky 1993).

The study of pause-context allomorphy is based on verbs, because, as it is often the case, the verbal system is more systematic than the nominal system. The cross-linguistic evidence for the different status of nouns vs. verbs (Smith 2001) is manifested in terms of phonological privilege that excludes nouns from strict application of otherwise across-the-board constraints (Anttila 2002). Examples include deviation from templatic restrictions in Modern Hebrew (Bat-El 2008) and Arabic (McCarthy & Prince 1990), and position of prosodic heads for accent in Fukuoka Japanese (Smith 1999) and stress in Spanish (Harris 1969) and Modern Hebrew (Bat-El et al. 2019). The same is true for pause-context allomorphy in Tiberian Hebrew, which is relatively systematic in verbs but sporadic and unsystematic in nouns. For example, given the verbal alternation $[\text{kɔ.ˈθɔv}]_{\text{pause}}$ vs. $[\text{kɔ.ˈθav}]_{\text{context}}$ 'wrote $_{\text{3MSG}}$', it is expected that a structurally similar noun like /bɔsɔr/ 'meat' will alternate in the same way, i.e. $[\text{bɔ.ˈsɔr}]_{\text{pause}}$ vs. $^*[\text{bɔ.ˈsar}]_{\text{context}}$. However, the only attested form for this word is [bɔ.ˈsɔr], which is structurally equivalent to the verbal pausal form. An account of pausal phenomena in nouns would require handling various patterns of lexicalization and probably the stratification of the nominal lexicon (Ito & Mester 2008; Gouskova et al. 2015). The high number of synchronically unexplained irregularities found in nouns does not allow a comprehensive theoretical study of pause-context allomorphy within the score of this paper; therefore, the data used in this study includes verbs only (see, however, §3.6 for some inconsistencies in verbs).[2]

The thesis proceeds as follows: §2 provides the relevant theoretical background for stress assignment, vowel reduction, final lengthening, and phenomenon-specific prominence. §3 starts with background on Tiberian Hebrew, and then goes on to detail the distribution and typology of

---

[2] Diachronic studies propose that the inconsistencies exhibited by pausal allomorphy in the nominal system stem from lexicalization (see Goerwitz 1993 for discussion). Phrase-final lengthening operated in early Hebrew, where vowel length contrast was phonemic. Since Tiberian Hebrew is a VSO language, nouns and adjectives were affected by phrase-final lengthening in the vast majority of cases. In conjunction with the loss of contrastive vowel length, phrase-final variants of nouns and adjectives were lexicalized *en masse*, thus yielding Tiberian Hebrew's non-alternating nominal forms (Brockelman 1908; Bauer et al. 1922; Birkeland 1940; Aartun 1967; Beyer 1984). In contrast, the effects of phrase-finality in the verbal system have been incorporated into the phonological grammar, yielding the system of context-pause allomorphy which was analyzed in this thesis.

pause-context allomorphy. §4 contains the metrical analysis proposed in this study and §5 presents a formal analysis within the framework of Optimality Theory. Finally, §6 provides concluding remarks.

2 Theoretical background

This study analyses the allomorphy exhibited by Tiberian Hebrew pausal and contextual forms as a case of interaction between vowel reduction and phrase final lengthening.

§2.1 presents a short overview of word-level stress and its phonetic correlates. §2.2 discusses prosodic domain boundary effects, with emphasis on *Final Lengthening*. §2.3 broadly explores the phenomenon of vowel reduction and the major approaches employed to account for it in current linguistic literature. This discussion pertains to the broader question regarding the nature of the phonology-phonetics interface. §2.3.5 presents data exemplifying three distinct vowel reduction systems: Russian (§2.3.5.1), Brazilian Portuguese (§2.3.5.2) and Northern Welsh (§2.3.5.3), which are ultimately used to summarize the theoretical discussion in §2.3.6. Finally, §2.4 introduces the notion of *Phenomenon-Specific Prominence*, whereby different phenomena may treat similar syllable structures differently within a single language.

2.1 Word stress

Stress is the phonological marking prominent syllables within the prosodic word. The phonetic correlates of stress are (i) pitch contour, (ii) increased intensity, and/or (iii) prolonged duration (Hayes 1995), such that a stressed vowel differs from its unstressed counterpart in one or more of these acoustic properties. Different languages may employ varying subsets of these acoustic characterization to mark stress (Gordon & Roettger 2017). For example, stress in Modern Hebrew mainly correlates by duration, however, a peak of high pitch is shifted to the first pre-tonic syllable (Bat-El, Cohen & Silber-Varod 2019; Becker 2003). On the other hand, stress in Welsh correlates only to intensity while increased duration and pitch rise are associated with the word-final syllable (Ball & Williams 2001; Hannahs 2013).

In Gordon & Roettger's (2017) survey, 90% (65/72) of the languages feature increased duration as the most robust phonetic cue to stress. In most languages, the lengthened segment is the stressed vowel, in a few cases rhyme consonants are lengthened as well. Pitch and intensity successfully identify stress position in 73% (46/63) and 75% (39/52) of cases, respectively. Beyond their lower success rate, pitch and intensity cues were found to be methodologically problematic; pitch marks phrasal events which are not easy to isolate, while intensity measurement methods vary significantly among studies. Finally, in 86% (25 of 29) of languages, vowel quality differs as a function of stress. The correlation of stress to formant frequencies was examined – most commonly F1 (height) and F2 (backness). Typically, stressed vowels are more peripheral than unstressed vowels. In many such languages, the effect is limited to certain vowels and/or only one formant.

The present explores stress for the purposes of establishing its interaction with vowel reduction. Vowel reduction has been long known to correlate with phonetic vowel duration (Lindblom 1963; Moon & Lindblom 1994). Therefore, the following discussion refers mainly to phonetic duration, which, as noted above, is the most common and most robust cue to stress. Moreover, the interaction of stress with vowel quality alternations is elaborated below in §2.3.

2.2 Prosodic domain boundaries

Prosodic structure shapes the production of phonological units at the boundaries of prosodic domains. In the vicinity of prosodic boundaries, segments exhibit acoustic final lengthening (Klatt 1976; Wightman et al. 1992) and initial lengthening (Oller 1973), and gestures are spatially more extreme, temporally longer and further apart (Byrd & Saltzman 2003; Byrd et al. 2000; Beckman & Edwards 1992; Fougeron & Keating 1997; Cho & Jun 2000). Phrase initial and final articulatory lengthening have been observed to increase cumulatively for larger prosodic boundaries (phrase finally: Byrd & Saltzman 1998; Cho 2006; Tabain 2003; Tabain & Perrier 2005; and phrase initially: Cho & Keating 2001; Fougeron 2001; Cho 2006; Tabain 2003; Keating et al. 2004). Articulatory studies have also shown that there is less temporal overlap between articulations separated by or adjacent to a boundary, and that gestures are less overlapped across stronger boundaries (Byrd 2000; Cho 2004).

2.2.1 Final lengthening

Acoustic studies exploring the durational effects of phrase boundaries have shown that lengthening affects segments in phrase final words and increases progressively as the segment draws closer towards the phrase boundary. Berkovits (1994) found that phrase-final disyllabic words show significant lengthening in compare to the same words when positioned phrase-medially. Lengthening was observed on both the initial and the final syllable. When the initial syllable was stressed, it accounted for 25% of the word's total lengthening, while the final syllable for 75%. When the final syllable was stressed, the initial syllable accounted only for 5% of the word's total lengthening, while the final syllable accounted for 95%. This interaction suggests that the final syllable was always lengthened significantly (by ~75%), in parallel, the stressed syllable also attracted some amount of lengthening (~20%). In the specific case of final-stressed disyllabic words, the final syllable is lengthened on account of both stress and finality, amounting to ~95% of the total amount of lengthening. The percentages mentioned here are specific to disyllabic words in Modern Hebrew (Berkovits 1994), so the exact numbers may vary when target words have different numbers of syllables and between languages. However, the measurements in Turk (1999) point to a similar distribution in American English.

Significant lengthening mainly occurs on rhymes, not on onsets. Final lengthening manifests at all levels of the prosodic hierarchy, starting from the prosodic word and climbing up to the utterance (see also Hyde 2007 for foot-level lengthening). The amount of lengthening increases with higher prosodic boundaries (Cambier-Langeveld 1997).

Three major models have been developed to account for final lengthening and its domain of application: The *Structure-based* model, the *Content-based* model and the *Hybrid* model. The Structure-based model assumes that final lengthening operates on fixed speech sequences which can be defined by linguistic structure, e.g. the final-syllable rhyme (Wightman et al. 1992). The Content-based model propagates that final lengthening is independent of linguistic structure, but rather relies on an abstract articulatory lengthening gesture called the π-gesture. The π-gesture is anchored at the end of the final syllable and overlaps with adjacent segmental gestures. This overlap causes a slow-down in the articulation of segmental gestures, which results in lengthening the affected segments (Byrd & Saltzman 2003; Byrd et al. 2006; Cho 2016). In the Hybrid model, final lengthening operates over a domain defined by linguistic structure (e.g. the rhyme of the final syllable), but in cases where the lengthening may result in neutralization of phonological quantity contrasts – the domain of lengthening may expand further leftwards (Cambier-Langeveld 1997).

Evidence supporting the superiority of the Structure-based model is starting to amount in recent studies. Turk & Shattuck-Hufnagel (2007) have found that phrase-final lengthening targets two distinct positions – the final syllable and the rightmost stressed syllable in the phrase. Significant and consistent lengthening effects were found to apply discontinuously, providing evidence against both the Content-base and the Hybrid models, which predict only one domain of application stretching from the boundary backwards. Similar results were found in a study of phrase-final lengthening in Estonian (Plüschke & Harrington 2013), where again, two non-adjacent domains in the phrase-final word were found to be significantly lengthened. The first domain is the final syllable's rhyme and the second was defined by the authors as "the main bearer of quantity contrast". While the scope of this study does not venture into Estonian's three-fold system of quantity distinctions (Lehiste 1960; Prince 1980), a gross parallel can be drawn between the Estonian "main bearer of quantity contrast" and the typically "heavier and longer" stressed syllable of the common stress-based language.

Henceforth, the present study adopts the Structure-based model of final lengthening. At the level of the prosodic word, lengthening affects the final syllable by increasing the phonetic duration of the vowel in this syllable (Beckman & Edwards 1987). At the phrase level, final lengthening affects two positions: the final syllable of the final word and rightmost stressed syllable, increasing the duration of the vowels they host.

2.2.2 Final strength vs. final weakness

Final lengthening in a prosodic domain is cross-categorized as both a strengthening and a weakening effect at the same time. On the one hand, increased vowel duration supports accurate articulation of vowels which could otherwise be under pressure to reduce (see §2.3.4). This produces the effect of reduction blocking in phrase final positions, as found in both Russian (§2.3.5.1) and Brazilian Portuguese (§2.3.5.2). At its extreme, final lengthening can give rise to a system in which the final syllable is the strongest licenser of vowel features in the entire prosodic word, as attested by Northern Welsh (§2.3.5.3). On the other hand, phrase final position is characterized by weakening effects such as final devoicing, glottalization and vowel deletion. From a diachronic point of view, final position is notoriously known as a "weakening" environment. Barnes (2006) mentions Gauthiot's (1913) monograph, *La Fin de Mot en Indo-Européen*, wittily describing it as "an encyclopedic treatment of the phonological history of final syllables in Indo-European; a narrative of what fell off where and when" (p. 114).

Weakening in phrase final position affects both consonants and vowels. Consonant weakening stems from the absence of a CV transition which would accommodate the phonetic cues for laryngeal features like voicing and aspiration (Steriade 1997). Vowel weakening stems from a steep drop in subglottal pressure associated with ends of phrases or utterances, and with a lowering of F0 (Dauer 1980; Gordon 1998). Decreased subglottal pressure results in the elimination of the pressure drop necessary for voicing to be maintained. Gordon (1998) presents a cross-linguistic survey of vowel devoicing in domain final positions. One emerging generalization is that word-final devoicing implies the presence of phrase-final devoicing, but not vice versa.

The importance of this cross-categorization of final lengthening as both a strengthening and a weakening effect lies in its implications regarding the phonology-phonetics interface. As opposed to word stress, which is unquestionably a prosodically strong position, it is not straightforward to account for the conflicting prosodic status of the phrase final position. Therefore, theories dealing with the architecture of phonology-phonetics interface must explain the typology, by which phrase-final phenomena manifests differently in different languages. Theories accounting for the phonology-phonetics interface are presented below in §2.3.

2.3 Vowel reduction

Vowel reduction is a case of *Positional Neutralization* (Trubetzkoy 1969; Steriade 1994) which manifests in different distributions of vowel quality inventories as a function of prosodic position. The most widely studied case of vowel reduction is the reduction of unstressed vowels (Crosswhite 2001; Flemming 2005; Harris 2005; van Bergem 1993; Lindblom 1963; *inter alia*). In terms of surface distribution, it is common for stressed syllables to host larger vowel quality inventories in compare to unstressed syllables. As this effect is clearly evident in surface forms and attested in numerous languages, it has become the canonical example of vowel reduction in linguistic literature.

The prevalence of vowel reduction has inspired a varied set of theories, which differ, quite fundamentally, with respect to their assumptions on the phonetics-phonology interface. The main questions in this debate relate to the linguistic module in which vowel reduction operates. Some argue it is essentially a phonetic effect (Lindblom 1963; Flemming 2005), some claim it should be represented only in the abstract phonological grammar (Hale & Reiss 2008), while others propagate hybrid analyses (Beckman 1997; Crosswhite 2001; Barnes 2006). Ultimately, any such theory is evaluated with regard to its ability to predict the attested typology and the compatibility of its assumptions with respect to other independently motivated phenomena found in the languages of the world.

Within the theory of Autosegmental Phonology, rules and constraints were proposed to capture an explicit relationship between stress and the licensing of features (Goldsmith 1989; Lombardi 1991, 1995; *inter alia*). This approach, named *Positional Licensing*, postulates that certain features require structural association with certain prosodic positions to be deployed, e.g. [voice] with onset, or [mid] with stress (Beckman 1997). However, the close tie between stress and vowel reduction has been decoupled in later studies. While in most stress languages, the stressed syllable exhibits the behavior attributed to prosodically prominent positions, prominence is found to be manifested independently of stress. Examples for such decoupled phenomena are found in rhythmic vowel reduction (or deletion) in stress-less languages like French (Garcia, Goad & Guzzo 2017), phrase-level effects where segments vary in implementation as a function of their boundary-adjacent position (Pierrehumbert & Talkin 1992; Fougeron & Keating 1997; Keating et al. 2004), prosodically conditioned licensing of segmental features where stress is irrelevant (Bosch & Wiltshire 1993), and the explicit reduction of stressed vowels (Bosch 1996).

On the phonetic level, the main acoustic correlate of vowel reduction is duration (Lindblom 1963). Decreased vowel duration is challenging for both production and perception. From the speaker's point of view, the production of a vowel may result in *undershoot* – the case where vowel duration is decreased to the point that the articulator (typically the tongue) cannot reach its target position fast enough, thus resulting in the production of a vowel with a different quality. From the listener's point of view, decreased duration may result in misperception due to an insufficiently stable acoustic signal (ibid.). These two points of view are tied together in Steriade's (1997) *Licensing-by-Cue* approach, according to which a speaker "does not bother" to produce accurate articulations where the phonetic context would render these productions imperceptible. Investing the required articulatory effort in these cases would be inefficient and fruitless.

Three main approaches to phonetics-phonology interface can be identified: the *Integrated Phonetics and Phonology* approach (§2.3.1) where phonology refers to phonetics directly; the *Phonetically Driven Phonology* approach (§2.3.2) where phonology refers to phonetics indirectly; and the *Structural Prominence* approach (§2.3.3) where phonetics is not the only context for phonology.

2.3.1 Integrated phonetics and phonology

The *Integrated Phonetics and Phonology* approach (Flemming 2001, 2005; Kirchner 1998), propagates a direct phonology-phonetics interface. In effect, this is the elimination of the formal distinction between phonetics and phonology. Phonological principles are implemented by direct reference to the various physical dimensions of acoustics and articulation (duration, formant values etc.). The inherently gradient nature of phonetic dimensions poses a problem with regard to the formulation of categorical contrasts. Therefore, phonological rules and constraints are implemented as thresholds imposed on acoustic dimensions, geometrical properties of vowel space etc.

For example, in Flemming's (2001) theory, the MINIMAL DISTANCE constraint defines the minimal (geometrical) distance required to facilitate proper recognition of a contrast in vowel quality; falling below the minimum threshold would result in perceptional ambiguity. In parallel, the MAINTAIN CONTRAST constraint requires two distinct phonemes to be produced in a manner that preserves their contrast. In vowel reduction, the decreased phonetic duration of vowels puts pressure on their accurate production and results in undershoot (Lindblom 1963). Consider a case where the mid-vowel /e/ appears in an unstressed syllable and is therefore pressured to reduce and surface in the form of its high counterpart [i]. MAINTAIN CONTRAST demands the preservation of contrast between [e] and [i]. In a grammar where MAINTAIN CONTRAST outranks MINIMAL DISTANCE, the contrast is preserved even if the phonetic distance between the produced [e] is shrunk perilously close to the high [i]. In a different grammar, where MINIMAL DISTANCE outranks

MAINTAIN CONTRAST, the contrast is neutralized because it does not respect the minimal required distance.

The *Integrated Phonetics and Phonology* approach suffers from pathologies regarding typological predictions. If phonological phenomena are derived by placing thresholds over gradient scales, a prediction ensues that all categorical effects can be reversed (or prevented) by adjusting articulation. Assuming that vowel reduction is triggered by decreased duration, this theory puts forward two incorrect predictions: (i) given an appropriate *increase* in phonetic duration (by means of slow speech, hyper-articulation etc.), any reduction effect is reversible; and (ii) given an appropriate *decrease* in phonetic duration, even vowels in prominent positions, like under stress, are predicted to be reduced. However, typological surveys of vowel reduction phenomena show that this is not the case; rather, there are categorical phenomena that are clearly not reversible by the adjustment of articulation (Barnes 2006; Crosswhite 2001).

These pathologies stem from the direct reference to the phonetic detail of the singular vowel token. One may suggest resolving this pathology by the introduction of some statistical component that would refer to the mean duration calculated over the entire set of tokens of the target vowel in the target position. However, such modification would re-introduce an abstract feature into the system, thus undermining the essence of the proposal regarding direct reference to phonetic details.

2.3.2 Phonetically driven phonology

The *Phonetically Driven Phonology* approach (Crosswhite 2001; Zhang 2001) propagates that phonological grammar should be abstract on the one hand, but phonetically grounded on the other. This approach originates from Steriade's (1997) *Licensing-by-Cue* scheme which identifies the connection between specific prosodic positions (e.g. coda/onset, stressed/unstressed, initial/final) with specific phonetic cues. Some phonetic environments support more accurate perceptibility of features, while other positions may deteriorate the perceptibility of certain facets of the acoustic signal. For example, a consonant-vowel (CV) transition enhances the perceptibility of the consonant's laryngeal features, while a consonant in coda or word-final position is a poor environment for the perceptibility of these features. Following this argumentation, the reason for the different typological distribution of laryngeal contrasts in coda and onset consonants is the phonetic environments that associate with these positions. Of itself, a given prosodic position does not license any features or structures, rather, licensing is indirectly attributed to prosodic positions due to the phonetic environments they correlate with.

Under this approach, the phenomenon of vowel reduction is expected to manifest in unstressed syllables due to their tendency to be durationally impoverished. The phonetic context of an unstressed syllable is a poor licenser for vowel features. Formal accounts following this approach will include the assignment of an abstract [strong] feature to stressed syllables – which will make the stressed syllable a good licenser for vowel features. On the other hand, it will ban the deployment of marked vowel features outside of these designated [strong] positions.

Crosswhite (1999, 2001) postulates a two-fold typology of vowel reduction. She distinguishes between the two types because they stem from different phonetic motivations and lead to different results in regard with the alternation of vowel quality. The first type, called *Prominence Reduction*, is bound to the notion of sonority. Highly sonorous vowels are inherently longer and louder, yielding higher psycho-acoustic prominence. To ground this type of reduction, Crosswhite follows the *Prominence Alignment* mechanism which was originally devised to provide an analysis for sonority-driven syllabification patterns in Berber (Prince & Smolensky 1993; Crosswhite 2001). Prominence Reduction is achieved by reducing sonority, i.e. the alternation of vowel quality towards the lower end of the universal sonority scale:

(2) The universal sonority scale of vowels (Hankamer & Aissen 1974; Selkirk 1984)

a > ɛ, ɔ > e, o > i, u > ə

In accord with this scale, Prominence Reduction commonly results in raising {a, ɛ, ɔ, e, o} towards {i, u} or centralization to [ə].

The second type of vowel reduction in Crosswhite's (1999) two-fold typology is *Contrast Enhancement*. This reduction type embodies the motivation of avoiding vowel productions which may result in perceptional ambiguity, and more specifically mid-vowels. The phonetic grounding for this type of reduction is based on the *Dispersion Theory* (Liljencrants and Lindblom 1972; Padgett & Tabain 2005), according to which the corner vowels {a, i, u} show maximal acoustic dispersion, and hence minimal perceptional ambiguity. In other words, corner vowels are maximally discernable, while mid-vowels are inherently less discernable, especially in short durations. Therefore, Contrast Enhancement is achieved by the cornering of mid-vowels {e, ɛ, o, ɔ} => {a, i, u}. The data below exemplifies the different vowel reduction types.

(3) Vowel reduction in Bulgarian and Belarusian (data from Crosswhite 2001)

Bulgarian				Belarusian			
Prominence Reduction				***Contrast Enhancement***			
Unstressed		***Stressed***		***Unstressed***		***Stressed***	
ˈro.guf	'horn GEN'	ru.ˈgat	'horned'	ˈkol	'pole'	ka.ˈla	'pole GEN'
ˈse.lu	'village'	si.ˈla	'villages'	ˈʃept	'whisper'	ʃap.ˈtatsʲ	'to whisper'
ˈra.bu.tə	'work'	rə.ˈbot.nik	'worker'	man.ˈtaʒ	'editing'	man.ta.ˈʒor	'editor'

According to the *Prominence Reduction* scheme, Bulgarian mid-vowels {o, e} are raised to {i, u}, while [a] is centralized to [ə]. Conversely, following *Contrast Enhancement*, Belarusian mid-vowels {o, e} are lowered to [a], while [a] remains unaffected. Crosswhite (1999) proposes that the aforementioned two types of vowel reduction are not mutually exclusive. Both types may manifest simultaneously within a language, as in Brazilian Portuguese, Russian, Central Eastern Catalan, and Italian.

Apparently, these two types of vowel reduction are partially overlapping and partially contradictory. Firstly, when a mid-vowel is raised to [i] or [u], there is no clear way to designate which type of reduction took place. Secondly, when a mid-vowel is lowered to [a], it would constitute reduction w.r.t. the *Contrast Enhancement* type ([a] is a corner vowel) but enhancement w.r.t. the *Prominence Reduction* type ([a] is the most sonorous vowel).

2.3.3 Structural prominence

The *Structural Prominence* approach to phonetics-phonology interface propagates that prominence ensues from the grammatical characterization of prosodic positions. Following this approach, phonological grammar may assign the abstract feature [strong] to any position, regardless of its phonetic correlates. Strong positions are phonologically prominent by definition, i.e. they have greater licensing capabilities for featural content which is otherwise avoided in weak positions. In theory, any position may be designated [strong], assuming it can be properly identified by the metrical system (may it be the prosodic hierarchy, metrical grid etc.). In Optimality Theoretic approaches, the abstract feature of prominence is formalized by the *Positional Faithfulness* and *Positional Markedness* constraint families (Beckman 1997; Zoll 1998). The former propagates faithful production of features in strong positions, while the latter ban the production of marked features in weak positions. While Beckman (1997) refers to Steriade's (1997) notion of Licensing-by-Cue, her model does not strictly require that prominent positions be grounded in phonetics. Other motivations such as lexicon optimization and psycholinguistic salience are regarded equally relevant. Other studies make similar claims regarding the structure-derived nature of prominent positions, one such example is the greater licensing capabilities of the initial syllable in Tamil (Bosch & Wiltshire 1993). A more extreme version of this approach is presented in *Substance-Free Phonology* (Hale & Reiss 2008; Iosad 2016) which argues that phonology should be kept abstract and free of any reference to phonetic realia.

The *Structural Prominence* approach it well equipped to account for language specific patterns, which may or may not pattern in agreement with phonetic cues. On the other hand, its decoupling from phonetic cues allows formulation of patterns which are phonetically arbitrary or contradictory. For example, while typology suggests that vowel reduction mainly affects vowel height, under the *Structural Prominence* approach any feature can be licensed or banned (e.g. ban [+anterior] vowels in unstressed syllables).

2.3.4 Duration induced licensing

Given a language which features both vowel reduction and stress correlating with prolonged duration (see §2.1), the expected targets of reduction are unstressed vowels. Boxed within the perspective of the *unstressed* vowel reduction, it may seem, mistakenly, that vowel reduction cannot co-occur with stress and must occur in unstressed syllables. However, the patterns of application for vowel reduction not exclusive to the dichotomy of stressed vs. unstressed.

Firstly, vowel reduction patterns vary in relation to different patterns of stress. In languages which employ rhythmic stress, the application of reduction will typically be rhythmic as well – alternating stressed and reduced syllables (e.g. English; Moon & Lindblom 1994). Otherwise, where secondary stress is irrelevant, reduction will typically apply as a function of distance from the primary stress, exhibiting different vowel quality targets for different unstressed positions (e.g. Russian; Padgett & Tabain 2005).

Secondly, stressed syllables are not the only position which acts as a strong licenser for large vowel quality inventories. The increased duration induced by final lengthening (§2.2.1) also provides for the expression of wider sets of contrasts. This effect is attested in numerous languages and it is manifested by the blocking (of otherwise regular patterns of) vowel reduction in final syllables. Following Barnes' (2006) typological survey, this phenomenon is attested both word-finally (e.g. Belarusian, Ukrainian, Central Eastern Catalan, English, Bonggi) and phrase-finally (e.g. Russian, Brazilian Portuguese, Yakan, Nawuri, Shimakonde, Murut).

To summarize, vowel reduction correlates primarily with phonetic duration, and typically affects vowels with impoverished duration. Both stress and final lengthening induce the phonetic lengthening of vowels. Finally, it is the prolonged vowel duration that accounts for both the typology of vowel quality licensing in stressed syllables and final syllables.

2.3.5 Three vowel reduction systems

The following sub-sections present three languages that feature different patterns of vowel reduction: Russian, Brazilian Portuguese and Northern Welsh. Russian (§2.3.5.1) exhibits unstressed vowels reduction where the output depends on distance from stress and in Brazilian

Portuguese (§2.3.5.2), the outcome of reduction is different for pre-tonic vs. post-tonic syllables; in both languages, some reduction effects are gradient whereas others are categorical. Additionally, phrase-final vowels resist to some of the effects of vowel reduction due lengthening. Finally, Northern Welsh (§2.3.5.3) features a stress system which is not cued by duration, and so, vowel reduction applies to stressed syllables.

2.3.5.1 Russian

The widespread description of the pattern of vowel reduction in Russian (based on the standard description in Slavic grammatical traditions) is that the underlying vowel /o/ is licensed to surface only under stress. Outside of the stressed syllable, it is produced as [a] in the first pre-tonic syllable and as [ə] elsewhere (Crosswhite 2004; Barnes 2006, 2007; Padgett 2004; Padgett & Tabain 2005). This two-degree pattern of reduction is exemplified by the word /moloko/ => [məlakó] ‘milk’; the final /o/ is stressed and thus realized faithfully, the penultimate /o/ is in the first pre-tonic syllable and thus realized as [a], and the antepenultimate /o/ is further away from stress and thus realized as [ə].

Crosswhite (2001) interprets the two degrees of reduction in accordance to her two-fold typology of reduction types (see §2.3.2). The Contrast Enhancement type is responsible for the reduction of /o/ to [a] in unstressed syllables (Degree 1), and the Prominence Reduction type is responsible for the reduction of [a] to [ə] in further syllables (Degree 2). Degree 2 reduction targets both underlying /a/ and [a] which is a reduced variant of underlying /o/.

(4) Vowel reduction in Russian (data from Crosswhite 2004, Padgett & Tabain 2005)

Stressed		***First Pretonic (Degree 1)***		***Elsewhere (Degree 2)***	
ˈbolʲ	‘pain’	bɐ.ˈletʲ	‘to hurt/be sick’	bə.lɪ.ˈvoj	‘house $_{\text{ADJ}}$’
ˈmo.lə.dəstʲ	‘youth’	mɐ.ˈlo.dʲɪnʲ·kʲɪj	‘young $_{\text{DIM}}$’	mə.lɐ.ˈdoj	‘young $_{\text{ADJ}}$’

There are elaborate discussions regarding the exact quality of the reduced vowel that is produced instead of the underlying /o/. The common transcription is [ɐ], though this seems to differ both as a function of local dialect and rate of speech (Crosswhite 2000, 2004; Padgett & Tabain 2005, Barnes 2006). Finally, another phenomenon manifested in Russian is the consistent reduction of unstressed /e/ to [ɪ] and the assimilation of [a] to [ɪ] when following a palatalized consonant, both underlying /a/ and the reduced variant of underlying /o/ (e.g. [ˈde.lə] ‘business’ – [dɪ.ˈlʲiʃ.kʲɪ] ‘affairs $_{\text{DIM}}$’ – [dɪ.lɐ.ˈvoj] ‘busy $_{\text{ADJ}}$’).

However, there are additional facts that complicate this neat schematic analysis. While degree 1 reduction (/o/ => [a]) is categorical and exceptionless, experimental data show that degree 2 reduction ([a] => [ə]) can be blocked in various positions (Padgett & Tabain 2005; Barnes 2006): (i) phrase-final open syllables, (ii) onsetless word-initial vowels, and (iii) same-vowel hiatus. All of these positions are associated with increased duration. Additionally, reduction to [ə] is experimentally shown to be blocked in hyper-articulation (Barnes 2007). In these aforementioned cases, the surface vowel is realized somewhere along the scale from [a] to [ə] in a gradient manner, with direct correlation to the duration of the vowel. To emphasize the difference between the gradient Degree 2 reduction ([a] => [ə]) to the categorical Degree 1 reduction of (/o/ => [a]) – the addition of phonetic duration can never result in the surfacing of [o] in an unstressed syllable. If so, two distinct types of vowel reduction seem to operate in Russian. One type of reduction, the merger of /o/ and /a/ in unstressed syllables, is phonological, i.e. categorical and exceptionless. The other type, the reduction of [a] to [ə], is phonetic, i.e. gradient, duration dependent and optional.

2.3.5.2 Brazilian Portuguese

The case of Brazilian Portuguese is similar to Russian in its general scheme. The entire 7 vowel inventory {i, u, e, o, ɛ, ɔ, a} surfaces only in stressed syllables. In pre-tonic syllables, underlying open-mid vowels /ɛ, ɔ/ are neutralized and surface as mid-close [e, o]. In post-tonic syllables, all mid-vowels are neutralized, surfacing as high [i, u] while underlying /a/ is realized as [ə].

As in the case of Russian, a pattern of phonological vs. phonetic reduction arises. The realization of open-mid vowels /ɛ, ɔ/ as [e, o] in unstressed syllables is categorical. No additional duration, emphasis or formal register can reverse the effect of this reduction pattern. However, the realization of mid-close vowels /e, o/ as [i, u] depends on duration. Generally, vowels in pre-tonic syllable in Brazilian Portuguese are longer. However, experimental data show that "casual" register or fast speech rate may allow the reduction of /e, o/ to [i, u] in pre-tonic syllables as well (Major 1985). Phrase-final open syllables, which are significantly lengthened, resist the gradient type of reduction (/e, o/ => [i, u]). The lengthened state renders phrase-final vowels durationally and spectrally equivalent to pre-tonic vowels, suggesting once more that the differences in the patterns of vowel reduction, pre-tonic vs. post-tonic in this case, stem from phonetic duration.

(5) Vowel reduction in Brazilian Portuguese (data from Major 1985)

Citation	***Normal Rate***	***Causal / Fast Rate***	
fes.ˈtʃi.vo*	fes.ˈtʃi.vu	fis.ˈtʃi.vu	'festive $_{\text{ADJ}}$'
po.ˈli.do	po.ˈli.du	pu.ˈli.du	'polite $_{\text{ADJ}}$'
pe.ˈdɛs.tre	pe.ˈdɛs.tri	pi.ˈdɛs.tri	'pedestrian'

*Base is [ˈfɛ.sta] 'party'

Interestingly, there is some variation among speakers in regard to phrase-final reduction blocking. For some speakers, phrase-final open syllables reduce categorically, as if the effect of final lengthening (i.e. vowel duration) has ceased to condition the blocking of reduction. Major (1985) proposes that for those speakers, the pattern of post-tonic vowel reduction has been lexicalized.

2.3.5.3 Northern Welsh

The pattern of vowel reduction in Northern Welsh differs in regard to the interaction of reduction and stress. Therefore, it is a crucial case for understanding the breadth of vowel reduction typology. It is argued that stress and vowel reduction in Northern Welsh are independent, or to the least, not mutually exclusive (Bosch 1996; Williams 1989). In the vast majority of words, stress is positioned on the penultimate syllable, but contrary to the usual case, the stressed vowel may be reduced.

(6) Reduction of stressed vowels in Northern Welsh (data from Ball & Williams 2001)

Full stressed vowel		***Reduced stressed vowel***	
ˈkuχ	'boat'	ˈkə.χɔd	'boats'
ˈbrɨn	'hill'	ˈbrə.nja	'hills'
ˈmə.nið	'mountain'	mə.ˈnə.ðɔɨð	'mountains'

The vowels [ɨ] and [u] are realized in the monosyllabic bases but are reduced to [ə] in the derived disyllabic forms. Crucially, although its vowel is reduced to [ə], the stressed syllable remains stressed in the affixed form. This reduction behavior is exhibited by the underlying high vowels /y/ and /u/ (see Hannahs 2007 for discussion). On the other hand, vowels in the final syllable are consistently faithful to their underlying quality. Following this state of affairs, the strongest licenser of vowel contrasts in Northern Welsh is not the stressed syllable, but the final syllable. Additional evidence to this behavior exists in other Welsh dialects. In Cwm Tawe Welsh, reduction of the penultimate syllable applies to the low vowel /a/ (Watkins 1953). Watkins notes explicitly, that while the penultimate syllable may be "weakened", the final syllable remains "clear" and its vowel is longer than the penult.

(7) Reduction of underlying /a/ in Cwm Tawe Welsh (data from Watkins 1953)

Underlying form	***Surface form***	
/dangos/	ˈdəŋ.gos	'to show'
/darllen/	ˈdə.ɬen	'to read'
/arian/	ˈər.jan	'silver'

Acoustic study of Northern Welsh (Ball & Williams 2001) confirms that the final syllable associates both with the longest duration and the highest pitch in the word. Stress in Northern

Welsh seems to correlate only with intensity. Given that stress is stripped from the phonetic cues of duration and pitch, the case of Northern Welsh is in line with the prediction that vowel reduction is mainly associated with duration (Lindblom 1963; Flemming 2001, 2005; see §2.3.4). Therefore, it is not surprising that the final syllable is the strongest licenser of vowel quality. The difference being that it is final lengthening, rather than stress, which contributes the most significant amount of duration increase, thus singling out the final syllable as the most prominent position.

Bosch (1996) analyses this behavior by posing two distinct positions of prominence in the prosodic word. Each position correlates with different phonetic dimensions, and crucially, the position which associates with increased duration is analyzed as a strong licenser for deploying vowel quality contrasts. Hannahs (2007) promotes a diachronic explanation to the durational prominence of the final syllable, arguing that, historically, Welsh had final stress, while the shift to penultimate stress is of later development.

2.3.6 Summary

The exposition of vowel reduction phenomena in Russian and Brazilian Portuguese has introduced another two-fold typology of vowel reduction to this discussion: phonological vs. phonetic. The phonological type being categorical and irreversible, while the phonetic type is gradient and duration-dependent. In parallel, Crosswhite's (2001) two-fold scheme distinguishes between two different phonetic motivations for reduction: Prominence Reduction and Contrast Enhancement.

Crosswhite (2001) presents a list of languages which feature two degrees of reduction: "moderate" vs. "extreme" (her terms). The "extreme" degree of reduction triggers sonority-reducing effects, in contrast to the "moderate" degree of reduction which *may* be sonority-increasing (e.g. Russian and Bulgarian /o/ => [a]). The targets of the "extreme" reduction are the most durationally impoverished syllables found in a given language (ibid.). Thus, Crosswhite identifies the "extreme" reduction with Prominence Reduction, which is crucially sensitive to vowel duration. On the other hand, the "moderate" reduction manifests in syllables which are not necessarily shortened. One counter-example is the first pre-tonic syllable in Russian, which may host a longer vowel than the stressed vowel (e.g. first pre-tonic is [a] and stressed vowel is [i], where the latter is inherently short). Following this, Crosswhite analyses the "moderate" reduction as the result of Contrast Enhancement. In other words, for Contrast Enhancement to target an unstressed vowel it needs not be durationally impoverished – reduction occurs due to a structural motivation, i.e. the weak prosodic status of unstressed syllables. The only phonetic detail involved in this scheme is that Contrast Enhancement targets only mid-vowels, while corner vowels are exempt. According to this dichotomy, Contrast Enhancement patterns as a phonological phenomenon, as it operates on abstract representations and can be motivated by linguistic structure. Conversely, Prominence Reduction patterns as a phonetic phenomenon, as it is gradient and closely coupled with the phonetic duration – in line with widely proposed phonetic motivations (Lindblom 1963; *inter alia*).

Given the dichotomy of phonetic vs. phonological vowel reduction types, it is not at all clear how theoretical approaches such as Integrated Phonetics and Phonology (§2.3.1) and Phonetically Driven Phonology (§2.3.2) can formalize this difference. Any theory that requires phonology to reference phonetic context will be plagued by such pathologies by design, because purely phonological phenomena effectively do not exist within this approach. Finally, the Structural Prominence approach (§2.3.3) allows a more flexible framework, which is free of the strong coupling of phonological phenomena with phonetic correlates. Therefore, it can accommodate phenomena which are purely phonological and leave the phonetic type of reduction to the realm of phonetics.

Steriade's (1994) bases her notion of licensing-by-cue on the basis of the typological observation that phonological licensing correlates with phonetic cues. However, an alternative explanation to this correlation is available from the perspective of *Phonologization* (Belvins 2004; Barnes 2006). The phonologization approach rests on the assumption that phonetics and phonology are formally segregated components (Keating 1988, 1996). While the formulation may vary between different models, the common ground is that the phonetic component operates on physical representations, which are gradient by nature and include quantitative specifications for various acoustic dimensions. Phonology, on the other hand, operates on abstract and symbolic representations. Phonology derives abstract representations which are interpreted by phonetics to produce the surface form (Keating 1996). On the other hand, the influence of phonetics on phonology is proposed to be diachronic in nature. Robust and consistent phonetic patterns emerge as phonological patterns due to the reinterpretation of phonetic regularities as intentional by the listener (Hyman 1976; Ohala 1981, 1993). For example, given a language where stress correlates with duration, the production of unstressed vowels will be characterized by short(er) durations. Decreased duration leads to vowel undershoot, hindering accurate production of fine distinctions in vowel quality. The emergent phonetic regularity where vowels outside of the stressed syllable are characterized by vowel quality alternations leads to the reinterpretation of these productions as intentional (ibid.). For instance, speakers of Brazilian Portuguese may interpret the production of pre-tonic [e] and [o] for underlying /ɛ/ and /ɔ/ as intentional (§2.3.5.2). Through such a process, the reduction of pre-tonic open-mid vowels is phonologized and becomes categorical, i.e. not reversible by any amount of increase in phonetic duration. Phonologization proposes that phonological patterns correlate with phonetically natural phenomena because phonological patterns *emerge* from phonetic regularities – not because phonology *requires* an appropriate phonetic context. This analysis allows the decoupling of phonology from phonetics, thus providing a solution for the pathologies that plague theories which assume that phonology refers to phonetic detail. The explanatory power of this proposal is superior to that of licensing-by-cue because it allows inter-language variation while retaining a correct prediction for typological distributions.

Following the discussion above, this study adopts the notion of formal segregation between the phonological and phonetic components. The formal analysis of vowel reduction (§5.3) is couched in terms of the Structural Prominence approach, which employs Positional Markedness constraints to account for the distribution of vowel quality in prosodically weak positions.

2.4 Phenomenon-specific prominence

The *Structural Prominence* approach (§2.3.3) postulates that reduction affects weak prosodic positions while prominent positions resist it. The notion of phonological prominence is formalized by employing Positional Faithfulness and Positional Markedness constraints (Zoll 1998; Beckman 1997). A case similar to the reduction pattern in Russian (§2.3.5.1), where reduction is blocked in stressed and phrase-final syllables, is schematically formalized in the following manner:

(8) FAITH-V́ , FAITH-V]$_{\varphi}$ » *FULL-V » FAITH-V

The *FULL-V constraint represents the motivation of vowel reduction; it propagates against the realization of full (i.e. non-reduced) vowels. The different FAITH constraints above propagate that underlying features are faithfully realized in the surface form. The general FAITH-V refers to all vowels, while the specific FAITH-V́ and FAITH-V]$_{\varphi}$ refer to stressed and phrase-final vowels respectively. The given ranking thus results in a faithful realization of stressed (FAITH-V́) and phrase-final (FAITH-V]$_{\varphi}$) vowels, while all other vowels will be reduced to respect *FULL-V.

However, typology suggests that there are cases where a given position may exhibit both strengthening and weakening effects (Barnes 2006; see §2.2.2). According to Gordon's (1998) survey of vowel devoicing, there is an abundance of languages where final devoicing affects stressed syllables. This effect, however, does not amount to a categorical phonological phenomenon in the common case – it remains a "low-level" phonetic effect. An example of prominence conflict at the phonological level is presented by Bosch's (1996) account for vowel reduction in Northern Welsh (see §2.3.5.3). According to her proposal, a prosodic word in Northern Welsh has two distinct notions of prominence, and thus two distinct prominent positions. The first "metrically prominent" position determines the position of stress, which is commonly the penultimate syllable. The second "phonetically prominent" position determines the syllable where the entire vowel inventory is licensed, which is the final syllable in all cases. In other words, her account suggests that there are two parallel metrical schemes that single out different prosodic heads for the purposes of two different phonological phenomena. Novel for Welsh at its time, Bosch’s multi-plane metrics are reinforced by more recent studies (Gordon 2006; Ryan 2019).

Gordon (2006) presents a comprehensive typological survey which shows that numerous languages employ different syllable weight schemes as a function of the phenomenon at hand. These languages treat the same syllable structure as heavy for the purposes of one phenomenon, but as light for the purposes of another. For example, Lhasa Tibetan treats CVR syllables (where R is a sonorant) as heavy for the purposes of licensing a contour tone, but at the same time, this same CVR syllables are treated as light for the purposes of stress. Furthermore, Lhasa Tibetan exhibits not only two, but three different syllable weight schemes corresponding to three phenomena: stress, contour tone, and compensatory lengthening (Dawson 1980).

(9) Phenomenon specific prominence in Lhasa Tibetan

	Stress		***Contour Tone***		***Compensatory Lengthening***	
a.	ˈtýː.tű̃ː	‘shirt’	lɔ̂ː	‘electricity’	tsík ~ tsîː	‘one’
b.	kʰá.ˈpáː	‘school GEN’	kâː	‘stop’	kə̀pkí ~ kə̀ːki	‘will do’
c.	láp.ˈʈéː	‘telephone’	khâm	‘Kham’	tʃúrkú ~ tʃúːkú	‘nineteen’

The data above show that for the purposes of stress, only a CVV syllables are heavy; the initial CVV syllable is stressed (9a) but not the initial CVC (9c). In parallel, for the purposes of contour tone licensing, both CVV and CVR are treated as heavy; there are no CVC syllables with contour tone where the coda is an obstruent. Finally, for the purposes of compensatory lengthening, any deleted consonant is compensated for by lengthening of the preceding vowel. Gordon (2006) provides a detailed analysis grounding this behavior in the phonetic manifestation of the different phenomena. In brief, a contour tone requires a long sequence of sonority to be realized, with this regard, any sonorous segment is “good enough” whether provided by a vowel or a sonorant. So, the phonetic realization of tone necessitates a metric system which is different than the metric system used for stress. Compensatory lengthening on the other hand, seems to originate as a compensation for the deletion of a segment with no distinction between coda segment types. Thus, Lhasa Tibetan exhibits three syllable weight schemes for different phonological phenomena.

This state of affairs is problematic for the standard moraic theory (Hyman 1984; Hayes 1989). The moraic theory encodes weight distinctions as a difference in the number of timing positions. Syllables with long vowels (CVV) should be represented by two morae. Allowing a representation whereby a segment is associated with three morae is undesirable because the third mora would constitute a purely theoretic element that never manifests nor triggers any surface phenomena. Thus, it is a problematic to represent weight distinctions which are three-fold (or higher). To complicate matters, the account for the Lhasa Tibetan data in (9) would require a four-fold weight distinction. A similar problematic state is reported for Early and Classical Greek (Steriade 1991), where different weight criteria are required for the pitch accent system as opposed to the systems of stress, poetic metre and minimal root requirement. The solution proposed in recent literature is to redefine weight distinction as *phenomenon-driven* rather than *language-driven* (Gordon 2006; Ryan 2019). In such a system, different phenomena can utilize distinct metrical planes within the same language, where each phenomenon determines prominent (and weak) positions for its own purposes. The proposed system is restricted in the sense that all syllable weight schemes must adhere to the universal scale of syllable weight: CVV > CVR > CVC > CV. However, different schemes may place the borderline between light and heavy syllables in different positions along the universal scale. The different syllable weight schemes employed in Lhasa Tibetan are thus as follows (grayed cells represent bi-moraic syllable types).

(10) Phenomenon specific syllable weight schemes in Lhasa Tibetan

Stress	CVV $\sigma_{\mu\mu}$	>	CVR	>	CVO	>	CV
Tone	CVV $\sigma_{\mu\mu}$	>	CVR $\sigma_{\mu\mu}$	>	CVO	>	CV
CL	CVV $\sigma_{\mu\mu}$	>	CVR $\sigma_{\mu\mu}$	>	CVO $\sigma_{\mu\mu}$	>	CV

Under such analysis, each phenomenon adheres to a strict dichotomy of light vs. heavy, where heavy syllables are bi-moraic. Thus, the theoretic problem of assigning more than two morae is avoided.

Introducing new phenomenon-specific syllable weight schemes must be rigorously constricted because it is a powerful theoretic device that may over-generate very easily. It is crucial that any phenomenon granted with its own proprietary syllable weight scheme is well grounded in typology as well as the details of its phonetic manifestation. Following current typological surveys (Gordon 2006; Ryan 2019), there is support for proprietary syllable weight schemes for the following phenomena: stress, tone, minimal word constraint, compensatory lengthening, syllabic template and poetic meter.

In the present study, I propose the definition of a new phenomenon-specific syllable weight scheme for vowel reduction (see §4.2). The proprietary vowel reduction syllable weight scheme will be used to resolve an apparent conflict between stress and vowel reduction systems in Tiberian Hebrew.

3 Pausal forms in Tiberian Hebrew

Tiberian Hebrew exhibits positional allomorphy, whereby the same lexical word has different surface structures: the *pausal* form in phrase final position, and the *contextual* form in phrase medial position (Revell 1981, 2012, 2015). In most cases, pausal forms co-occur with major syntactic divisions which are denoted by major disjunctive cantillation marks (Churchyard 1999; DeCaen 2005). Surface differences between the allomorphs are manifested in vowel quality and stress position (Goerwitz 1993), as in [ʃɔ.ˈmɔ.ru]$_{pause}$ vs. [ʃɔ.mə.ˈru]$_{context}$ 'kept $_{3MPL}$'. The two allomorphs pertain to the same morphological class and share identical semantics (Gesenius-Kautzsch-Cowley 2006; Qimron 2008), thus differing only in their phonological form. The selection between the two allomorphs is conditioned by phrase-level prosodic structure (Dresher 1994).

Throughout this study, the term *allomorph* is used in the classical sense of "alternative word form" and interchangeably with the terms *form* and *variant*. This study views Tiberian Hebrew pausal phenomena as a phonological phenomenon, continuing a long line of research (Prince 1975; McCarthy 1981; Rappaport 1984; Dresher 2009). However, morphology-based analyses have been proposed as well (see Georwitz 1993).

This chapter is an exposition of pausal phenomena in Tiberian Hebrew. §3.1 presents the background for the Tiberian Hebrew corpus, its transliteration and the nature of its vowel system. §3.2 presents introductory examples for pausal and contextual forms, adjoined with full context (verse), the original Hebrew script, translation and a tagged gloss. §3.3 describes the distribution of pausal forms through the Tiberian Hebrew corpus. §3.4 presents a detailed typology of the phonological alternations exhibited in pausal-context allomorphy. The exhibited alternations are categorized according to different syllable structures. §3.5 discusses the derivational base assumed for both pausal and contextual forms. Finally, §3.6 discusses some exceptional cases and residual phenomena.

3.1 Tiberian Hebrew transcription

The modern version of the Hebrew Bible is composed of three major orthographic strata: one base consonantal text and two diacritic systems denoting vocalization and cantillation. The consonantal text, being the oldest stratum, was completed and canonized between the 2nd century BCE to the 2nd century CE. As implied by its name, the consonantal text includes only consonants, viz. lacking explicit vocalization, punctuation and division to verses. The diacritic strata were introduced by a scholarly tradition called the *Mesorah*, which was based in the city of Tiberias between the 7th and 10th centuries CE. The diacritic systems introduced by the *Tiberian Masoretes* were superimposed over the consonantal text to denote: (i) word-level vocalization and stress position, and (ii) phrase-level prosodic parsing that acts as both an equivalent of modern-day punctuation, and as a musical-motif notation system for the purposes of liturgical cantillation (Dresher 1994, 2009). The composition of these three strata yields the *Masoretic Text*, which was received as the authoritative version of the Hebrew Bible in Rabbinic Judaism. For the purposes of linguistic study, the language of the Masoretic Text is referred to as Tiberian Hebrew.

One of the controversies in the phonological study of Tiberian Hebrew is the nature of its vowel system (Khan 1987). In the absence of empirical phonetic evidence, one must resort to the scholarly treaties produced by traditional grammarians. One of the most notable grammarians, Rabbi David Qimḥi (1160–1235, abbr. Radaq), has analyzed the Masoretic vocalization as a five-vowel quantity-sensitive system which includes /i, u, e, o, a/ and their long counterparts /iː, uː, eː, oː, aː/. The Qimḥian analysis was the prevalent approach to Tiberian Hebrew vocalization until the 20th century. However, there are several reasons to surmise otherwise. First, descendant cantillation traditions disagree; while the *Mizrahi* and *Sephardi* cantillation flavors adhere to the strict five vowel Qimḥian system, the *Ashkenazi* and *Yemenite* flavors feature additional vowel qualities.[3] Notably, Yemenite Hebrew features the open-mid rounded vowel [ɔ], which is insightful due to its absence in both Classical and Yemenite Arabic. The second reason originates from the study of *Karaite* manuscripts from the *Cairo Genizah*[4], which contain the Masoretic Text transliterated to Arabic script (Khan 1987). These texts are adorned with the Masoretic diacritic system but make unusual use of *matres lectionis* (the characters: ʾalif [ا], wāw [و] and yāʾ [ي]). Instead of strict transcription of the Hebrew orthography, these glyphs are used to denote *phonetically* long vowels. Manuscripts of this type are composed with the purpose of preserving and transmitting the accurate tradition of pronunciation. As such, they practically serve as the best alternative to an audio recording one can hope to obtain for an ancient language, providing a rare glimpse into the *phonetic* reality of Tiberian Hebrew. Following Khan's (1987) influential paper, an alternative analysis of the Masoretic diacritics has emerged: a seven-vowel quantity-insensitive system which features the vowels: /i, u, e, o, ɛ, ɔ, a/. In addition to the vowel inventory, Khan's

---

[3] *Mizrahi* (Oriental) Jews are descendants of Jewish communities spanning from Morocco in North Africa, through the Levant, the Caucasus and to Uzbekistan in Central Asia; *Sephardi* Jews are descendants of Jewish communities that originally flourished in Spain and the Iberian Peninsula, later to be exiled and spread throughout the world, notably in North Africa, the Balkan and Anatolia; *Ashkenazi* Jews are descendants of Jewish communities originating in the Holy Roman Empire (France and Germany), later spreading into the Baltic region and the Slavic countries of North East Europe; and *Yemenite* Jews are descendants of Jewish communities in Yemen.

[4] The Cairo Genizah is a collection of some 300,000 Jewish manuscript fragments that were found in the storeroom of the Ben Ezra Synagogue in Old Cairo, Egypt. The manuscripts outline a 1,000-year continuum (870 CE to 19th century) of Jewish Middle-Eastern and North African history and comprise the largest and most diverse collection of medieval manuscripts in the world.

study uncovered the phonotactic scheme of phonetic vowel duration: vowels are long when stressed or when hosted in open syllables, and short in closed unstressed syllables. The two close-mid vowels [e] and [o] are always long (appear only in open syllables or in stressed closed syllables). According to Khan's analysis, vowel duration in Tiberian Hebrew is not contrastive, thus phonetic and not phonemic. This study adopts the Khan's seven-vowel quantity-insensitive vowel system for Tiberian Hebrew.

The following table contains the transliteration scheme employed in this study, based on Khan (1987) and Anstey (2005).

(11) Transliteration (word final grapheme in parenthesis)

Hebrew Grapheme	***IPA Transliteration***
א	ʔ
בּ ב	b v
גּ ג	g ʁ
דּ ד	d ð
ה	h
ו	w
ז	z
ח	ħ
ט	tˤ
י	j
כּ כ (ך)	k χ
ל	l

Hebrew Grapheme	***IPA Transliteration***
מ (ם)	m
נ (ן)	n
ס	s
ע	ʕ
פּ פ (ף)	p f
צ (ץ)	tsˤ
ק	q
ר	r
שׂ	s
שׁ	ʃ
תּ ת	t θ

Hebrew Diacritic	***IPA Transliteration***
אִ	i
אֵ	e
אֶ	ɛ
אַ	a
אָ	ɔ
אֹ	o
אֻ	u
אְ	ə

Some graphemes have a special final variant which is used when the letter appears last in the orthographic word. Final variants are specified in a proprietary column above in (11).

The graphemes ב, ג, ד, כ, פ, ת are used to represents the corresponding stop and spirant variants. The spirant version is diacritic-free, while the stop variant is marked by the *dagesh* diacritic (a dot in the middle of the grapheme). The same diacritic (dagesh) is used to signify geminates. Disambiguation between the two meanings of this diacritic is not always straightforward as it depends on syllable structure and in some cases prescribed by the template of the relevant morphological class.

Reduced vowels (called *hataf*) are signified by a composed diacritic of the relevant vowel and the schwa diacritic. For example, the grapheme אֲ signifies [ʔă] – a glottal stop with a reduced [ă] vowel. The schwa diacritic is used to signify either the absence of a vowel or the schwa vowel, the disambiguation once more depends mainly on syllable structure (Bat-El 1995). The schwa vowel is assumed to be a featureless vowel, i.e. it has no underlying segmental features and its surface quality is context dependent (Flemming 2009).

3.2 Pausal phenomena: the data

The following data is an introductory presentation of the pause-context allomorphy. Pausal allomorphy applies across lexical categories and manifests via differences in vowel quality and stress position. The contextual allomorph is marked in purple, the pausal allomorph in red:

1. וַיִּגְבְּרוּ הַמַּיִם וַיִּרְבּוּ מְאֹד עַל־הָאָרֶץ וַתֵּלֶךְ הַתֵּבָה עַל־פְּנֵי הַמָּיִם׃ (בראשית ז, יח)

wajjiʁbəˈru	**hamˈmajim**	wajjirˈbu	məˈʔoð	ʕal-hɔˈʔɔrɛts^ʕ
prevailed	**the-water**	increased	much	on-the-earth

waˈtelɛχ	hateˈvɔ	ʕal-pəˈnej	**hamˈmɔjim**
and-went	the-ark	upon-face	**the-water**

‘And the waters prevailed and increased upon the earth; and the ark went upon the face of the waters’ (Genesis 7:18)

2. אֶת־זֶה תֹּאכְלוּ מִכֹּל אֲשֶׁר בַּמָּיִם כֹּל אֲשֶׁר־לוֹ סְנַפִּיר וְקַשְׂקֶשֶׂת תֹּאכֵלוּ׃ (דברים יד, ט)

ʔɛθ-ˈzɛ	**oχəˈlu**	miˈkol	ʔaˈʃɛr	bamˈmɔjim	kol	ʔaʃɛr-ˈlo	sənaˈpir	wəqasˈqɛsɛθ	**toˈχelu**
this	**eat** 2PL	miˈkol	that	in-the-water	all	that-has	fin	and-scale	**eat** 2PL

‘These you shall eat of all that is in the waters: all that have fins and scales you shall eat’ (Deuteronomy 14:9)

3. כִּי ׀ אֲנִי יְהוָה הַמַּעֲלֶה אֶתְכֶם מֵאֶרֶץ מִצְרַיִם … וִהְיִיתֶם קְדֹשִׁים כִּי קָדוֹשׁ אָנִי׃ (ויקרא יא, מה)

ki	**ʔaˈni**	jəhˈwɔ	hammaʕaˈlɛ	ʔɛθˈχɛm	meˈʔɛrɛts^ʕ	mits^{ʕ}ˈrajim	…
for	**I**	Jehova	bringing	you 2PL	from-land	Egypt	…

wihjiˈθɛm	qəðoˈʃim	ki	qɔˈðoʃ	**ˈʔɔni**
be 2PL	holy PL	for	holy SG	**I**

‘For I am the Lord that brought you out of the land of Egypt … you shall be holy, for I am holy’ (Leviticus 11:45)

The pausal and context forms that appear in the above examples are presented below in (12). Although these examples were picked for the purposes of demonstration – by virtue of containing both pausal and contextual allomorphs in the same verse, they are nonetheless representative of the alternations exhibited by pause-context allomorphy in general.

(12) Vowel alternations in introduction examples

	Pause		***Context***		***Alternation***	
a.	ham.ˈm**ɔ**.jim	הַמָּיִם	ham.ˈm**a**.jim	הַמַּיִם	ɔ ~ a	‘the water’
b.	ˈʔ**ɔ**.ni	אָנִי	ʔ**a**.ˈni	אֲנִי	ɔ ~ a & stress	‘I’
c.	to.ˈχ**e**.lu	תֹּאכֵלוּ	to.χ**ə**.ˈlu	תֹּאכְלוּ	e ~ ə & stress	‘eat $_{\text{2PL}}$’
d.	ʔa.mɔ.ˈθ**ɛ**.χɔ	אֲמָתֶךָ	ʔa.mɔ.θ**ə**.ˈχɔ	אֲמָתְךָ	ɛ ~ ə & stress	‘your $_{\text{2MSG}}$ maid’

These data present three types of alternations between pausal and contextual forms: (a) is alternation of pausal [ɔ] and contextual [a] without stress alternation; (b) is the same [ɔ] – [a] alternation, but with stress alternation; (c) and (d) alternation between a stressed mid vowel [e, ɛ] in the pausal variant and an unstressed schwa [ə] in the context form, accompanied with alternation in the position of stress.

3.3 Distribution

The distribution of pausal forms is conditioned by the verse structure of the Biblical text, which is denoted by an elaborate system of cantillation marks (*te'amim*). Although pausal forms do not strictly co-occur with any specific cantillation mark, their appearance is nevertheless largely predictable on grounds of the cantillation system reflecting the underlying prosodic structure of the text (Dresher 1994; Churchyard 1999). In the majority of cases, pausal forms co-occur with the major disjunctive cantillation marks *silluq* and *atnah*, which mark the verse's main subdivisions (DeCaen 2005).

According to Revell (1981, 2012), there are about 9,250 tokens of pausal forms in the Biblical text, about 85% of which appear clause finally, and a further 85% of these (~72% of the total) co-occur with major disjunctive cantillation marks (only some ~15 pausal forms are marked by conjunctive accents). The remaining 15% are found initially or medially in positions corresponding to syntactic and semantic pivots. Even when pausal forms are not final in major disjunctive phrases, the common positions they occupy are: final words of syntactic constituents, ends of introductions to direct speech and delimiters between composite items in lists. Following this distribution, Revell (2012) poses that pausal forms correlate with clause structure more than with cantillation marks (see Ben David 1990, 1995). This view is consistent with Dresher's (1994) analysis which positions pausal forms at the edge of the intonational phrase – which is not denoted explicitly by the Masoretic cantillation marks. The cantillation marks found at these positions are not used uniquely to mark intonational phrases, but rather phrase boundaries in general. Therefore, with the exception of absolute verse ends, there is no explicit notation to mark pausal forms.

Tiberian Hebrew is commonly characterized as manifesting many facets of a truly natural language (Goerwitz 1993; Churchyard 1999). It is variegated with respect to many phenomena such as differing lexical strata, grammatical inconsistencies and an abundance of plain exceptions (Dresher 1994; Revell 2015). Accordingly, not all words in Tiberian Hebrew have distinct pausal and contextual allomorphs; some words are "neutral" (Revell 2012), i.e. they do not alternate and thus have the same form in both pausal and contextual position. However, while phrase structure is the conditioning factor for the *appearance* of a specific pausal or contextual allomorph, it is not the conditioning factor of its *existence*. Whether a given word has distinct pausal and context allomorphs is a function of its phonological structure. The next chapter describes the typology of pausal and contextual forms, and the phonological alternations that comprise their differences.

3.4 Phonological alternations

This section presents the typology of alternation exhibited by pausal forms in compare to their corresponding context forms. The attested alternations are shown to correspond to cross-linguistically attested patterns of vowel reduction (see §2.3). The types of alternation differ with respect to syllable structure, i.e. vowels in open syllables (CV) alternate differently to vowels in closed syllables (CVC). This crucial generalization will be used to provide an analysis for the derivation of pausal and context forms, which involves the interaction between vowel reduction and final lengthening.

3.4.1 Open syllables (CV)

This section presents pausal–context pairs in which the alternation is manifested in open syllables. The pattern of alternation is consistent – the penultimate syllable features a full mid vowel in the pausal allomorph vs. schwa in contextual allomorph. The following data show that the mid vowels [o, ɔ, e, ɛ] can appear in the pausal allomorph, in correspondence to the contextual schwa [ə]. The high vowels [i, u] resist alternation.

(13) Alternation in open syllables (CV)

	Pause		***Context***		***Alternation***	
a.	tiʃ.ˈm**o**.ru	תִּשְׁמֹרוּ	tiʃ.m**ə**.ˈru	תִּשְׁמְרוּ	o ~ ə & stress	‘keep 2MPL’
	hɔ.ˈj**ɔ**.θɔ	הָיָתָה	hɔ.j**ə**.ˈθɔ	הָיְתָה	ɔ ~ ə & stress	‘was 3FSG’
	to.ˈχ**e**.lu	תֹּאכֵלוּ	to.χ**ə**.ˈlu	תֹּאכְלוּ	e ~ ə & stress	‘eat 2PL’
b.	ji.rɔ.ˈʃ**ɛ**.χɔ	יִירָשֶׁךָ	ji.rɔ.ʃ**ə**.ˈχɔ	יִירָשְׁךָ	ɛ ~ ə & stress	‘inherit 3MSG you’
c.	jɔ.ˈm**u**.θu	יָמוּתוּ	jɔ.ˈm**u**.θu	יָמוּתוּ	—	‘die 3MSG’
	jag.ˈg**i**.ðu	יַגִּידוּ	jag.ˈg**i**.ðu	יַגִּידוּ	—	‘say 3MSG’

In the examples specified in (13) above, group (a) additionally contains verbs in *wajjiqtol* class, such as [waj.ji.mo.ˈl**e**.tˤu]$_{\text{pause}}$ vs. [waj.ji.mo.l**ə**.ˈtˤu]$_{\text{context}}$ ‘escape 3MPL’, and passive forms such as [jə.vuq.ˈq**ɔ**.ʕu]$_{\text{pause}}$ vs. [jə.vuq.q**ə**.ˈʕu]$_{\text{context}}$ ‘be cleaved 3MPL’. These forms are grouped together because they undergo the same alternation. Group (b) features a similar alternation but involves the 2nd masculine singular accusative suffix [-ɛχɔ]. This alternation is not strictly contained within the verbal system as there exists a phonologically identical nominal suffix, marking the 2nd masculine singular genitive (e.g. אִמֶּךָ [ʔim.ˈmɛ.χɔ] ‘your 2MSG mother’). However, once more, the pattern of alternation is identical in both its prosodic and segmental details, and thus included in (13) above for the sake of completeness[5].

The resisting nature of high vowels, as shown in group (c), is consistent throughout the typology of pause-context alternation, postulating that segmental factors are in play. Moreover, whenever the vowel does not alternation, stress does not alternate as well. However, vowel alternation, as in groups (a) and (b), always produces schwa in the contextual form and triggers stress alternation. These data thus reveal the incompatibility between stress and schwa, and indeed, there are no words in Tiberian Hebrew which feature a stressed schwa (Gesenius-Kautzsch-Cowley 2006).

This incompatibility can be explained in two ways: (i) stress protects vowels from reducing to schwa, and thus V → [ə] affects only unstressed vowels, or (ii) stress avoids schwas, and thus V → [ə] is not related to stress at all, but to vowel reduction. In derivational terms, in (i) stress is assigned before vowel reduction and in (ii) stress is assigned (or re-assigned) after vowel reduction. The

[5] Another type of pause-context alternation manifesting in open syllables (CV) is attested in “nunated” forms. These are verbal forms which feature additional final [n], which is traditionally called *Nun Paragogicum* (Gesenius-Kautzsch-Cowley 2006; DeCaen 2003; Goerwitz 1993). Stress in nunated forms is consistently final, while the context-pause alternation is similar to that found in open syllables, e.g. יִשְׁכָּבוּן [jiʃ.kɔ.ˈvun] vs. יִשְׁכְּבוּן [jiʃ.kə.ˈvun] ‘lie 3MPL’. Philological studies analyze nunated forms as archaisms, or otherwise sporadic remains of different diachronic stages of the evolution of the Biblical Hebrew present tense. The phonology of these forms is claimed to be inconsistent, often manifesting behaviors which are identical to their non-nunated counterparts due to analogy (Robar 2013).

distinction between pausal and context forms must be post syntactic, because it is the position in the phrase that triggers this alternation. Therefore, words must either enter the syntax without stress or stress must be re-assigned following vowel reduction. Both these options require cumbersome assumptions to be included in any derivational account for these data.

Under the assumption that the distinct pausal and context forms are derived from the same base (see §3.5), the differences in their surface representation emerge due to different application of vowel reduction. The metrical scheme that determines the positions where vowel reduction applies is conditioned by vowel durations (see §4.1). Specifically, vowel reduction is blocked by phrase-final lengthening which applies to the pausal form, thus yielding its distinct phonological representation. Finally, stress assignment operates independently, and alternates only under the motivation to avoid a stressed schwa.

The patterns of vowel quality alternation in (13) mirror prototypical patterns of vowel reduction in line with the typology of the world's languages. First, mid vowels are the most commonly attested targets of vowel reduction, targeted due to their low contrastivity and distinctiveness in compare to corner vowels [i, a, u]. This notion is based on the Dispersion Theory (Lindblom 1963; Padget & Tabain 2005) and employed in approaches such as Contrast Enhancement (Crosswhite 2004; see §2.3.2) and Flemming's (2005) direct phonetics interface model (see §2.3.1). Similarly, from the perspective of the Elements Theory (Harris & Lindsey 1995, 2000), mid vowels are targeted for reduction due to their informational complexity (Harris 2005). Second, schwa is the most common output of vowel reduction cross-linguistically (Barnes 2006; *ibid.*); it is typically considered the most unmarked vowel, bearing no featural specification (Anderson 1982). The ultimate phonetic realization of schwa and *hataf* vowels (§3.1) is highly dependent on their context, often being the result of co-articulation (also, see Flemming 2009 for different kinds of schwa). Thus, pausal-context alternation in open syllables presents a prototypical case of vowel reduction – both targeting and resulting in the most expected vowel qualities.

3.4.2 Closed syllables (CVC)

This section presents pausal–context pairs in which the alternation is manifested in closed syllables. As in the case of open syllables, pausal forms feature more vowel quality contrasts than contextual forms. However, in closed syllables, the quality of the vowel in the contextual allomorph is not schwa but the low vowel [a].

(14) Alternation in closed syllables (CVC)

	Pause		***Context***		***Alternation***	
a.	jo.ˈχ**e**l	יֹאכֵל	jo.ˈχ**a**l	יֹאכַל	e ~ a	‘eat $_{\text{3MSG}}$’
	hɔ.ˈr**ɔ**ʁ	הָרָג	hɔ.ˈr**a**ʁ	הָרַג	ɔ ~ a	‘killed $_{\text{3MSG}}$’
b.	ʔɔ.ˈm**ɔ**r.ti	אָמָרְתִּי	ʔɔ.ˈm**a**r.ti	אָמַרְתִּי		‘said $_{\text{1MSG}}$’
	ʃɔ.ˈl**ɔ**ħ.tɔ	שָׁלָחְתָּ	ʃɔ.ˈl**a**ħ.tɔ	שָׁלַחְתָּ	ɔ ~ a	‘sent $_{\text{2MSG}}$’
	mɔ.ˈr**ɔ**ð.nu	מָרָדְנוּ	mɔ.ˈr**a**ð.nu	מָרַדְנוּ		‘rebelled $_{\text{1PL}}$’
c.	jɔ.ˈmuθ	יָמוּת	jɔ.ˈmuθ	יָמוּת	–	‘die $_{\text{3MSG}}$’
	jag.ˈgið	יַגִּיד	jag.ˈgið	יַגִּיד	–	‘say $_{\text{3MSG}}$’
d.	tir.ˈdof	תִּרְדֹּף	tir.ˈdof	תִּרְדֹּף	–	‘chase $_{\text{2MSG}}$’
	ʔă.vaq.ˈqeʃ	אֲבַקֵּשׁ	ʔă.vaq.ˈqeʃ	אֲבַקֵּשׁ	–	‘ask $_{\text{1SG}}$’

The data in groups (a) and (b) show that the close-mid vowels [ɔ] and [e] alternate with [a], where group (b) includes two other types of forms: The first are forms with a stem final geminate, such as [te.ˈħ**ɔ**t.tu]$_{\text{pause}}$ vs. [te.ˈħ**a**t.tu]$_{\text{context}}$ ‘feared $_{\text{2MPL}}$’; note that [te.ˈħ**ɔ**t.tu] is morphologically equivalent of [tiʃ.ˈm**o**.ru] ‘will keep $_{\text{2MP}}$’, which is introduced as an example for alternations in an open syllable above in (13). The second are feminine plurals such as [ti.ˈʃ**ɔ**m.nɔ]$_{\text{pause}}$ ‘will be desolate $_{\text{3FPL}}$’. The behavior of these forms supports the claim that it is the phonological form that conditions the alternation, not the morphological class[6].

As with open syllables (§3.4.1), high vowels [i, u] are not affected in closed syllables as well (14). However, group (d) shows that also mid-close vowels [e, o] may resist alternation, but this behavior is only partial given the data in group (a). The exceptional behavior of mid vowels is not specifically related to pause-context allomorphy and will be addressed separately in §3.6.2.

Focusing on the attested alternations in (14), the vowel quality contrast [e, o, ɔ] found in the pausal allomorph is neutralized in the contextual allomorph to [a]. In other words, contextual allomorphs exhibit less structural complexity, and it is in this sense that they can be considered reduced (Bosch & Wiltshire 1993).

Within a universal context, also in this case the attested alternations find parallels in the cross-linguistic typology of vowel reduction (see §2.3). As shown below in (15), similar pattern of vowel reduction is found in Belarusian.

---

[6] Forms with /ʔ/ as the 3rd stem radical are excluded from this discussion as they exhibit penultimate stressed [ɔ] both in pause and context (e.g. קָרָאתָ [qɔ.ˈr**ɔ**.tɔ] ‘read $_{\text{3MSG}}$’). In analyses assuming a five-vowel system with phonemic length contrast, the deletion of /ʔ/ from coda position triggers compensatory lengthening of the preceding vowel (McCarthy 1981). Conversely, in the present study I assume vowel reduction is blocked in order to preserve lexical contrast.

(15) Vowel reduction in Belarusian (data from Crosswhite 2004)

	Stressed		***Unstressed***		***Alternation***
a.	ˈno.ɣi	'legs'	na.ˈɣa	'leg'	o ~ a
			naʐ.ˈnoj	'of legs ADJ'	o ~ a
	ˈre.ki	'rivers'	ra.ˈka	'river'	e ~ a
			ratʂ.ˈnoj	'of rivers ADJ'	e ~ a
b.	ˈru.ki	'hands'	ru.ˈka	'hand'	–
	ˈspi.nɨ	'backs'	spi.ˈna	'back'	–

The Belarusian reduction pattern mirrors the alternations presented above for closed syllables. Both include non-alternating high vowels, and the reduction of the mid vowels /o/ and /e/ to [a]. Notice that in Belarusian the output of vowel reduction in both open and closed syllables is [a] (see §3.4.3). The same reduction pattern is also attested in certain southern dialects of Russian (Crosswhite 2000) and in Shimakonde (Barnes 2006).

3.4.3 The phonetic realization of Shewa

The Shewa diacritic (אְ) in Tiberian Hebrew orthography can signify either the absence of a vowel (referred to as "silent Shewa") or a reduced vowel (referred to as "vocalic Shewa"). To generalize, when Shewa is marked on an onset consonant it signifies a reduced vowel in an open syllable and on the coda consonant when it is silent. Other, less pervasive, principles for the distribution of silent vs. vocalic Shewa are conditioned to specific morphological and phonological environments (Khan 2013). Notably, realization of silent Shewa (no vowel) is blocked in specific phonological environments (Bat-El 1995). For example, where a silent Shewa would result in a word-medial guttural coda, the guttural instead surfaces as a separate syllable with Shewa realized as [a], e.g. תַּעַבְדוּ [ta.ʔ**a**.və.ˈdu][7] 'work 3MPL'; cf. תִּשְׁמְרוּ [tiʃ.m**ə**.ˈru] 'keep 3MPL'. Additionally, vocalic Shewa surfaces as [ă] in open syllables with guttural onset, e.g. תִּשְׁמְרוּ [tiʃ.m**ə**.ˈru] 'keep 3MPL' vs. תִּשְׁחֲטוּ [tiʃ.ħ**ă**.ˈtˤu] 'slay 3MPL'.

The widespread explanation for the origin of surface [a]/[ă] is assimilation with the [low] feature of the adjacent guttural (Prince 1975; McCarhy 1986; Bat-El 1995). However, philological studies claim that the phonetic realization of the Hebrew Shewa was [a] regardless of gutturals, and not the IPA's mid-central [ə] (Khan 2013). This notion is supported by interchanges between the

[7] I disregard the effect of cross-guttural vowel harmony which occurs in the initial syllable of תַּעַבְדוּ [ta.ʔa.və.ˈdu] 'work 3MPL'. For discussion, see Prince (1975), Bat-El (1994).

Shewa (אְ) and Hataf-Patah (אֲ), transcribed as [ă] in Masoretic manuscripts, e.g. אָזְלַת יָד [ʔɔ.z**ə**.ˈlaθ jɔð] vs. אָזֲלַת יָד [ʔɔ.z**ă**.ˈlaθ jɔð] ‘powerlessness’ (notice, no gutturals are involved). Within the Leningrad Codex[8], sporadic interchanges between Shewa (אְ) and Patah (אַ) are found, e.g. יִרְדֹּף [ji.r**ə**.ˈdof] vs. יִרַדֹּף [ji.r**a**.ˈdof] ‘chase 3MSG’. Additionally, the Babylonian and Palestinian vocalization traditions systematically transcribe vocalic Shewa with the same signs used to signify [a].

Therefore, philology suggests that the appearance of [a]-like quality in the vicinity of gutturals may not involve assimilation at all, but rather the explicit marking of surface quality. That is to say, where the *Shewa* diacritic (אְ) is placed, it does not denote any surface quality, but rather a purely phonological marking. This suggestion provides a straightforward explanation for the appearance of [a]-like quality around gutturals, and goes hand in hand with the general philological claim that Shewa was realized as [a] in all cases, e.g. נִתְחַכְּמָה [niθ.ħa.ka.ˈmɔ] ‘deal wisely 1PL’ and מִקְדָּשׁ [miq.qa.ˈðɔʃ] ‘temple’ (Khan 2013). Moreover, Shewa is claimed to exhibit additional characteristics of a weak vowel, namely, vowel harmony. According to Khan (2013), when Shewa precedes a guttural consonant, it is realized with the quality of the vowel which follows the guttural, e.g. בְּאֵר [be.ˈʔer] ‘well NOM’, מְחִיר [mi.ˈħir] ‘price’, מְאֹד [mo.ˈʔod] ‘very’.

This study adopts the philological analysis regarding the realization of Shewa as [a]. This suggests that the output of vowel reduction in both open syllables (§3.4.1) and closed syllables (§3.4.2) is phonetically identical, i.e. cornering of mid-vowels to low [a]. Instead of two different phenomena, all vowel reduction data can be analyzed as a uniform effect of lowering mid-vowels to [a].

Finally, for the purposes of this study, the actual phonetic realization of Shewa is not crucial. The main focus of this study is the metrical system required to derive the prosodic positions where vowel reduction applies (see §4). What is of importance, is that Shewa represents a phonologically reduced vowel. Therefore, throughout this study the Hebrew Shewa is transcribed as [ə] and referred to using the spelling “schwa”. In line with the original Masoretic notation, the [ə] symbol is used to denote the phonological status of a reduced vowel, rather than its phonetic realization.

---

[8] Codex Leningradensis (dated ~1008 CE) is the oldest complete manuscript of the Hebrew Bible using the Masoretic Text and Tiberian vocalization. The Leningrad Codex serves as the basis for most modern Jewish editions of the Hebrew Bible.

3.5 Base of derivation

Side by side comparison of pausal and contextual forms suggests that pausal forms are structurally more complex, i.e. contain more vowel quality contrasts. Previous studies, conducted under the assumption of a five-vowel system, commonly treat the pausal form as phonologically lengthened, where the underlying vowels /o, a, e/ are realized as [a, ə] in context vs. [oː, o, ɔː, eː, e] in pause (Prince 1975; Rappaport 1984; Churchyard 1999; Dresher 2009; *inter alia*). In these analyses, the vowel [ɔ] is commonly derived by an additional rounding rule [aː] => [ɔː]. However, when working under the assumption of a seven-vowel system without phonemic quantity (§3.1), a lengthening analysis cannot be maintained.

In contrast, pausal forms have been noted for their close similarity to the base, whether to the synchronic underlying form or the diachronic predecessor (Revell 1981; Qimron 2008). If the quality of the pausal mid vowel is unpredictable – it must originate in the underlying base (Goerwitz 1993). Hence, assuming pausal forms simply preserve the segmental content of the underlying base renders the account of the pausal vowel pattern predictable and straightforward. Moreover, in light of the alternation found in closed syllables, it is not at all clear what kind of lengthening-based derivation process can account for the alternation [a] => [e] (e.g. $[\text{jo.ˈ}\chi\textbf{a}\text{l}]_{\text{context}}$ vs. $[\text{jo.ˈ}\chi\textbf{e}\text{l}]_{\text{pause}}$ 'will eat $_{\text{3MSG}}$').

The present study reinterprets the effect of lengthening from the phonological level to the phonetic level. Pausal forms are phonetically lengthened due to phrase-final lengthening (see §2.2). The effect of this lengthening is the *blocking of vowel reduction*, which otherwise applies to contextual forms. Invoking vowel reduction to account for vowel quality alternation offers a simple explanation for the attested alternation.

Qimron (2008) proposes to treat pausal forms as citation forms, and in some cases even as identical to the base of derivation. This proposal is correct for most pausal forms, in the cases where the pausal form features the entire set of vowel features which surface in both allomorphs. However, upon examination of forms containing more than four syllables, this generalization is not maintained. The data in (16) shows pentasyllablic forms in which both pausal and contextual allomorphs feature some vowels that do not appear in the corresponding form. The "potential base" column provides the abstract representation from which both pausal and context forms may be derived, as they present the entire set of vowel qualities for both allomorphs. These data are presented in order to account for the derivation of vowel qualities in the stem, therefore I intentionally ignore the quality of the vowel in the prefix ([lə-] and [ʔɛ-]), and the [k] ~ [χ] alternation in the suffix [-ɛχɔ] (for details on these phenomena see §1.4, §9 and §10 in Ben David 1995).

(16)   Pausal forms missing segmental information w.r.t to Context forms

	Pause		***Context***		***Potential base***	
a.	lə.hat.tsi.ˈlɛ.χɔ	לְהַצִּילֶךָ	lə.hat.tsi.lə.ˈχɔ	לְהַצִּילְךָ	lə.hat.tsi.lɛ.χɔ	‘to save you’
b.	lə.hɔ.rə.ˈʁɛ.χɔ	לְהָרְגֶךָ	la.hă.rɔ.ʁə.ˈχɔ	לַהֲרָגְךָ	lə.hɔ.rɔ.ʁɛ.χɔ	‘to kill you’
c.	ʔɛ.ʕɛ.zə.ˈvɛ.kɔ	אֶעֱזְבֶךָ	ʔɛ.ʕɛ̆.zɔ.və.ˈχɔ	אֶעֱזָבְךָ	ʔɛ.ʕɛ.zɔ.vɛ.χɔ	‘leave 1SG you’
d.	ʔă.ʃal.lə.ˈħɛ.kɔ	אֲשַׁלְּחֶךָ	ʔă.ʃal.le.ħă.ˈχɔ	אֲשַׁלֵּחֲךָ	ʔă.ʃal.le.ħɛ.χɔ	‘send 1SG you’
e.	lə.χal.kə.ˈlɛ.χɔ	לְכַלְכְּלֶךָ	lə.χal.kɛ.lə.ˈχɔ	לְכַלְכֶּלְךָ	lə.χal.kɛ.lɛ.χɔ	‘to support you’

The main point of interest in these data is the contrast between the penultimate and the antepenultimate syllables. The state of the penultimate (open) syllable is in accord with the data presented so far – pausal forms feature a mid-vowel while contextual forms feature a reduced vowel [ə] or [ă] (where the latter appears in the environment of a guttural). However, the antepenultimate syllable shows the exact opposite – context forms feature a full vowel {ɔ, e, ɛ} while pausal forms feature schwa. Form (a) features a high vowel in its antepenultimate syllable, confirming once more that high vowels do not alternate. Forms (a), (d) and (e) contain closed syllables featuring the low vowel [a] in both allomorphs. Being the output of reduction in closed syllables (see §3.4.2), it is obscure whether this [a] are a result of reduction or not.

These data are incompatible with the proposal that pausal forms are identical to the base of derivation (or that the pausal form *is* the base of derivation). For example, it is unclear how the antepenultimate [ɔ] in the context form [ʔɛ.ʕɛ̆.zɔ.və.ˈχɔ] can be derived if the base of derivation were the pausal [ʔɛ.ʕɛ.zə.ˈvɛ.kɔ] – which crucially lacks any [ɔ] vowel in the stem ([-ɛχɔ] is a suffix). Thus, the contextual form cannot be derived from the pausal form, in complete parallel to the argument which denies deriving the pausal form from the contextual form (Goerwitz 1993).

(17)   Impossible derivation: Deriving the context form directly from the pausal form

Pausal form	ʔɛ . ʕɛ . zə. vɛ . kɔ	אֶעֱזְבֶךָ
Context form	ʔɛ . ʕɛ̆ . zɔ . və . χɔ	אֶעֱזָבְךָ

Therefore, a common abstract base of derivation must be assumed, from which both pausal and contextual forms are derived (the base may, or may not, be identical to one of the derived forms). Based on the alternation data presented earlier in this chapter (§3.4.1 and §3.4.2), the derivation of the contextual allomorph always involves vowel reduction. However, the data presented above in (16) suggest that vowel reduction is applicable in pausal forms as well. The pattern of reduction in these forms is similar to the pattern presented for open syllables: high vowels resist reduction and mid vowels reduce to schwa.

(18) Proposed derivation: Deriving both allomorphs from a common base

Pausal form	lə . hɔ . rə . gɛ. χɔ	לְהָרְגֶךָ
Base	lə . hɔ . rɔ . gɛ . χɔ	
Context form	la . hă . rɔ . gə . χɔ	לַהֲרָגְךָ

Finally, it is not surprising that these effects surface in longer (pentasyllablic) forms. Vowel reduction systems target prosodically weak positions which are determined by the metrical structure of the word. The data suggests that vowel reduction in Tiberian Hebrew applies rhythmically. This is evident in context forms like [ʔɛ.ʕɛ̆.zɔ.və.ˈχɔ] 'I will leave you' where the penult and the pre-antepenult syllables feature reduced vowels. A metrical analysis is thus required in order to account for the surface differences between the pausal and the contextual allomorphs. Such metrical account is proposed in §4.

3.6 Residual phenomena

In addition to the alternations discussed above in §3.4, there are some exceptions to the pattern of alternation in closed syllables (CVC). The first case is the inconsistency exhibited by the mid vowel [e], attributed to an incomplete diachronic sound change (§3.6.1). The second case is the lack of alternation in /CoC/ and /CeC/ syllables, which exhibit a separate and distinct vowel reduction effect that relates to stress (§3.6.2).

3.6.1 Alternation in CeC syllables

The behavior of the mid vowel /e/ is inconsistent in the alternation of pause-context allomorphy, specifically /e/ exhibits a four-fold typology of alternation in closed (CeC) syllables.

(19) Alternation in CeC syllables (type count based on Ben David 1995)

	Pause		***Context***		***Types***	***Alternation***	
a.	ʔă.vaq.ˈqeʃ	אֲבַקֵּשׁ	ʔă.vaq.ˈqeʃ	אֲבַקֵּשׁ	many	e = e	'ask 1SG'
b.	jo.ˈχ**e**l	יֹאכֵל	jo.ˈχ**a**l	יֹאכַל	~40	e ~ a	'eat 3MSG'
c.	dib.ˈb**e**r	דִּבֵּר	dib.ˈb**ɛ**r	דִּבֶּר	3	e ~ ɛ	'spoke 3MSG'
d.	je.ʔɔ.ˈm**a**r	יֵאָמַר	je.ʔɔ.ˈm**e**r	יֵאָמֵר	~10	a ~ e	'say 3MSG'

Item (a) represents the cases where /e/ does not alternate (see §3.6.2). Item (b) presents cases where a pausal [e] alternated with contextual [a]. Item (c) represents alternations of pausal [e] with contextual [ɛ], this alternation is limited to very few cases. Finally, item (d) presents an additional case where pausal [a] alternates with contextual [e].

The inconsistent behavior of /e/ was examined in diachronic studies (Qimron 1986, 2006; Khan 1994). These studies suggest that a diachronic sound change [e] => [a] has operated in stressed closed syllables in pre-Tiberian Hebrew. This sound change started its operation at an early time, when pre-Hebrew still had phonemic vowel quantity contrasts, and it applied only to the short variant of [e], i.e. in CeC but not Ce:C syllables. In addition, the application of this sound change was conditioned by several additional segmental factors, and thus applied only partially. By the time of Tiberian Hebrew, phonemic vowel quantity was lost (Khan 1987). Thus, the application of the [e] => [a] sound change was abrupted in mid process, resulting in an opaque system with regard to the derivation of some words and word classes.[9] The result of this historical process is that either of the two vowels, [e] or [a], can be arbitrarily exhibited as the reflex of the historic short [e], without adhering to a consistent conditioning environment. Examples are singular exceptions like [je.ʔɔ.ˈm**a**r]$_{\text{pause}}$ vs. [je.ʔɔ.ˈm**e**r]$_{\text{context}}$ 'say $_{\text{3MSG}}$', or entire word classes such as the *waw*-consecutive *wajjiqtol* forms (Qimron 2006, 2008).[10]

However, in terms of tendency, pausal forms predominantly feature the mid vowel [e], while context forms predominantly feature [a] (Qimron 1986; Khan 1994; Ben David 1995). Therefore, for the purposes of this study, cases where pausal forms feature a stressed [a] are treated as lexical exceptions. Although seemingly problematic, this is not different from any other natural language that contains variation, lexical sub-strata and plain exceptions. The following table summarizes the proposed analyses for the different alternation patterns of the mid vowel /e/.

(20) Summary of the inconsistencies of /e/

Pause	***Context***	***Analysis***
[e]	[a]	Synchronic effect of vowel reduction
[a]	[e]	Lexical exception (applies to single words and entire classes)
[e]	[ɛ]	Lexical exception (applies to 3 verb types)

The first case, pausal [e] vs. contextual [a], is treated as a synchronic effect of vowel reduction, e.g. [gi.ˈd**e**l]$_{\text{pause}}$ vs. [gi.ˈd**a**l]$_{\text{context}}$ 'grew $_{\text{3MSG}}$'. This behavior is parallel to the widespread

[9] This in contrast with the Babylonian tradition of Biblical Hebrew, where the shift was more consistent and pervasive (Qimron 1986).

[10] Notice that vowel-final *waw*-consecutive forms with do not exhibit any exceptional behavior; e.g. [waj.ji.mo.ˈl**e**.tˤu]$_{\text{pause}}$ vs. [waj.ji.mo.lə.ˈtˤu]$_{\text{context}}$ 'escape $_{\text{3MPL}}$'.

alternation of pausal [ɔ] vs. contextual [a], e.g. [ʔɔ.ˈm**ɔ**r.ti]pause vs. [ʔɔ.ˈm**a**r.ti]context ‘I said 1MSG’. The second case, pausal [a] vs. contextual [e], represents lexical exceptions which originate from the aforementioned diachronic sound change. The third case, pausal [e] vs. contextual [ɛ], is very limited in its distribution – it applies only to three verbs in the entire corpus. On the one hand, this alternation may be treated as adhering to the scheme of vowel reduction by lowering, which is the predominant alternation whereby mid vowels /e/ and /ɔ/ reduce to [a] (see §3.4.2). On the other hand, as the surface quality of the reduced vowel is not [a], and this alternation applies only to three types – it must be treated as a lexical exception.

3.6.2 Non-alternation in CeC and CoC syllables

In parallel to the exceptional alternations exhibited by CeC syllables, they are numerous cases where CoC and CeC syllables do not exhibit alternation at all.

(21) Non alternating CeC and CoC syllables

Pause		***Context***		***Alternation***	
tir.ˈdof	תִּרְדֹּף	tir.ˈdof	תִּרְדֹּף	o = o	‘chase 2MSG’
ʔă.vaq.ˈqeʃ	אֲבַקֵּשׁ	ʔă.vaq.ˈqeʃ	אֲבַקֵּשׁ	e = e	‘ask 1SG’

Following the diachronic background of the /e/ => [a] sound change discussed above in §3.6.1, non-alternating CeC syllables are analyzed as diachronic descendants of an original long [eː] (Qimron 1986, 2008). However, focusing on synchronic grammar, non-alternating CeC and CoC forms pattern together with respect of their interaction with stress. Typically, when a word features a final CVC syllable – it is stressed. However, there are three prosodic conditions under which final CeC or CoC syllables may surface unstressed: affixation, cliticization and phrase-level stress clash. In all of these cases, the surface quality of the vowel alternates from close-mid [e]/[o] to the corresponding open-mid [ɛ]/[ɔ].

(22) Vowel alternation in CeC and CoC syllables with relation to stress

Condition	***Stressed***		***Unstressed***		***Alternation***	
Affixation	lir.ˈd**o**f	לִרְדֹּף	lir.d**ɔ**f.ˈχɔ	לִרְדָפְךָ	o ~ ɔ	‘to chase’
	lə.vaq.ˈq**e**ʃ	לְבַקֵּשׁ	lə.vaq.q**ɛ**ʃ.ˈχɔ	לְבַקֶּשְׁךָ	e ~ ɛ	‘to ask’
Cliticization	ʔɛʃ.ˈm**o**r	אֶשְׁמֹר	ʔɛʃ.m**ɔ**r.ˈlo	אֶשְׁמָר־לוֹ	o ~ ɔ	‘keep 1SG’
	ʔă.ða.ˈb**e**r	אֲדַבֵּר	ʔă.ða.b**ɛ**r.ˈbo	אֲדַבֶּר־בּוֹ	e ~ ɛ	‘talk 1SG’
Phrasal stress-clash	hiʃ.ʃɔ.ˈm**e**r	הִשָּׁמֵר	hiʃ.ˈʃɔ.m**ɛ**r lə.ˈχɔ	הִשָּׁמֶר לְךָ	e ~ ɛ	‘beware 2MSG’

According to Khan (1987), the phonetic duration of [e] and [o] is always long. Additionally, CVC syllables can host phonetically long vowels only under stress. Accordingly, the vowels [e] and [o] never occur in unstressed CVC syllables. Put otherwise, this is a clear case of unstressed vowel reduction.

This pattern of vowel qualities finds parallel in vowel reduction systems such as Standard Slovene and certain North Eastern dialects of Brazilian Portuguese (Crosswhite 2004).[11]

(23) Mid vowel reduction in Standard Slovene (data from Crosswhite 2004)

Stressed		***Unstressed***		***Alternation***
ˈmoʒ	'man'	mɔʒ.ˈjeː	'men PL'	o ~ ɔ
ˈkoːst	'bone'	kɔ.ˈstiː	'bones GEN'	o ~ ɔ
ˈreːtʃ	'word'	rɛ.ˈtʃiː	'words GEN'	e ~ ɛ
ˈtseː.sta	'road'	tsɛ.ˈsteː	'roads GEN'	e ~ ɛ

These data suggest that the vowels [e] and [o] cannot be sustained provided the phonetically short vowel duration that is available in unstressed CVC syllables. Crucially, this phenomenon is distinct from the alternations exhibited by pause-context allomorphy. Simply because these syllable types do not alternate between pausal and contextual allomorphs. Additionally, pause-context allomorphy does not include the alternations [o] vs. [ɔ] and [e] vs. [ɛ].[12] As the main focus of this study is the allomorphy of pausal vs. contextual forms, these phenomena will not be further elaborated.

3.7 Minor pause

In addition to the pausal and contextual allomorphs discussed so far, there is another class of pausal phenomena commonly called *Minor Pause* (Goerwitz 1993; DeCaen 2005; Revell 2015). While pausal and contextual allomorphs differ in their vowel pattern and (in some cases also) stress position, minor pausal forms are identical to contextual forms in their vowel pattern but differ in stress position. Minor pausal forms are also found at phrase boundaries, coinciding in the majority of cases with the end of a syntactic or a semantic clause.[13] While major pausal forms tend to terminate major clauses and phrases, minor pausal forms are most commonly terminating the first part of a clause pair (Revell 2015). Therefore, minor pausal forms mark a phrase boundary of a

[11] See Lehiste (1960) for alternative analysis involving underspecified archiphonemes as the endpoints of reduction.

[12] Excluding the marginal [dib.ˈber] vs. [dib.ˈbɛr] 'said 3MSG' type which is exhibited only by 3 verbs (see §3.6.1).

[13] Revell (2015) attributes some 65% of his corpus of minor pausal forms to clause ends. The rest are terminating lesser phrasal boundaries, mostly the penultimate constituent.

lesser strength. The different forms of the two pausal allomorphs are exhibited below with reference to the 2MSG pronoun:

(24) Minor pause - example phrase

ləˈmi	**ˈʔattɔ**	wəˈʔej	mizˈzɛ	**ˈʔɔttɔ**	לְמִי־אַ֫תָּה וְאֵי מִזֶּה אָתָּה: (שמואל א׳, ל, יז)
to-whom	you	and where	from	you	

‘To whom do you belong? And where are you from?’ (Samuel 1, 30:17)

The first occurrence of the 2MSG pronoun is a minor pausal form [ˈʔat.tɔ]. It has the same vowel pattern as the contextual form [ʔat.ˈtɔ], but its stress is penultimate, like the major pausal [ˈʔɔt.tɔ]. The following data (25) presents some examples of words with three distinct forms:

(25) Words with three-way alternations

same stress pattern (Major Pause – Minor Pause) *same vocalic pattern* (Minor Pause – Context)

	Major Pause		***Minor Pause***		***Context***		
a.	ˈʕɔt.tɔ	עָתָּה	ˈʕ**a**t.tɔ	עַ֫תָּה	ʕ**a**t.ˈtɔ	עַתָּה	‘now’
b.	ˈʔɔ.ni	אָ֫נִי	ˈʔ**a**.ni	אֲ֫נִי	ʔ**a**.ˈni	אֲנִי	‘I’
c.	hin.ˈn**e**.ni	הִנֵּ֫נִי	hin.ˈnɛn.ni	הִנֶּ֫נִּי	hi.nə.ˈni	הִנְנִי	‘here I am’
d.	wə.ʔɔ.ˈm**ɔ**r.tɔ	וְאָמָ֫רְתָּ	wə.ʔɔ.ˈm**a**r.tɔ	וְאָמַ֫רְתָּ	wə.ʔɔ.mar.ˈtɔ	וְאָמַרְתָּ	‘said 2MS’

The existence of minor pausal forms suggests there are two distinct effects to phrase finality. The contextual and minor pausal forms pattern together in regard with the vowel pattern. This similarity suggests that the environment that induces vowel alternation is found only where major pausal forms are found, i.e. at the right edge of the intonational phrase (IP). Conversely, minor and major pausal forms pattern together with regard to stress position. The resulting generalization is that pausal forms never have stress on a final CV syllable. This suggests that stress is avoided in phrase-final position. Major pausal forms terminate intonational phrases (Dresher 1994), so, the minor pausal form [ˈʔat.tɔ] in phrase (24) is terminating a lesser constituent, i.e. the phonological phrase. Therefore, the relevant phrase boundary which triggers the avoidance of phrase-final stress is the phonological phrase (φ).

Additionally, the minor pause data suggest that stress and vowel reduction are independent. If vowel reduction was dependent on stress position, one would expect the stress shifts exhibited by minor pausal forms to affect vowel quality as well. However, vowel quality alternates only as a function of the word’s position with regard to the right edge of the intonational phrase. Thus, vowel reduction in Tiberian Hebrew is conditioned by phrase level prosodic structure, not stress.

3.8 Interim summary

This section has presented the typology of vowel alternations involved in pausal vs. context allomorphy. It has been shown that the exhibited alternations match cross-linguistically attested patterns of vowel reduction. Viewing these alternations as vowel reduction, provides for a simple and straightforward account for the pattern of vowel qualities features in both allomorphs.

Hereafter, the aforementioned vowel alternation data will be treated as effects of vowel reduction. Chapter §4 proposes the metrical scheme which determines the positions where vowel reduction is applied. Crucially, the reduction scheme applies uniformly to both pausal and contextual forms, while interaction with phrase-level phonetic lengthening provides the basis for the surface contrast between pausal and contextual forms.

4 Metrical structure

In the previous chapter (§3), the segmental alternations manifested in pause-context allomorphy were presented and analyzed as vowel reduction. While §3 dealt primarily with *what* alternates with *what*, this chapter is focused on the question of *where* it happens and *why*, specifically alluding to the role of stress and phrase-level prosodic structure.

This chapter presents a metrical analysis that accounts for the prosodic positions at which vowel reduction occurs. Following the analysis of penta-syllabic words in §3.5, it has been suggested that vowel reduction applies in an alternating rhythm in both pausal and contextual forms, where the pausal allomorph emerges due to phrase-final lengthening, which affects metrical parsing.

One of the main issues elaborated in this chapter is the a-typical phenomenon of reduction in stressed syllables (§4.1). I argue that stress and vowel reduction differ in their schemes of weight assignment. Stress metrics are is sensitive syllable structure, thus CVC syllables are treated as heavy. On the other hand, vowel reduction is sensitive vowel duration, therefore syllables hosting phonetically long vowels are treated as heavy (§4.2).

Finally, detailed derivations for both the contextual and pausal allomorphs will be presented in §4.3 and §4.4 respectively.

4.1 A conflict in prominence: stress vs. vowel reduction

The following table (26) presents the prosodic positions where pause–context alternation occurs. The generalization is that the position where the two allomorphs differ is the stressed syllable of the pausal allomorph. However, this position varies as a function of word and syllable structure.

(26) Positions of vowel reduction in pause-context allomorphy

	Position	***Structure***	***Pause***		***Context***		
a.	Penultimate	CVC	ʔɔ.ˈmɔr.tɔ	אָמָרְתָּ	ʔɔ.ˈmar.tɔ	אָמַרְתָּ	‘said $_{\text{2MSG}}$’
b.	Penultimate	CV	ʃɔ.ˈmɔ.ru	שָׁמָרוּ	ʃɔ.mə.ˈru	שָׁמְרוּ	‘kept $_{\text{3MPL}}$’
c.	Final	CVC	kɔ.ˈθɔv	כָּתָב	kɔ.ˈθav	כָּתַב	‘wrote $_{\text{2MSG}}$’
d.	Final	CV		*not attested*			

The data in (26) pose a theoretical problem, as they exhibit a typologically a-typical reduction behavior. Cross-linguistically, vowel reduction tends to affect unstressed syllables, as stressed syllables are prosodically strong positions, thus exempt from reduction (Crosswhite 2004; Barnes 2006). Contrary to cross-linguistic tendencies, here a vowel in a stressed syllable is reduced, where reduction is either centering to schwa or lowering to [a] (see §3.4).

However, it is not the case that stress is isomorphic with prosodic strength, nor that vowel reduction always targets unstressed syllables. The accurate phrasing is that vowel reduction applies to prosodically weak positions, where stress is but one example of a phenomenon which is commonly (but not always) titled “prosodically strong position”.

Evidence to the independence of vowel reduction from stress can be drawn from French and Northern Welsh. French lacks word-level stress, but it does exhibit vowel reduction. Phrase-level foot structure has been shown to account for an alternating pattern of vowel reduction in French casual speech (Garcia et al. 2017). This indicates that vowel reduction can apply independently of stress. Even more insightful is the case of Northern Welsh (see §2.3.5.3), where vowel reduction can apply in stressed syllables. In this dialect of Welsh, stress is uniformly penultimate, while vowel reduction applies to all syllables except the final one.[14] Thus, vowels in the stressed penult are commonly reduced to schwa [ə], while stress remains in its position (Hannahs 2007). The data from (6) are repeated below in (27).

(27) Reduction of stressed vowels in Northern Welsh (data from Ball & Williams 2001)

Full stressed vowel		***Reduced stressed vowel***	
ˈkuχ	‘boat’	ˈkə.χɔd	‘boats’
ˈbrɨn	‘hill’	ˈbrə.nja	‘hills’
ˈmə.nið	‘mountain’	mə.ˈnə.ðɔɨð	‘mountains’

Bosch (1996) proposes that prosodic words in Northern Welsh have two distinct prominent positions. One position is prominent for the purposes of stress assignment and determined by the metrical system (a trochaic foot at the right edge of the word). The other prominent position affects the application of vowel reduction and determined by the phonetic properties of syllable. Specifically, the final syllable is the longest in terms of duration (Ball & Williams 2001), thus resisting vowel reduction.

Bosch’s (1996) analysis is in line with recent studies on the effect of conflicting syllable weight criteria and prosodic prominence within the same language (Ryan 2016, 2019). In fact, it has been shown that such apparent discrepancies are typologically not uncommon (Gordon 2006). So, if languages employ distinct syllable weight criteria for stress assignment vs. tone licensing, as shown for Lhasa Tibetan (see §2.4), why not for stress assignment vs. vowel reduction?

Earlier proposals for the resolution of the conflict between stress and vowel reduction in Tiberian Hebrew have invoked multi-planar metrical structure. One such proposal includes an independent plane of vowel reduction feet (*VR-feet*) in parallel to stress feet (Rappaport 1984). Specifically,

[14] Excluding some restricted and lexically specified noun sub-classes (Hannahs 2007, 2013).

one metrical plane is used to determine the position of stress and a second distinct metrical plane determines the position of vowel reduction. The difference between these two systems is that the stress plane employs trochaic feet, while the reduction plane employs iambic feet. The superimposition of the two metrical planes achieves the sought situation where a single syllable occupies a strong position for stress, and a weak position for reduction.

The VR-feet approach was proposed for a five-vowel quantity-sensitive vowel inventory. However, its exposition here has the purpose of highlighting its conceptual merit. The exposition is followed by a discussion of its incompatibilities with the seven-vowel quantity-insensitive vowel system assumed in the present study (see §3.1). Figure (28) presents an analysis based on VR-feet for the context forms שָׁמְרוּ [ʃaa.mə.ˈru] ‘guarded 3MPL’ and כָּתַב [kaa.ˈθav] ‘wrote 3MSG’.

(28) VR-feet analysis: Context forms

	a. ʃɔː.mə.ˈruː שָׁמְרוּ	b. kɔː.ˈθav כָּתַב
Stress plane	[* _]	[*]
Underlying base	ʃaa . ma . ru	kaa . tav
Reduction plane	[*] [_ *]	[*] [*]
Derived form	ʃaa . mV . rú	kaa . táv
Surface form	ʃɔː . mV . rúː	kɔː . θáv

The penultimate syllable in (28b) exemplifies the main idea of a multi-planar metrical system, namely, the co-occurrence of prosodic strength w.r.t stress (marked with *) and prosodic weakness w.r.t vowel reduction (marked with _). However, since the vowel is reduced (on the reduction plane) stress must shift (to the final syllable) since a reduced vowel is never stressed in Tiberian Hebrew.

Additional rules are applied to derive the surface representation, including the lengthening of word-final vowels, rounding of [aː] which surfaces as [ɔː], and post-vocalic spirantization. The surface form of (28a) contains the vowel placeholder “V” signifying a reduced vowel; the surface segmental content (or lack thereof) may be further conditioned by the adjacency of guttural consonants or set by default (Rappaport 1984). In the case of (28b), there is no environment for vowel reduction to occur, i.e. no weak position. Notice that this analysis does not assume that the stressed [ɔ́ː] in pausal [ʃɔːmɔ́ːru] and [kɔːtɔ́ːv] is long in the underlying representation; in both cases this vowel is underlyingly a short [a]. An additional rule of pausal lengthening is assumed, which is responsible for lengthening the stressed vowel in pausal forms.

Rappaport's (1984) VR-feet are not compatible with the seven-vowel system assumed in the present study, where the underlying base contains the full set of vowel qualities exhibited by both the pausal and the contextual allomorphs (see §3.5). In a seven-vowel system, the underlying base of (28b) is not /kaːtav/, as in Rappaport (1984), but rather /kɔtɔv/. With /kɔtɔv/ as an underlying base, the derivation /ɔ/ => [a] in the final syllable of the contextual form [kɔ.ˈtav] is not expected with VR-feet. If VR-feet are quantity-sensitive iambs, i.e. treating the final syllable [tɔv] as heavy, reduction is not expected to apply. Conversely, if VR-feet are quantity-insensitive iambs, i.e. treating [tɔv] as light, reduction of the penultimate syllable [kɔ] is expected, but not attested.

This problem may lead one to the conclusion that the seven-vowel system for Tiberian Hebrew assumed in the present study is simply wrong. However, Dresher (2009) points out that VR-feet cannot fully account for the data, even with a five-vowel quantity sensitive system. The admission of the pausal lengthening rule into this account predicts that all stressed vowels in pausal forms surface long. Per contra, pausal forms affixed with the accusative clitic [-eχɔː], such as [lə.hɔː.rə.ˈʁe.χɔː] 'to kill $_{\text{INF}}$ you', feature a short [e] in the stressed penultima. This is a case where the rule of pausal lengthening predicts an incorrect form. VR-feet also predict that this penultimate [e] should be reduced, as per the iambic reduction foot at the prosodic word's right edge: lə.hɔː.rə.[ˈʁe.χɔː]. Had vowel reduction taken place, the expected output would be a schwa in the penultimate syllable – in effect, yielding the contextual form of this word. Thus, neither pausal lengthening nor vowel reduction apply to the penultimate [e] in this case, and so the case of affixed forms with [-eχɔː] cannot be accounted for under VR-feet.

Alternatively, under the assumption of a seven-vowel system, the underlying quality of the penultimate vowel is /ɛ/. Phrase final lengthening renders this vowel phonetically long, thus protecting it from vowel reduction. The result is a straightforward preservation of the underlying quality. Thus, no derivation process is required to account for /-ɛxɔ/ affixed words under the seven-vowel system. In the present study, the seven-vowel system for Tiberian Hebrew is adopted as a fundamental assumption. Therefore, no further argumentation in defense of this assumption is included. However, for detailed discussion see Khan (1987) and Churchyard (1999).

Finally, while Rappaport's (1984) VR-feet analysis is not compatible with the seven-vowel system for Tiberian Hebrew. However, its employment of distinct metrical planes for stress and vowel reduction is in line with the notion of phenomenon-specific prominence (Gordon 2006; Ryan 2019). Additional support for the existence of separate metrical planes comes from the minor pause data (§3.7), which suggests that stress and vocalization can be independently affected by the prosodic environment. Therefore, the scheme of a multi-planar metrical system is adopted and employed to account for vowel reduction in stressed syllables. Albeit, a novel architecture for the reduction plane is proposed, one that is compatible with the seven-vowel system. Specifically, vowel reduction metrics are assumed to be sensitive to *phonetic* vowel duration. Following the reference to phonetic duration, the difference in the application patterns of vowel reduction between pausal and contextual allomorphs is grounded in the effect of phrase-final lengthening (Turk & Shattuck-Hufnagel 2007).

This study argues that vowel reduction in Tiberian Hebrew is independent of stress.[15] Stress does not block, license or determine the positions where vowel reduction occurs. Rather, the application of vowel reduction is determined by prosodic factors, which include the word's position in the phrase, the syllable's position in the word and syllable structure. The correlations that are found between stress and vowel reduction stem from the fact that the same prosodic factors, like syllable structure, also determine stress.

4.2 Syllable weight scheme for vowel reduction

Cross-linguistic typology shows numerous cases of *phenomenon-specific weight criteria*, whereby languages employ different syllable weight schemes as a function of the phenomenon at hand (see §2.4). For example, Lhasa Tibetan (Dawson 1980) treats CVC syllables as heavy for the purposes of stress assignment, but as light for the purposes of tone licensing (Gordon 2006). Here I propose that Tiberian Hebrew employs two different syllable weight schemes for stress and vowel reduction.

Previous studies on phenomenon-specific weight criteria propose three elements that are required to support the existence of a proprietary weight scheme: (i) a phonological phenomenon with a binary contrast, (ii) the phonetic manifestation of the phenomenon, and (iii) typological evidence supporting the correlation between (i) and (ii) (Gordon 2006; Ryan 2019).

Let's take the licensing of contour tone in Lhasa Tibetan as an example. On the phonetic level, contour tone is implemented by modulation of pitch (raising then falling) over a continuous sonorous signal. In order to achieve a perceptible contrast between the two parts, "sufficient" duration of the sonorous signal is required. Notice that in phonetic terms, "sufficiency" is determined by assuming some critical threshold over the temporal dimension. However, from a phonological point of view, licensing is binary – contour tone is either licensed or not. In Lhasa Tibetan, only CVV and CVR syllables boast such "sufficiently" long sonorous sequences. Thus, the relation between the phonetic implementation and the phonological contrast is established. Within the moraic theory, such binary contrasts are represented by using different number of morae

---

[15] This argument does not refer to the alternation of vowel quality which occurs within CeC and CoC syllables, which are clearly related to stress position , but have no relation to pausal phenomena (see §3.6.2).

(Hyman 1984; Hayes 1989). By definition, morae encode the number of timing positions as weight distinctions (*ibid.*), making them a fitting means of representation when the relevant categorical contrast is determined by the duration of the underlying phonetic signal. Therefore, for the purposes of contour tone licensing in Lhasa Tibetan, CVV and CVR syllables are considered bi-moraic, while CVC and CV are mono-moraic. Thus, the three required elements for postulating a proprietary weight scheme for contour tone are as follows:

1. Categorical phenomenon: Licensing of contour tone
2. Phonetic manifestation: Pitch modulation over "sufficient" sonorous sequence
3. Typological evidence: Lhasa Tibetan and other languages (see survey in Gordon 2006)

We now turn to the argument that vowel reduction should have its own proprietary phenomenon-specific weight criteria. On the phonetic level, the main correlate of vowel reduction is phonetic vowel duration (Lindblom 1963; Flemming 2005). Like the case of contour tone, some "sufficient" phonetic duration is required for the accurate production and perception of vowel quality. Vowel reduction starts manifesting when duration falls below the "sufficient" threshold. This effect is best seen in the cases of gradient reduction systems such as non-first-pretonic syllables in Russian (§2.3.5.1), where vowel quality is gradually altered in direct correlation with phonetic duration (Barnes 2006, 2007). Conversely, vowels with durations longer than the aforementioned "sufficient" threshold suffer no quality degradation. Therefore, vowels having durations above "sufficient" can be considered resistant to vowel reduction, while vowels with durations below "sufficient" are reducible. The exact phonetic duration that comprise "sufficiency" is language specific (Barnes 2006) and also vowel specific, as some vowels are inherently longer than others (Becker-Kristal 2010). Therefore, I intentionally leave the term "sufficient" unspecified, as it is not strictly relevant for purposes of the argument. Rephrasing the reducible vs. non-reducible contrast to fit the terminology of the moraic theory results in a binary contrast between reduction-resistant vowels which are bi-moraic and reducible vowels are mono-moraic.

The actual application of vowel reduction is further conditioned by metrical structure, which is language specific. Just as different languages exhibit different stress patterns, be they rhythmically alternating or not, left or right aligned, trochaic or iambic, the positions where vowel reduction applies are too determined by the parsing and grouping of morae attributed to vowels or syllables. Therefore, a mono-moraic vowel is not necessarily reduced, it is just reduc*ible*. Commonly attested vowel reduction systems target prosodically weak positions. The most widespread case being the licensing of large vowel inventories in stressed syllables as opposed to small vowel inventories in unstressed syllables. In such languages, stress correlates with increased phonetic duration of the stressed vowel (Gordon 2017). In other words, the phonetic lengthening that is incurred by stress renders vowels in stressed syllables non-reducible. In such "simple" cases, there is a clear position which is prominent both in terms of stress and in terms of vowel non-reducibility, while other positions are prosodically weak and prone to vowel reduction (for languages with secondary stress like English, this scheme is repeated in an alternating pattern throughout the entire word).

However, stress is not the sole phenomenon to bestow immunity to vowel reduction. Some languages exhibit blocking of vowel reduction in final syllables due to the effect of domain-final lengthening (Turk & Shattuck-Hufnagel 2007). Similarly to vowel non-reducibility due to stress, the increase in phonetic duration in final positions renders vowels resistant to reduction (see §2.2). This behavior is attested both at the word-level, in languages such as Northern Welsh, Belarusian, Ukrainian, C.E. Catalan, English, and Bonggi, and at the phrase-level, in languages such as Russian, Brazilian Portuguese, Yakan, Nawuri, Shimakonde, Murut (Barnes 2006).

Crucially, the effect of resistance to vowel reduction is incurred by prolonged phonetic duration, regardless of the phenomenon that caused duration increase – be it stress or final-lengthening. Therefore, in this study I propose a syllable weight scheme specific to vowel reduction. Namely, syllable weight is assigned as a function of the vowel's *phonetic* duration – a phonetically long vowel which resists reduction is bi-moraic, while reducible vowels are mono-moraic. Consonants do not contribute weight for the purpose of vowel reduction, regardless of their position (onset or coda). Finalizing the argument, here are the three elements required to support the existence of a proprietary vowel reduction weight scheme:

1. Categorical phenomenon: The reducibility vs. reduction-resistance of a vowel.
2. Phonetic manifestation: Vowel production over "sufficient" phonetic duration.
3. Typological evidence: Non reducible vowels under stress or final lengthening in various languages (see survey in Barnes 2006).

This proposal finds both theoretical support and parallels in previous literature. In general, the notion of bi-moraic non-reducible vowels is a case of *inalterability* (Hayes 1986). Reformulated in the terminologies of the moraic and prosodic theories, it follows the same line of thought regarding the inalterability of segments which are associated with multiple prosodic slots. With regard to the phenomenon of vowel reduction, the current proposal is very similar to Bosch's (1996) notion of phonetic-level vs. word-level prominence types. In both proposals, phonetic duration determines prominence, which in turn conditions the application of vowel reduction. In parallel, a separate prominence level – called "word-level" in her terms – determines the position of the word's stress. In my proposal, "word-level" prominence is simply called stress. Finally, within the literature of Tiberian Hebrew, the notion of *VR-Feet* (vowel-reduction feet) is similar in essence (Rappaport 1984). Both proposals postulate the separation of stress and vowel reduction to proprietary metrical planes (see §4.1).

The main difference between this proposal and previous ones is the explicit invocation of final-lengthening (Turk & Shattuck-Hufnagel 2007) effects to account for the exact positions where vowels are rendered non-reducible. In addition, the present proposal is formulated within the moraic (Hyman 1984; Hayes 1989, 1995) and prosodic (Nespor & Vogel 2007) theories.

4.3 Vowel reduction in the *contextual* allomorph

This section begins the exposition of the core proposal of this study. Based on the theoretical devices discussed previously in §4.1 and §4.2, an analysis of the derivation of contextual forms via vowel reduction can now be presented. In order to employ the metrical plane of vowel reduction developed above (§4.2), the distribution of phonetic vowel durations must be determined. Following Khan (1987), phonetic duration in Tiberian Hebrew is conditioned by stress and syllable structure:

(29) Tiberian Hebrew phonetic vowel duration (Khan 1987)

- Phonetically long:
  - Vowels in stressed syllables
  - Vowels in open syllables (CV)
- Phonetically short:
  - Vowels in unstressed closed syllables (CVC)
  - Reduced (*hataf*) vowels and schwa [ə]

Stressed vowels are long regardless of syllable structure. When unstressed, vowels in open syllables (CV) are long while vowels in closed syllables (CVC) are short. Finally, reduced vowels are always short (and never stressed). This scheme yields the following vowel duration scale, where a comma indicates the absence of ranking differences:

(30) Vowel duration hierarchy (first version)

$\text{C}\acute{\text{V}}\text{(C)]}_\sigma$	,	CV]_σ	>	CVC	>	$\text{C}\check{\text{V}}$
Stressed		Open		Closed		Reduced

However, this scale does not prove useful for predicting the alternation involved in pause-context allomorphy, because all (non-reduced) syllable types featured on this scale can be reduced (as shown in (26), repeated below as (31)).

(31) Positions of vowel reduction in pause-context allomorphy

	Position	***Pause***		***Context***		
a.	Penultimate CVC	ʔɔ.ˈmɔr.tɔ	אָמָרְתָּ	ʔɔ.ˈmar.tɔ	אָמַרְתָּ	‘said $_{2MSG}$’
b.	Penultimate CV	ʃɔ.ˈmɔ.ru	שָׁמָרוּ	ʃɔ.mə.ˈru	שָׁמְרוּ	‘kept $_{3MPL}$’
c.	Final CVC	kɔ.ˈθɔv	כָּתָב	kɔ.ˈθav	כָּתַב	‘wrote $_{2MSG}$’
d.	Final CV			*not attested*		

Conversely, the only position that never undergoes reduction is the vowel of a word-final open syllable. In this study I propose that word-final vowels in Tiberian Hebrew are phonetically lengthened by final lengthening at the word-level. The lengthened state of the final vowel renders it resistant to vowel reduction. Although all open syllables are phonetically long, they can nevertheless be reduced, as seen in (31). The word-final open syllable thus needs to be represented separately from word-medial open syllables. Thus, the word-final open syllable, CV]$_\omega$, is added to the scale of phonetic vowel duration.

(32) Vowel duration hierarchy (revised version; cf. (30))

CV]$_\omega$	>	CV́(C)]$_\sigma$	,	CV]$_\sigma$	>	CVC	>	CV̌
Open Word-Final		Stressed		Open		Closed		Reduced

CV]$_\omega$ is the only syllable type that should be considered heavy (or bi-moraic) for the purposes of vowel reduction – as it is never reduced. The analysis of word-final vowels as long (or heavy) has been proposed in Balcaen (1995) and Dresher (2009). The novel approach of the current proposal is that word-final vowels should be considered long/heavy only for the purposes of vowel reduction, not for the purposes of stress. Finally, the resulting scheme is similar to the state of affairs in Northern Welsh, where the vowel in the ultimate syllable is both longer than the stressed vowel, and it is never reduced (Ball & Williams 2001; Bosch 1996; see §2.3.5.3). The following table presents the proposed phenomenon-specific syllable weight schemes for stress and reduction:

(33) Phenomenon-specific weight schemes for stress and reduction

Syllable structure	***Stress assignment***	***Vowel reduction***	
		Word medial	***Word final***
CV	CV$^{\mu}$	CV$^{\mu}$	CV$^{\mu\mu}$
CVC	CV$^{\mu}$C$^{\mu}$	CV$^{\mu}$C	

For the purposes of stress, CV syllables are monomoraic while CVC syllables are bi-moraic. For the purposes of vowel reduction, CVC syllables are monomoraic, while CV syllables vary –

monomoraic when word-medial but bi-moraic when word-final (i.e. word-final vowels receive extra mora). Thus, the two phenomena of stress and vowel reduction have different definitions of prominence (or bi-moracity). Stress is sensitive to the complexity of syllable structure; thus, coda consonants receive an extra mora. Vowel reduction is sensitive to phonetic vowel duration; thus, lengthened vowels receive an extra mora.

The following tables present the application of the proposed multi-planar metrical structure for context forms אָמַרְתָּ [ʔɔ.ˈmar.tɔ] 'said $_{2MSG}$' and הָרַג [hɔ.ˈraʁ] 'killed $_{3MSG}$'.

(34) Context forms

a. Stress assignment

	Base	***Weight Assignment***	***Trochaic Footing***	***Stress***
a.	hɔ.rɔʁ	hɔ^{μ}.rɔ^{μ}ʁ^{μ}	hɔ^{μ}.[rɔ^{μ}ʁ^{μ}]	hɔ.[ˈrɔʁ]
b.	ʔɔ.mɔr.tɔ	ʔɔ^{μ}.mɔ^{μ}r^{μ}.tɔ^{μ}	ʔɔ^{μ}.[mɔ^{μ}r^{μ}.tɔ^{μ}]	ʔɔ.[ˈmɔr.tɔ]

b. Vowel reduction (context forms)

	Base	***Weight Assignment***	***Trochaic Footing***	***Reduction***
a.	hɔ.rɔʁ	hɔ^{μ}.rɔ^{μ}ʁ	[hɔ^{μ}.rɔ^{μ}ʁ]	[hɔ.raʁ]
b.	ʔɔ.mɔr.tɔ	ʔɔ^{μ}.mɔ^{μ}r.tɔ^{μμ}	[ʔɔ^{μ}.mɔ^{μ}r].[tɔ^{μμ}]	[ʔɔ.mar].[tɔ]

As discussed above, the only difference between the application of these metric systems is the assignment of moraic weight to: coda consonants in (34a) vs. word-final vowels in (34b). Otherwise, the derivation follows from a straightforward right-to-left construction of quantity-sensitive trochaic feet. The different weight assignment affects the footing, which in turn affects the output (rightmost columns): in the case of stress, the *strong* position of the trochaic foot is assigned with stress, whereas in the case of reduction, the *weak* position of the trochaic foot undergoes vowel reduction (ɔ => a). When a single bi-moraic syllable is parsed into a foot, there are no distinct strong vs. weak positions (vowel reduction, item b). This explains the lack of vowel reduction in the case of final bi-moraic syllables (see inalterability, Hayes 1986).

The forms presented in (34) are cases where stress and vowel reduction do not conflict, and perhaps do not interact at all. However, there are forms in which the two metrical planes interact in a manner that causes alternation in the resulting stress pattern. An example for such a form is שָׁמְרוּ [ʃɔ.mə.ˈru] 'kept $_{3MPL}$'. This form lacks CVC syllables, so its metrical parsing for the purpose of stress assignment results in one foot which spans the final and penultimate syllables – ʃɔ^{μ}.[mɔ^{μ}.ru^{μ}]. Therefore, it is expected that the surface form should be stressed at the penultima – *[ʃɔ.ˈmɔ.ru]. In parallel, vowel reduction metrics single out the same penultimate syllable as weak and thus targeted for reduction – [ʃɔ^{μ}.mɔ^{μ}].[ru^{μμ}]. The actual surface form [ʃɔ.mə.ˈru] suggests that reduction wins; consequently, stress shifts to the final syllable since a syllable with a reduced vowel cannot host stress. Note that this is not likely to be an independent effect of stress assignment, as parallel forms featuring high vowels in the penultimate syllable do no surface with final stress; e.g. יָמוּתוּ [jɔ.ˈmu.θu] ‘will die 3PL’. The following scheme presents the multi-planar metrics for the context form שָׁמְרוּ [ʃɔ.mə.ˈru] ‘kept 3MPL’.

(35) Multi-planar metrical systems (S=strong, W=weak)

Stress			[S		W]
Base	ʃɔ	.	mɔ	.	ru
Vowel Reduction	[S		W]		[S]

The alternation in stress position is explained by the exceptionless generalization that schwa is never stressed in Tiberian Hebrew. In the cases presented above in (34), the surface quality of reduced vowels is [a], providing no motivation for stress shift. However, in the case where vowel reduction results in a schwa, stress cannot remain in its designated position, it thus shifts rightward within its foot.

This is an important theoretical difference between the present analysis and the VR-Feet analysis (Rappaport 1984; see §4.1). In the multi-planar architecture of the VR-Feet analysis, the vowel reduction plane takes precedence by incapacitating weak prosodic positions from bearing stress. Consequently, feet parsing on the stress plane is affected directly, and in some cases even forced to re-parse. The current proposal eliminates this additional complexity because it does not suppose any direct interaction between the different metrical planes, the alternation in stress position is motivated solely by the inability of schwa [ə] to bear stress. This behavior is easily accountable in parallel derivation frameworks like the Optimality Theory, by posing a constraint which bans stress from schwa (see analysis in §5.3).

4.4 Vowel reduction in the *pausal* allomorph

The pausal form is commonly assumed to be similar to the base (Prince 1975; Rappaport 1984; Revell 1981, 2012; Dresher 2009; Qimron 2008; *inter alia*). In this study I show that the pausal forms resemble the base because they undergo less vowel reduction relative to the context form, and the reason they undergo less reduction and are thus more “faithful” to the underlying base is phrase-final lengthening.

In the previous section, the analysis of vowel reduction in context forms has employed *word-level* final lengthening to account for reduction resistance in word-final open syllables. Pausal allomorphs appear at the right edge of the intonational phrase (IP), and are thus affected both by *word-level* and *phrase-level* final lengthening (see §2.2). The effects of final lengthening at different levels are not identical is their domain of application. Lengthening at both word and phrase level affects final vowels (of each domain respectively). However, phrase-final lengthening targets another position – the stressed syllable of the phrase’s last word (Turk & Shattuck-Hufnagel 2007). This is the crucial phenomenon that distinguishes phrase-final vs. phrase-medial words – the lengthening of the stressed vowel in phrase-final position. Ultimately, this is also the origin of pausal forms. Recall that the position of alternation between pause and context forms is always the stressed vowel of the pausal form. Inversely phrased, the data in (13), (14) and (26) suggest that the pausal form’s stressed vowel never undergoes reduction – it is non-reducible. Conversely, the stressed vowel of the context form is not protected by additional lengthening, and so it does undergo reduction, yielding the attested context forms.

In complete parallel to the analysis of word-final vowels as reduction resistant, in this study, I propose to analyze the pausal form’s stressed vowel as reduction resistant, i.e. $\acute{V}]_{IP}$ and $CV]_{\omega}$ are analyzed as bi-moraic for the metrical scheme of vowel reduction. Thus, the growing vowel duration scale can now be extended with its final member: $\acute{V}]_{IP}$ – the last stressed vowel in an intonational phrase.

(36) Vowel duration hierarchy: final version

$\acute{V}]_{IP}$	,	$CV]_{\omega}$	>	$C\acute{V}(C)]_{\sigma}$	,	$CV]_{\sigma}$	>	CVC	>	$C\check{V}$
Stressed Phrase-Final		Open Word-Final		Stressed		Open		Closed		Reduced

The following table presents the complete set of proposed phenomenon-specific syllable weight schemes for stress and reduction:

(37) Phenomenon-specific weight schemes for stress and reduction

Syllable structure	***Stress assignment***	***Vowel reduction***		
		Word medial	***Word final***	***Last stressed in IP***
CV	CV^{μ}	CV^{μ}	$CV^{\mu\mu}$	$CV^{\mu\mu}$
CVC	$CV^{\mu}C^{\mu}$	$CV^{\mu}C$		

For the purposes of stress assignment, phrase-level position is irrelevant, thus no change is required by the added reference to the phrase-final position. For the purposes of vowel reduction, the stressed vowel of the last word in the phrase is lengthened and thus bi-moraic.

The following tables present the application of the proposed multi-planar metrical structure for pausal forms: שָׁמָרְתִּי [ʃɔ.ˈmɔr.ti] ‘kept $_{1MSG}$’, הָרָג [hɔ.ˈrɔʁ] ‘killed $_{3MSG}$’. The data from (34) is repeated in (38) for convenience, the metrical account for stress assignment in both context and pausal forms is identical.

(38) Pausal forms

a. Stress assignment

	Base	Weight Assignment	Trochaic Footing	Stress
i.	hɔ.rɔʁ	hɔ$^{\mu}$.rɔ$^{\mu}$ʁ$^{\mu}$	hɔ$^{\mu}$.[rɔ$^{\mu}$ʁ$^{\mu}$]	hɔ.[ˈrɔʁ]
ii.	ʃɔ.mɔr.ti	ʃɔ$^{\mu}$.mɔ$^{\mu}$r$^{\mu}$.ti$^{\mu}$	ʃɔ$^{\mu}$.[mɔ$^{\mu}$r$^{\mu}$.ti$^{\mu}$]	ʃɔ.[ˈmɔr.ti]

b. Vowel reduction

	Base	Weight Assignment	Trochaic Footing	Reduction
i.	hɔ.rɔʁ	hɔ$^{\mu}$.rɔ$^{\mu\mu}$ʁ	hɔ$^{\mu}$.[rɔ$^{\mu\mu}$ʁ]	hɔ.[rɔʁ]
ii.	ʃɔ.mɔr.ti	ʃɔ$^{\mu}$.mɔ$^{\mu}$r.ti$^{\mu\mu}$	ʃɔ$^{\mu}$.[mɔ$^{\mu\mu}$r].[ti$^{\mu\mu}$]	ʃɔ.[mɔr].[ti]

The resulting metrical structure in both items in (38b) contains only bi-moraic feet. There are no metrically weak positions, and therefore there is no reduction (inalterability; Hayes 1986). This is the common state of affairs in pausal forms which span up to 4 syllables.

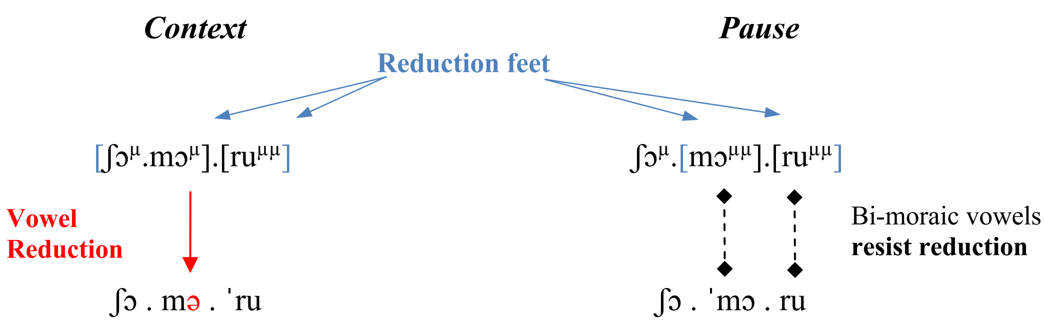
However, given a longer word such as /lə.hɔ.rɔ.ʁɛ.χɔ/ 'to kill you' which is long enough to host 3 feet – vowel reduction will manifest in a pausal form. The metrical parsing will result in: lə$^{\mu}$.[hɔ$^{\mu}$.rɔ$^{\mu}$].[ʁɛ$^{\mu\mu}$].[χɔ$^{\mu\mu}$] – crucially where the leftmost trochee is disyllabic, targeting the antepenultimate syllable [rɔ] for vowel reduction. Following is a schematic derivation process of both contextual and pausal allomorphs of /lə.hɔ.rɔ.ʁɛ.χɔ/. While this study adheres to the parallel grammar framework of the Optimality Theory (Prince & Smolensky 1993), the following derivational representation is nevertheless useful for the means of depicting the argument (see formal OT analysis in §5).

(39) Schematic derivation: Deriving both allomorphs from a common base

		Context לַהֲרָגְךָ	***Pause*** לְהָרְגֶךָ
	Base	lə . hɔ . rɔ . gɛ . χɔ	lə . hɔ . rɔ . gɛ . χɔ
VR	weight assignment	lə$^{\mu}$.hɔ$^{\mu}$.rɔ$^{\mu}$.ʁɛ$^{\mu}$.χɔ$^{\mu\mu}$	lə$^{\mu}$.hɔ$^{\mu}$.rɔ$^{\mu}$.ʁɛ$^{\mu\mu}$.χɔ$^{\mu\mu}$
	trochaic footing	[lə$^{\mu}$.hɔ$^{\mu}$].[rɔ$^{\mu}$.ʁɛ$^{\mu}$].[χɔ$^{\mu\mu}$]	lə$^{\mu}$.[hɔ$^{\mu}$.rɔ$^{\mu}$].[ʁɛ$^{\mu\mu}$].[χɔ$^{\mu\mu}$]
	trochaic reduction	[la.hă].[rɔ.ʁə].[χɔ]	lə.[hɔ.rə].[ʁɛ].[χɔ]
Stress	weight assignment	la$^{\mu}$.hă$^{\mu}$.rɔ$^{\mu}$.ʁə$^{\mu}$.χɔ$^{\mu}$	lə$^{\mu}$.hɔ$^{\mu}$.rə$^{\mu}$.ʁɛ$^{\mu}$.χɔ$^{\mu}$
	trochaic footing	la$^{\mu}$.hă$^{\mu}$.rɔ$^{\mu}$.[ʁə$^{\mu}$.χɔ$^{\mu}$]	lə$^{\mu}$.hɔ$^{\mu}$.rə$^{\mu}$.[ʁɛ$^{\mu}$.χɔ$^{\mu}$]
	Stress assignment	la.hă.rɔ.ʁə.ˈχɔ	lə.hɔ.rə.ˈʁɛ.χɔ

The crucial point of divergence in the derivation processes of the two allomorphs is the stage of "VR weight assignment". The assignment of an extra mora to the penultimate syllable in the pausal form renders its vowel non-reducible. The rest of the derivation process follows from standard parsing to trochaic feet and application of vowel reduction at the weak positions. The same schematic derivation process is shortly summarized in the following diagram:

(40) Schematic derivation: Deriving both allomorphs from a common base



5 Optimality Theory Analysis

This chapter presents a formal account for the analysis proposed above in §3 and §4, addressing stress assignment, vowel reduction, phrase-final lengthening and their interaction. The formal analysis is couched in the framework of the Optimality Theory (Prince & Smolensky 1993/2004; McCarthy & Prince 2004).

As proposed in §4, Tiberian Hebrew features a multi-planar metrical system, which employs phenomenon-specific syllable weight schemes for stress assignment and vowel reduction. Bearing on the proposed multi-planar metrical system, the grammar of weight assignment and metrical parsing are given a formal account for stress and vowel reduction separately in §5.1 and §5.2. Thereafter, the interaction between stress assignment and vowel reduction is given a conjoined formalization in §5.3. The subsections of §5.3 (§5.3.1 to §5.3.6) present detailed accounts for the derivation of pausal and contextual forms for the various word structures discussed in this study. Finalizing the analysis, the proposed grammar is summarized in §5.3.7 by presenting and discussing crucial constraint interactions.

5.1 The metrics of stress

Tiberian Hebrew stress resides within a disyllabic window at the right edge of the word (Hayes 1995; see §2.1). Stress is final if the ultimate syllable is closed (CVC), otherwise stress is penultimate. The following table presents the distribution of stress positions as a function of the syllable structure within the disyllabic window.

(41) Stress pattern as a function of syllable structure

	Stress window	***Pausal stress***	***Context stress***
a.	… CV.CVC	Final	Final
b.	… CVC.CVC	Final	Final
c.	… CV.CV	Penultimate	Final
d.	… CVC.CV	Penultimate	Penultimate

These stress patterns show that CVC syllables attract stress. A final CVC syllable is stressed regardless of the preceding syllable (a, b); in the absence of a final CVC syllable, the penultimate syllable is stressed (d). The context form in (c) does not follow this generalization, as the final CV is stressed, thus contrasting with the pausal counterpart where stress is penultimate as expected. However, this apparent surface exception is derived. In a disyllabic window with two light syllables, a full vowel in the pausal form alternates with a schwa in the context form, where the schwa results from vowel reduction, e.g. [ʃɔ.ˈmɔ.ru]$_{\text{pause}}$ vs. [ʃɔ.mə.ˈru]$_{\text{context}}$ ‘kept$_{\text{3MPL}}$’. Since a schwa cannot be stressed in Tiberian Hebrew (see §3.1 and §3.4.3), stress shifts to the final syllable. Therefore, the grammar of stress assignment is in fact identical for both context and pausal forms, and the difference between the patterns in the CV.CV window is formally accounted for by the interaction between vowel reduction and stress (see §5.3 below).

5.1.1 Weight Assignment

I have argued that the base of both pausal and context forms is an abstract underlying representation, as there are cases where one cannot be derived from the other (see §3.5). The underlying representation includes minimal moraic specification, just what is required to represent phonemic contrast (Hayes 1989). Length contrast for vowels is not assumed (see §3.1), and therefore vowels are not moraic in the underlying representation; every vowel is assigned a mora in the course of the derivation. Also, the contrast between high vowels and glides is predictable on the basis of syllable structure, so there is no need for underlying contrast specification. There is, however, phonemic contrast between geminates and singletons (e.g. שִׁלֵּם [ʃallɛm] 'amend' vs. שָׁלֵם [ʃɔlɛm] 'complete', שִׁוָּה [ʃiwwɔ] 'level' vs. שָׁוָה [ʃɔwɔ] 'proper') and therefore geminates are underlyingly moraic.

The grammar of weight assignment for the purposes of stress employs the following constraints:

(42) Weight constraints and ranking

a. **WEIGHT-BY-POSITION (W-BY-P)**: Codas are moraic (Hayes 1995)

b. **DEP-μ**: Every mora of the output has a correspondent in the input (McCarthy & Prince 1995)

c. Ranking: **W-by-P » DEP-μ**

The two constraints in (42) are in conflict, while W-BY-P requires to add a mora to a coda, DEP-μ penalizes for the addition of a mora. Thus, in order for moraic codas to surface, the ranking between these two constraints must be **W-by-P » DEP-μ.** For brevity, I do not mark violations of **DEP-μ** for vowels, and do not include candidates with non-moraic vowels.

(43) Weight assignment

a. [ʔɔ ˈmɔr] אָמָר 'said $_{3MSG}$'

/ ʔɔmɔr /	W-BY-P	DEP-μ
a. ʔɔ^{μ}.mɔ^{μ}r	*!	
b. ʔɔ^{μ}.mɔ^{μμ}r	*!	*
☞ c. ʔɔ^{μ}.mɔ^{μ}r^{μ}		*

b. [ʃɔ ˈmɔrti] שָׁמַרְתִּי ‘kept 1MSG’

/ ʃɔmɔrti /	W-BY-P	DEP-μ
a. $ʃɔ^{μ}.mɔ^{μ}r.ti^{μ}$	*!	
☞ b. $ʃɔ^{μ}.mɔ^{μ}r^{μ}.ti^{μ}$		*
c. $ʃɔ^{μ}.mɔ^{μ}r^{μ}.ti^{μμ}$		**!

c. [ʃɔmɔ ˈru] שָׁמְרוּ ‘kept 3MPL’

/ ʃɔmɔru /	W-BY-P	DEP-μ
☞ a. $ʃɔ^{μ}.mɔ^{μ}.ru^{μ}$		
b. $ʃɔ^{μ}.mɔ^{μμ}.ru^{μ}$		*!
c. $ʃɔ^{μ}.mɔ^{μ}.ru^{μμ}$		*!

As shown, morae can be inserted only when mandated by W-BY-P. In all other cases, the violation of DEP-μ is unjustified and the relevant candidate is eliminated.

5.1.2 Metrical parsing

The grammar of metrical feet construction for the purposes of stress assignment employs the following constraints:

(44) Metrical parsing constraints and ranking for stress assignment

a. **FTBIN** – Feet are binary on the moraic or syllable level (Prince & Smolensky 1993)

b. **TROCHEE** – Feet are trochaic, i.e. left-headed (Prince & Smolensky 1993)

c. **WEIGHT-TO-STRESS (W-TO-S)** – Heavy syllables are stressed (Prince & Smolensky 1993)

d. **PARSE-σ** – A syllable is parsed into a metrical foot (Prince & Smolensky 1993)

e. **ALIGNR(FT, PRWD)** – The right edge of the foot is aligned with the right edge of a prosodic word (McCarthy & Prince 1993/2004)

f. Ranking: **FTBIN , W-TO-S ,TROCHEE » PARSE-σ » ALIGNR(FT, PRWD)**

WEIGHT-BY-POSITION (42a) and WEIGHT-TO-STRESS (44c) are undominated and therefore, I hereafter exclude candidates that violate these constraints.[16] Degenerate feet are not allowed, this is formalized by the undominated status of FTBIN.

(45) Metrical parsing for stress

a. CV final forms – [ʔɔˈmɔr] אָמַר ‘said$_{3MSG}$’

/ ʔɔmɔr /	FTBIN	W-TO-S	TROCHEE	PARSE-σ	ALIGNR (FT, PRWD)
a. [ˈʔɔ$^{\mu}$].mɔ$^{\mu}$r$^{\mu}$	*!			*	*
b. [ˈʔɔ$^{\mu}$.mɔ$^{\mu}$r$^{\mu}$]		*!			
c. [ʔɔ$^{\mu}$.ˈmɔ$^{\mu}$r$^{\mu}$]			*!		
☞ d. ʔɔ$^{\mu}$.[ˈmɔ$^{\mu}$r$^{\mu}$]				*	

b. CVC.CV final forms – [ʃɔˈmɔrti] שָׁמַרְתִּי ‘kept$_{1MSG}$’

/ ʃɔmɔrti /	FTBIN	W-TO-S	TROCHEE	PARSE-σ	ALIGNR (FT, PRWD)
a. [ˈʃɔ$^{\mu}$].mɔ$^{\mu}$r$^{\mu}$.ti$^{\mu}$	*!	*		**	**
b. ʃɔ$^{\mu}$.mɔ$^{\mu}$r$^{\mu}$.[ˈti$^{\mu}$]	*!	*		**	
c. [ˈʃɔ$^{\mu}$.mɔ$^{\mu}$r$^{\mu}$.ti$^{\mu}$]	*!	*			
d. [ˈʃɔ$^{\mu}$.mɔ$^{\mu}$r$^{\mu}$].ti$^{\mu}$		*!		*	*
e. [ʃɔ$^{\mu}$.ˈmɔ$^{\mu}$r$^{\mu}$].ti$^{\mu}$			*!	*	*
f. ʃɔ$^{\mu}$.[mɔ$^{\mu}$r$^{\mu}$.ˈti$^{\mu}$]		*!	*		*
g. ʃɔ$^{\mu}$.[ˈmɔ$^{\mu}$r$^{\mu}$].ti$^{\mu}$				**!	*
☞ h. ʃɔ$^{\mu}$.[ˈmɔ$^{\mu}$r$^{\mu}$.ti$^{\mu}$]				*	

[16] In some morphological classes such as contextual *wajjiqtol* (e.g. [waj.ˈje.lɛχ] ‘will go’), morphological constraints (which are not be elaborated upon here) override regular stress placement, yielding penultimate stress albeit the presence of a heavy final syllable. These exceptional cases are not considered here.

c. *CV.CV final forms* – [ʃɔmɔˈru] שָׁמָרוּ ‘kept$_{3MPL}$’

/ ʃɔmɔru /	FTBIN	W-TO-S	TROCHEE	PARSE-σ	ALIGNR (FT, PRWD)
a. [ˈʃɔ$^{\mu}$].mɔ$^{\mu}$.ru$^{\mu}$	*!			**	**
b. ʃɔ$^{\mu}$.mɔ$^{\mu}$.[ˈru$^{\mu}$]	*!			**	
c. [ˈʃɔ$^{\mu}$.mɔ$^{\mu}$.ru$^{\mu}$]	*!				
d. [ˈʃɔ$^{\mu}$.mɔ$^{\mu}$].ru$^{\mu}$				*	*!
e. [ʃɔ$^{\mu}$.ˈmɔ$^{\mu}$].ru$^{\mu}$			*!	*	*
f. ʃɔ$^{\mu}$.[mɔ$^{\mu}$.ˈru$^{\mu}$]			*!	*	
☞ g. ʃɔ$^{\mu}$.[ˈmɔ$^{\mu}$.ru$^{\mu}$]				*	

The optimal candidate in (45c) is a pausal form. Recall from §3.4.1 that context forms ending with two open syllables bear final stress due to vowel reduction and the prohibition on stress on schwas (see analysis in §5.3.5 and §5.3.6).

I do not attend here to secondary stress, often marked by the Masoretic with a diacritic *Meteg* (McCarthy et al. 1985; Dresher 1981, 2009; Khan 1987). A long word, such as the contextual אֲשַׁלֵּחֲךָ /ʔă.ʃal.le.ħɛ.χɔ/, is thus parsed as ʔă.[ˌʃal.le].[ħă.ˈχɔ] ‘send $_{1SG}$ you’. I do not attend to secondary stress because it is only sporadically marked and it does not interact with vowel reduction, thus having no effect on the attested surface forms. Therefore, in the tableaux presented here, the stress plane includes only one foot (for primary stress), but I assume exhaustive footing in both metrical planes – stress and vowel reduction.

5.2 The metrics of vowel reduction

Vowel reduction in Tiberian Hebrew applies rhythmically, in an alternating manner in both the contextual and pausal allomorphs (see §4.3 and §4.4). Phonetically long vowels are parsed into bi-moraic metrical feet, and therefore are exempt from reduction since only vowels in weak positions are affected by vowel reduction (see §4.2). As the position of the word in the phrase is crucial for pause–context allomorphy, the tableaux in this section (§5.2) present two inputs – one at the end of the intonational phrase (marked by “]$_{IP}$”) and the other elsewhere (not marked).

5.2.1 Weight Assignment

The grammar of weight assignment for the purposes of vowel reduction employs the following constraints:

(46) Vowel reduction constraints and ranking

a. **$*V^{\mu}]_{\omega}$** – No mono-moraic word-final vowel.

b. **$*ˈV^{\mu}]_{IP}$** – No mono-moraic vowel in the rightmost stressed syllable of the I-phrase.

c. **DEP-μ** – Every output mora has an input correspondent (Prince & Smolensky 1993)

d. Ranking: **$*ˈV^{\mu}]_{IP}$, $*V^{\mu}]_{\omega}$ » DEP-μ » W-BY-P**

The constraint **$*V^{\mu}]_{\omega}$** refers to a word-final vowel, which is adjacent to the prosodic word boundary. In contrast, **$*ˈV^{\mu}]_{IP}$** does not refer to a phrase-final vowel, but rather to the rightmost stressed vowel in the phrase. Additional segments may appear between the referenced stressed vowel and the boundary of the intonational phrase; e.g. in $ʃɔ^{\mu}.ˈmɔ^{\mu}.ru^{\mu}]_{\omega}]_{IP}$ the relevant vowel is the stressed [ɔ] in the penultimate syllable.

DEP-μ here refers to the metrical plane of vowel reduction. The difference in the grammar of weight assignment between stress and vowel reduction is accounted for by assuming different constraint ranking. For stress, closed syllables are bi-moraic, as they attract stress (see §5.1). Therefore, coda consonants are assigned with an additional mora, i.e. W-BY-P » DEP-μ. Conversely, vowel reduction assigns additional morae on the basis of phonetic vowel duration, not syllable structure, i.e. DEP-μ » W-BY-P. Thus, these two constraints are flipped in their ranking in respect to each other. Moreover, for vowel reduction the two constraints that embody the effects of final lengthening, i.e. $*V^{\mu}]_{\omega}$, and $*ˈV^{\mu}]_{IP}$ are ranked above DEP-μ.

Both, the Cophonology Theory (Inkelas 1998, 2008) and the Indexed Constraint Theory (Pater 2000, 2009; Ito & Mester 2008) can account for grammatical inconsistencies. Commonly, these theories are employed to account for exceptionality and specific behavior of a morphological class. Both approaches are equally suitable for the purposes of the current study, thus the choice is not crucial for the argument at hand. Having said that, the current study employs co-phonologies for the formalization of the differences in the grammar of weight assignment between the metrical planes of stress and vowel reduction. The account provided here adheres to the restricted version of cophonologies proposed by Anttila (2002), which allows ranking differences only where the relevant constraints are unranked in the master grammar which applies throughout the entire language (see §5.3.7.1 for further discussion).

To account for the complex pattern of moraic projection, the grammar of weight assignment is allowed to refer to other levels in the prosodic hierarchy (see §2.4). For example, contour tone in Lhasa Tibetan is licensed on CVV and CVR syllables (R=Sonorant), but not CVC syllables (C=Stop). This suggests contour tone requires a structure where two consecutive prosodic slots are associated with the segmental feature [+son]. In other words, weight assignment for the purposes of tone refers to the segmental tier, thus it is able to distinguish between sonorant and non-sonorant consonants.

(47) Moraic projection in different structures of a CVC syllable

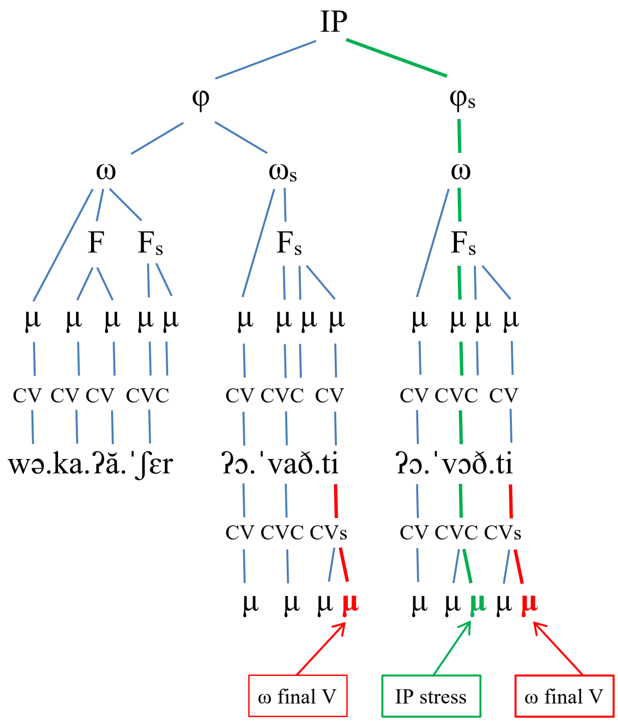
a. CVV	b. CVR	c. CVC
μ μ	μ μ	μ ~~μ~~
C V V	C V R	C V C
[+son]	[+son] [+son]	[+son]

In the classic case, the moraic projection for each CV slot is determined by its position within the syllable. Additionally, the ranking of constraints such as W-BY-P determine the moraic status of coda consonants. However, if the projection of a mora can be conditioned by its association with segmental features, the grammar of weight assignment must refer to more complex structures. In the case of contour tone licensing, it is necessary to refer to both the CV slot and the segmental tiers to determine whether a mora is to be projected. As exemplified above in (47), the conditions for the projection of two morae are met only in items (a) and (b), thus contour tone is licensed only in these two structures. This analysis can be used to formalize the grammars of various phenomenon-specific weight assignment schemes (Gordon 2006; Rayan 2019; see §2.4).

For the purposes of weight assignment for Tiberian Hebrew vowel reduction, I assume that the projection of additional morae (beyond the basic one-mora-per-vowel) requires a structure where a V slot is associated with a prosodic position which is phonologically prominent due to final lengthening. This analysis follows the Structural Prominence approach to the phonetics-phonology interface (see §2.3.3 and §2.3.6), according to which prosodic structure is assumed to include abstract prominence features such as [strong]. Prominence features are assumed to exist at different levels of the prosodic hierarchy. For example, at the foot level, the feature [strong] distinguishes between trochaic and iambic feet. At the word level, [strong] marks the foot which bears primary stress. At the phrase level, it marks the word which bears phrasal stress/focus.

Diagram (48) presents the prosodic parsing of an intonational phrase. The structure that extends upwards corresponds to the stress metrical plane; the structure that extends downwards represents the vowel reduction metrical plane. Strong prosodic positions are marked by a subscript "s" (e.g. φ_s or F_s).

(48)   Prosodic structure of an intonational phrase



... וְכַאֲשֶׁר אָבַדְתִּי אָבָדְתִּי (אסתר ד, טז)

wə.ka.ʔă.ˈʃɛr	ʔɔ.ˈvað.ti	ʔɔ.ˈvɔð.ti
and if	perish $_{1SG}$	perish $_{1SG}$

… and if I perish, I perish. (Esther 4:16)

Note that the word /ʔɔ.vɔð.ti/ ‘worked $_{1SG}$’ appears twice; the first occurrence is a contextual form [ʔɔ.ˈvað.ti] and the second is a pausal form [ʔɔ.ˈvɔð.ti]. In both occurrences of this word, an additional mora is projected by the word-final vowel (marked in red). This occurs because the word-final vowel is affected by final lengthening (§2.2.1), and thus, at the phonological level, it is assigned with the [strong] feature. Moreover, the pausal form’s stressed vowel also projects an additional mora (marked in green). This occurs because this vowel is the rightmost stressed vowel in the entire I-phrase, and thus it is also affected by final-lengthening – but at the IP level.

Thus, the grammar of weight assignment for the vowel reduction plane depends on higher prosodic levels, namely, the word-level and the IP-level. This behavior is embodied by the constraints **$*ˈV^{\mu}]_{IP}$** and **$*V^{\mu}]_{\omega}$** proposed in (46). At the word-level, **$*V^{\mu}]_{\omega}$** propagates that a final vowel is bi-moraic, this is supported by the significant duration increase incurred by final lengthening (see §2.2.1). On the I-phrase level, **$*ˈV^{\mu}]_{IP}$** propagates that the rightmost stressed vowel under the I-phrase must be bi-moraic. I use the phrasing “rightmost stressed vowel” because it corresponds to the phrasing used by studies of final lengthening (Turk & Shattuck-Hufnagel 2007). However, the same vowel can be describes as bearing the I-phrase stress, as predicted by phrase-level stress models such as the NSR (Chomsky & Halle 1968) and its later developments (Liberman & Prince 1977; Gussenhoven 1992; Cinque 1993; see Truckenbrodt 2006 for survey).

The following tableaux assume the stress patterns analyzed above in §5.1. Therefore, stress-related constraints are ignored, and the candidates are marked for the attested stress pattern.

(49) Vowel reduction weight assignment

a. CVC final forms – [ʔɔˈmɔr] אָמָר ‘said$_{3MSG}$’

/ ʔɔmɔr /	*V$^{\mu}$]$_{\omega}$	*ˈV$^{\mu}$]$_{IP}$	DEP-μ	W-BY-P
☞ a. ʔɔ$^{\mu}$.ˈmɔ$^{\mu}$r				*
b. ʔɔ$^{\mu}$.ˈmɔ$^{\mu}$r$^{\mu}$			*!	
/ ʔɔmɔr /]$_{IP}$	*V$^{\mu}$]$_{\omega}$	*ˈV$^{\mu}$]$_{IP}$	DEP-μ	W-BY-P
a. ʔɔ$^{\mu}$.ˈmɔ$^{\mu}$r		*!		*
b. ʔɔ$^{\mu}$.ˈmɔ$^{\mu}$r$^{\mu}$		*!	*	
☞ c. ʔɔ$^{\mu}$.ˈmɔ$^{\mu\mu}$r			*	*

b. CVC.CV final forms – [ʃɔˈmɔrti] שָׁמָרְתִּי ‘kept$_{1MSG}$’

/ ʃɔmɔrti /	*V$^{\mu}$]$_{\omega}$	*ˈV$^{\mu}$]$_{IP}$	DEP-μ	W-BY-P
a. ʃɔ$^{\mu}$.ˈmɔ$^{\mu}$r.ti$^{\mu}$	*!			*
b. ʃɔ$^{\mu}$.ˈmɔ$^{\mu}$r$^{\mu}$.ti$^{\mu}$	*!		*	
c. ʃɔ$^{\mu}$.ˈmɔ$^{\mu}$r$^{\mu}$.ti$^{\mu\mu}$			**!	
☞ d. ʃɔ$^{\mu}$.ˈmɔ$^{\mu}$r.ti$^{\mu\mu}$			*	*
/ ʃɔmɔrtɔ /]$_{IP}$	*V$^{\mu}$]$_{\omega}$	*ˈV$^{\mu}$]$_{IP}$	DEP-μ	W-BY-P
a. ʃɔ$^{\mu}$.ˈmɔ$^{\mu}$r.ti$^{\mu}$	*!	*		*
b. ʃɔ$^{\mu}$.ˈmɔ$^{\mu}$r$^{\mu}$.ti$^{\mu}$	*!	*		
c. ʃɔ$^{\mu}$.ˈmɔ$^{\mu}$r$^{\mu}$.ti$^{\mu\mu}$		*!	**	
d. ʃɔ$^{\mu}$.ˈmɔ$^{\mu}$r.ti$^{\mu\mu}$		*!	*	*
e. ʃɔ$^{\mu}$.ˈmɔ$^{\mu\mu}$r$^{\mu}$.ti$^{\mu\mu}$			***!	
☞ f. ʃɔ$^{\mu}$.ˈmɔ$^{\mu\mu}$r.ti$^{\mu\mu}$			**	*

b. CV.CV final forms – [ʃɔmɔˈru] שָׁמְרוּ ‘kept$_{3MPL}$’

/ ʃɔmɔru /	*V$^{\mu}$]$_{\omega}$	*ˈV$^{\mu}$]$_{IP}$	DEP-μ	W-BY-P
a. ʃɔ$^{\mu}$.mɔ$^{\mu}$.ˈru$^{\mu}$	*!			
b. ʃɔ$^{\mu}$.mɔ$^{\mu\mu}$.ˈru$^{\mu}$	*!		*	
c. ʃɔ$^{\mu}$.mɔ$^{\mu\mu}$.ˈru$^{\mu\mu}$			**!	
☞ d. ʃɔ$^{\mu}$.mɔ$^{\mu}$.ˈru$^{\mu\mu}$			*	
/ ʃɔmɔru /]$_{IP}$	***V$^{\mu}$]$_{\omega}$**	***ˈV$^{\mu}$]$_{IP}$**	**DEP-μ**	**W-BY-P**
a. ʃɔ$^{\mu}$.ˈmɔ$^{\mu}$.ru$^{\mu}$	*!	*		
b. ʃɔ$^{\mu}$.ˈmɔ$^{\mu}$.ru$^{\mu\mu}$		*!	*	
c. ʃɔ$^{\mu}$.ˈmɔ$^{\mu\mu}$.ru$^{\mu}$	*!		*	
☞ d. ʃɔ$^{\mu}$.ˈmɔ$^{\mu\mu}$.ru$^{\mu\mu}$			**	

The violation of DEP-μ due to the insertion of additional morae is mandated by *V$^{\mu}$]$_{\omega}$ and *ˈV$^{\mu}$]$_{IP}$, which trigger final vowel lengthening via mora addition, where the lengthened vowel is either in the rightmost open syllable of the word or the rightmost stressed syllable in the phrase. The W-BY-P constraint is not functional in this case as coda consonants do not contribute weight on the vowel reduction plane.

5.2.2 Metrical parsing

The grammar of metrical feet construction for the purposes of vowel reduction employs the same constraints and ranking used for stress feet construction (44). WEIGHT-TO-STRESS (W-TO-S) is, of course, not relevant for vowel reduction and therefore not mentioned below. I assume, however, one constraint ranking for both stress and vowel reduction (see (64)).

(50) Constraints and ranking for metrical feet for vowel reduction

a. **FTBIN** – Feet are binary on the moraic or syllabic level (Prince & Smolensky 1993)

b. **TROCHEE** – Feet are trochaic (Prince & Smolensky 1993)

c. **PARSE-σ** – All syllables are parsed into metrical feet (Prince & Smolensky 1993)

d. **ALIGNR(FT, PRWD)** – The right boundary of a foot is aligned to the right boundary of a prosodic word (McCarthy & Prince 2004)

e. Ranking: **FTBIN , TROCHEE , PARSE-σ » ALIGNR(FT, PRWD)**

Notice that TROCHEE here refers purely to weight contrast within a metrical foot, it has nothing to do with stress because the grammar in (50) is specific to vowel reduction. However, feet construction for the vowel reduction plane employs the same constraint ranking. The method of feet construction presented here is similar to the right-to-left scheme, where the word is parsed starting from the right edge and each foot is closed once two morae or two syllables are included in it. Degenerate feet are not allowed, this is formalized by the undominated status of FTBIN. I implicitly assume that moraic feet are preferred over syllabic feet, and therefore exclude candidates that construct quadri-moraic feet, e.g. ʃɔ$^{\mu}$.[mɔ$^{\mu\mu}$r.ti$^{\mu\mu}$].

(51) Vowel reduction metrical parsing

a. CVC final forms - [ʔɔmɔr] אָמַר ‘said$_{3MSG}$’

/ ʔɔmɔr /	FTBIN	TROCHEE	PARSE-σ	ALIGNR(FT, PRWD)
a. [ʔɔ$^{\mu}$].mɔ$^{\mu}$r	*!		*	*
b. ʔɔ$^{\mu}$.[mɔ$^{\mu}$r]	*!		*	
☞ c. [ʔɔ$^{\mu}$.mɔ$^{\mu}$r]				

/ ʔɔmɔr /]$_{IP}$	FTBIN	TROCHEE	PARSE-σ	ALIGNR(FT, PRWD)
a. [ʔɔ$^{\mu}$].mɔ$^{\mu\mu}$r	*!		*	*
b. [ʔɔ$^{\mu}$.mɔ$^{\mu\mu}$r]		*!		
☞ c. ʔɔ$^{\mu}$.[mɔ$^{\mu\mu}$r]			*	

b. CVC.CV final forms - [ʃɔmɔrti] שָׁמַרְתִּי ‘kept$_{1MSG}$’

/ ʃɔmɔrti /	FTBIN	TROCHEE	PARSE-σ	ALIGNR(FT, PRWD)
a. [ʃɔ$^{\mu}$].mɔ$^{\mu}$r.ti$^{\mu\mu}$	*!		**	**
b. ʃɔ$^{\mu}$.[mɔ$^{\mu}$r].ti$^{\mu\mu}$	*!		**	*
c. ʃɔ$^{\mu}$.mɔ$^{\mu}$r.[ti$^{\mu\mu}$]			*!*	
d. [ʃɔ$^{\mu}$.mɔ$^{\mu}$r].ti$^{\mu\mu}$			*!	*
e. ʃɔ$^{\mu}$.[mɔ$^{\mu}$r.ti$^{\mu\mu}$]		*!	*	
☞ f. [ʃɔ$^{\mu}$.mɔ$^{\mu}$r].[ti$^{\mu\mu}$]				*

/ ʃɔmɔrtɔ /]$_{IP}$	FTBIN	TROCHEE	PARSE-σ	ALIGNR(FT, PRWD)
a. [ʃɔ$^{\mu}$].mɔ$^{\mu\mu}$r.ti$^{\mu\mu}$	*!		**	**
b. ʃɔ$^{\mu}$.[mɔ$^{\mu\mu}$r].ti$^{\mu\mu}$			*!*	*
c. ʃɔ$^{\mu}$.mɔ$^{\mu\mu}$r.[ti$^{\mu\mu}$]			*!*	
d. [ʃɔ$^{\mu}$.mɔ$^{\mu\mu}$r].ti$^{\mu\mu}$		*!	*	*
e. [ʃɔ$^{\mu}$.mɔ$^{\mu\mu}$r].[ti$^{\mu\mu}$]		*!		*
f. [ʃɔ$^{\mu}$].[mɔ$^{\mu\mu}$r].[ti$^{\mu\mu}$]	*!			***
☞ g. ʃɔ$^{\mu}$.[mɔ$^{\mu\mu}$r].[ti$^{\mu\mu}$]			*	*

c. *CV.CV final forms* - [ʃɔmɔru] שָׁמְרוּ ‘kept $_{3MPL}$’

/ ʃɔmɔru /	FTBIN	TROCHEE	PARSE-σ	ALIGNR(FT, PRWD)
a. [ʃɔ$^{\mu}$].mɔ$^{\mu}$.ru$^{\mu\mu}$	*!		**	**
b. ʃɔ$^{\mu}$.[mɔ$^{\mu}$].ru$^{\mu\mu}$	*!		**	*
c. ʃɔ$^{\mu}$.mɔ$^{\mu}$.[ru$^{\mu\mu}$]			*!*	
d. [ʃɔ$^{\mu}$.mɔ$^{\mu}$].ru$^{\mu\mu}$			*!	*
e. ʃɔ$^{\mu}$.[mɔ$^{\mu}$.ru$^{\mu\mu}$]		*!	*	
☞ f. [ʃɔ$^{\mu}$.mɔ$^{\mu}$].[ru$^{\mu\mu}$]				*
/ ʃɔmɔru /]$_{IP}$	FTBIN	TROCHEE	PARSE-σ	ALIGNR(FT, PRWD)
a. [ʃɔ$^{\mu}$].mɔ$^{\mu\mu}$.ru$^{\mu\mu}$	*!		**	**
b. ʃɔ$^{\mu}$.[mɔ$^{\mu\mu}$].ru$^{\mu\mu}$			*!*	*
c. ʃɔ$^{\mu}$.mɔ$^{\mu\mu}$.[ru$^{\mu\mu}$]			*!*	
d. [ʃɔ$^{\mu}$.mɔ$^{\mu\mu}$].ru$^{\mu\mu}$		*!	*	*
e. [ʃɔ$^{\mu}$.mɔ$^{\mu\mu}$].[ru$^{\mu\mu}$]		*!	*	*
f. [ʃɔ$^{\mu}$].[mɔ$^{\mu\mu}$].[ru$^{\mu\mu}$]	*!		*!	***
☞ g. ʃɔ$^{\mu}$.[mɔ$^{\mu\mu}$].[ru$^{\mu\mu}$]			*	

5.3 The interaction of vowel reduction and stress

The previous sections laid the foundation for the analysis of stress and vowel reduction separately. However, as this study is couched in the parallel grammar framework of the Optimality Theory, no derivation steps are in fact supposed to occur in separation. The constraints employed to account for the segmental effects of vowel reduction are phrased in the style of Positional Markedness (Beckman 1997; Zoll 1998). The operation of these constraints is similar in essence to the Positional Licensing constraint family developed in Crosswhite (2004). However, they are rephrased to refer to the contrast of strong vs. weak positions of a metrical foot rather than to stress. The reference to strong vs. weak aims to reflect the interaction of vowel reduction with phonetic duration induced by final lengthening in the case of Tiberian Hebrew. Therefore, the proposed rephrased constraints can be viewed as a generalized version of Crosswhite’s Positional Licensing.

(52) Constraints and ranking for vowel reduction

a. ***V[MID]/WEAK** – No mid vowel in a weak position of a foot

b. ***V[F]/WEAK** – No vowel features in a weak position of a foot

c. **IDENTV** – Corresponding vowels have identical features (McCarthy & Prince 2004)

d. ***ə**^HEAD^ – Schwa is not a syllable head

e. Ranking: ***ə**^HEAD^ **, *V[MID]/WEAK » *V[F]/WEAK , IDENTV**

The constraint *V[MID]/WEAK penalizes for mid vowels in the weak position of a foot. The specific reference to mid vowels is grounded phonetically in the Dispersion Theory (Liljencrants & Lindblom 1972; Padgett & Tabain 2005), according to which corner vowels [a, i, u] show maximal dispersion, and hence minimal perceptional ambiguity. In other words, corner vowels are maximally discernable, while mid-vowels are inherently less discernable, especially in short durations. Typologically, many vowel reduction systems target mid vowels specifically, and reduction is achieved either by cornering towards [a, i, u] or centralization towards schwa (Barnes 2006; Crosswhite 2001, 2004; see §2.3.2). The schwa [ə] is not considered a mid-vowel for this purpose, as it is analyzed as a featureless vowel (see §3.1).

The constraint *V[F]/WEAK penalizes for any vowel feature in the weak position of a foot. This constraint embodies the motivation for minimizing articulatory effort and segmental complexity. The result of such reduction systems is the reduction of any vowel to schwa [ə] or a complete deletion of the vowel. This constraint corresponds the Prominence Reduction type in Crosswhite's (2001) two-fold reduction typology (see §2.3.2).

The ***ə**^HEAD^ constraint penalizes for any case where schwa occupies a head of a binary prosodic structure. This definition allows banning both stressed and closed syllables where schwa is the nucleus. Stressed syllables with schwa are banned as otherwise schwa would be the head of the prosodic word. Closed syllables are banned as otherwise schwa would be the head of the syllable's branching rhyme.

The schwa is the least sonorant vowel in the inventory of any language, making it the worst candidate to bear stress. Typologically, schwa [ə] is the most common output of vowel reduction across languages (Barnes 2006); it is typically considered the most unmarked vowel, bearing no featural specification (Anderson 1982; Flemming 2009). In Tiberian Hebrew, there are no stressed or closed syllables with schwa, i.e. ***ə**^HEAD^ never violated.

The candidates in the following tableaux are presented in three layers; the top layer represents the metrical parsing of the stress plane (annotated by "s"), the bottom layer represents the metrical parsing of the vowel reduction plane (annotated by "vr"), and the middle contains the surface form of the candidate. Moreover, following that DEP-μ is ranked differently within the co-phonologies of the different metrical planes, its violations are marked on separately on the layer corresponding to the respective plane.

5.3.1 Derivation of contextual CV.CVC-final forms

The following tableau presents the bi-planar analysis of the contextual form of the word /ʔɔmɔr/ ‘said 3MSG’.

(53) [ʔɔˈmar] אָמַר ‘said 3MSG’

/ ʔɔmɔr /	*Ə^{HEAD}	DEP-μ	*V/WEAK		IDENTV
			[MID]	[F]	
s μ [μμ] a. ʔɔ . ˈmɔr *vr* [μ μ]		*	*!	*	
s μ [μμ] b. ʔɔ . ˈmər *vr* [μ μ]	*!	*			*
s μ [μμ] ☞ c. ʔɔ . ˈmar *vr* [μ μ]		*		*	*

This tableau presents the derivation of contextual CVC-final forms, where the stressed ultimate syllable features a reduced vowel (ɔ ⇒ a). The segmentally faithful candidate (a) contains the mid-vowel [ɔ] in its ultimate syllable. On the vowel reduction plane, the metrical parsing of this candidate is [ʔɔ$^{\mu}$.ˈmɔ$^{\mu}$r], with the ultimate syllable in the weak position of the trochee. Therefore, this candidate violates both *V[MID]/WEAK and *V[F]/WEAK constraints. Candidate (b) solves the violation of these two constraints by reducing the [ɔ] in the weak position to [ə]; recall that a schwa is featureless, thus does not violate any constraints referring to features. However, this results in a stressed [ə], and thus candidate (b) is eliminated by the *Ə^{HEAD} constraint. Finally, candidate (c) is selected following its minimal violation of the vowel reduction constraints. It respects *V[MID]/WEAK because the vowel in the ultimate syllable is not a mid-vowel, but rather the low vowel [a]. However, it must violate *V[F]/WEAK to avoid a stressed schwa. The case presented here represents forms where a stress-attracting CVC syllable is present; it must be stressed, but its vowel cannot be reduced to schwa.

As presented in (14), where reduction targets a stressed CVC syllable, the resulting vowel quality is always [a]. This is not mandated by the *V[MID]/WEAK constraint, which could be satisfied with any corner vowel being the target of reduction. To account for such language specific behavior, Crosswhite (2001) invokes ad-hoc markedness scales which propagate in favor of some vowel qualities at the expense of others. In this case, the full grammar would include the following markedness scale: *i , *u » *a, which would force any emergent corner vowel to take the form [a]. Following that this behavior is consistent in Tiberian Hebrew, these markedness constraints are left out of the tableaux for the sake of brevity.

5.3.2 Derivation of pausal CV.CVC-final forms

The following tableau presents an analysis of the pausal form of the word /ʔɔmɔr/ ‘said $_{3ms}$’. To illustrate the completeness of the parallel grammar analysis presented here, the *ˈV$^{\mu}$]$_{IP}$ constraint is introduced into the tableau and the *Ə^{HEAD} constraint is omitted.

(54) [ʔɔˈmɔr] אָמָר ‘said$_{3MSG}$’

/ ʔɔmɔr /]$_{IP}$	*ˈV$^{\mu}$]$_{IP}$	DEP-μ	*V/WEAK [MID]	*V/WEAK [F]	IDENTV
s μ [μμ] a. ʔɔ . ˈmɔr *vr* [μ μ]	*!	*	*	*	
s μ [μμ] b. ʔɔ . ˈmar *vr* μ [μμ]		* *			*!
s μ [μμ] c. ʔɔ . ˈmər *vr* μ [μμ]		* *			*!
s μ [μμ] ☞ d. ʔɔ . ˈmɔr *vr* μ [μμ]		* *			

This tableau presents the derivation of pausal CV.CVC-final forms, where the stressed ultimate syllable is faithful to the vowel quality of the underlying base. In this tableau, candidate (a) does not conform to the proposed weight assignment scheme (developed above in §5.2.1). Instead, its ultimate syllable is assigned with only one mora. This state of weight assignment corresponds to the contextual form, but for the pausal form an additional mora has to be assigned to the stressed vowel. Therefore, candidate (a) is eliminated by the weight assignment constraint *ˈV$^{\mu}$]$_{IP}$. Candidates (b) and (c) feature a reduced vowel in their ultimate syllables, however in both forms the ultimate syllable is parsed into mono-syllabic foot. A mono-syllabic foot has no weak position, and therefore vowel reduction is not expected to occur. This parsing reflects the general notion of inalterability of bi-moraic vowels. The alternation of vowel quality in candidates (b) and (c) is thus unjustified, and therefore these candidates violate the IDENTV constraint. The winning candidate is (d), which preserves a segmental form which is faithful to the base, violating only the DEP-μ constraint due to the insertion of an additional mora to its stressed vowel – as final lengthening propagates through *ˈV$^{\mu}$]$_{IP}$. This tableau shows how CVC-final pausal forms are derived, while preserving their underlying vowel qualities. Vowel reduction is blocked due to the additional weight attributed to the ultimate syllable via phonetic lengthening of the IP-phrase-final stressed vowel.

5.3.3 Derivation of contextual CVC.CV-final forms

The following tableau presents an analysis of the contextual form of the word /ʃɔmɔrti/ ‘kept $_{\text{1ms}}$’.

(55) [ʃɔmarti] שָׁמַרְתִּי ‘kept $_{\text{1MSG}}$’

/ ʃɔmɔrti /	*Ə$^{\text{HEAD}}$	*V$^{\mu}$]$_{\omega}$	*V/WEAK		IDENTV
			[MID]	[F]	
s μ [μμ μ] a. ʃɔ . ˈmɔr . ti *vr* μ [μ μ]		*!	*	*	
s μ [μμ μ] b. ʃɔ . ˈmɔr . ti *vr* [μ μ] [μμ]			*!	*	
s μ [μμ μ] ☞ c. ʃɔ . ˈmar . ti *vr* [μ μ] [μμ]				*	*
s μ [μμ μ] d. ʃɔ . ˈmər . ti *vr* [μ μ] [μμ]	*!	*		*	*
s μ [μμ μ] e. ʃɔ . mər . ˈti *vr* [μ μ] [μμ]		*!		*	*

This tableau presents the derivation of contextual CV.CVC.CV forms, where the stressed penultimate syllable features a reduced vowel. Candidate (a) does not conform to the weight assignment scheme. Instead, its ultimate syllable is assigned with only one mora, violating *V$^{\mu}$]$_{\omega}$ which embodies the notion of word-level final lengthening. Candidate (b) features the mid-vowel [ɔ] in the penultimate syllable, which is also the weak position of the leftmost vowel reduction trochee. Thus, it is eliminated by the *V[MID]/WEAK constraint. Candidates (d) and (e) satisfy the vowel reduction constraints by boasting [ə] instead of the mid [ɔ] in the penultimate syllable. However, the resulting syllable structure is illegal, causing violation of *ƏC which does not allow closed syllables with a schwa nucleus. In the case of candidate (c), the *Ə$^{\text{HEAD}}$ is violated as well as the resulting form has a stressed schwa. The optimal candidate (b) allows a partial reduction of its stressed syllable – similarity to the behavior of CV.CVC forms (see §5.3.1). Any additional candidates involving different placement of stress like [ʃɔ.mar.ˈti] would be harmonically bound by the optimal candidate (c) as they would violate TROCHEE.

Comparing the behaviors of CV.CVC and CV.CVC.CV forms, it appears that the additional suffix syllable [tɔ] has no effect on the overall outcome. The word final open syllable is rendered bi-moraic due do word-level final lengthening. Thus, it is parsed into a mono-syllabic foot which is then exempt from vowel reduction. The parsing of the stem follows in the exact same manner which was shown for the non-suffixed CV.CVC form, resulting in the partial reduction of the vowel in the stressed CVC syllable to [a].

5.3.4 Derivation of pausal CVC.CV-final forms

The following tableau presents an analysis of the pausal form of the word /ʃɔmɔrti/ ‘kept $_{\text{1ms}}$’. The constraint $*V^{\mu}]_{\omega}$ is omitted from the tableau for brevity, accordingly, all presented candidates feature bi-moraic weight assignment to the vowel in the ultimate syllable on the vowel reduction plane.

(56) [ʃɔmɔrti] שָׁמָרְתִּי ‘kept $_{\text{1MSG}}$’

/ ʃɔmɔrti /]$_{\text{IP}}$	$*ə^{\text{HEAD}}$	$*ˈV^{\mu}]_{\text{IP}}$	*V/WEAK		IDENTV
			[MID]	[F]	
s μ [μμ μ] a. ʃɔ . ˈmɔr . ti *vr* [μ μ] [μμ]		*!	*	*	
s μ [μμ μ] ☞ b. ʃɔ . ˈmɔr . ti *vr* μ [μμ] [μμ]					
s μ [μμ μ] c. ʃɔ . ˈmar . ti *vr* μ [μμ] [μμ]					*!
s μ [μμ μ] d. ʃɔ . ˈmər . ti *vr* μ [μμ] [μμ]	*!*				*
s μ [μμ μ] e. ʃɔ . mər . ˈti *vr* μ [μμ] [μμ]	*!				*

This tableau presents the derivation of pausal CV.CVC.CV forms, where the stressed penultimate syllable is faithful to the vowel quality of the underlying base. Candidate (a) does not conform to the weight assignment scheme. Instead, its penultimate syllable is assigned with only one mora, violating $*ˈV^{\mu}]_{\text{IP}}$ which embodies the notion of IP-phrase-level final lengthening. Candidates (d) and (e) are eliminated by $*ə^{\text{HEAD}}$ due to illegal syllable structures involving schwa. Candidate (c) is eliminated by IDENTV due to unjustified alternation of vowel quality and is in fact harmonically bound to candidate (b). The optimal candidate (b) does not introduce any alternations in compare to the underlying base. Both the ultimate and penultimate syllables are assigned two morae, resulting in two mono-syllabic feet which require no vowel reduction.

5.3.5 Derivation of contextual CV.CV-final forms

The following tableau presents an analysis of the contextual form of the word /ʃɔmɔru/ ‘kept $_{3mp}$’. The constraint *V$^{\mu}$]$_{\omega}$ is omitted from the tableau, and all candidates feature bi-moraic weight assignment to the vowel in the ultimate syllable on the vowel reduction plane. The constraint *ƏC is omitted as there is no syllabification which yields CVC syllables.

(57) [ʃɔməˈru] שָׁמְרוּ ‘kept$_{3MPL}$’

/ ʃɔmɔru /	*Ə$^{\text{HEAD}}$	Dep-μ	*V/Weak		Trochee	IdentV
			[mid]	[f]		
s μ [μ μ] a. ʃɔ . ˈmɔ . ru *vr* μ [μμ] [μμ]		**!				
s μ [μ μ] b. ʃɔ . ˈmɔ . ru *vr* [μ μ] [μμ]		*	*!	*		
s μ [μ μ] c. ʃɔ . ˈma . ru *vr* [μ μ] [μμ]		*		*!		*
s μ [μ μ] d. ʃɔ . ˈmə . ru *vr* [μ μ] [μμ]	*!	*				*
s μ [μ μ] ☞ e. ʃɔ . mə . ˈru *vr* [μ μ] [μμ]		*			*	*

This tableau presents the derivation of contextual CV.CV.CV forms, where the penultimate syllable is reduced to shwa and the position of stress is ultimate. Candidate (a) does not conform to the scheme of weight assignment as it inserts an additional mora to the penultimate vowel. This shows a crucial interaction between the weight assignment and the vowel reduction grammar parts. Namely, weight assignment constraints are undominated, i.e. they are never violated. Candidate (b) is eliminated by the vowel reduction constraint *V[mid]/Weak as it features a mid-vowel in the penultimate syllable, which is the weak position of the left vowel reduction trochee. The option of partial reduction of the penultimate vowel is presented in candidate (c), which is consequently eliminated by the *V[f]/Weak constraint. Candidate (d) features a further step of reduction, altering the underlying [ɔ] to schwa. However, stress cannot be maintained on a syllable with a schwa nucleus, and thus candidate (d) is eliminated by *Ə$^{\text{HEAD}}$. Finally, candidate (e) feature both reduction of the penultimate [ɔ] to schwa, and the alternation of stress position to the ultimate syllable. These alternations successfully avoid the violation of vowel both reduction constraints and *ə^HEAD – yielding the optimal form, at the expense of violating TROCHEE.

An alternative analysis would be to postulate that the effect of vowel reduction is incapacitating the moraic status of the reduced vowel on the stress plane – as proposed in Rappaport 1984). In such case, the alternation of stress position would violate FTBIN, creating a degenerate foot on the right edge of the prosodic word. However, such analysis would require assuming and defining a direct interface between the planes of stress and vowel reduction. Indeed, such proposal is introduced in Crosswhite (2001), namely that vowel reduction cancels the moraic status of the reduced vowel (on the stress plane). However, the proposal is not elaborated upon and it remains unclear how such inter-plane interactions are to be defined and characterized. Considering the complex typology of phenomenon-specific weight assignment schemes presented in Gordon (2006) and Ryan (2016, 2019) – assuming such direct interactions between parallel metrical planes will require a full-blown theory of the nature of interaction in multi-planar metrical systems. In parallel, independent motivation for the avoidance of stress on a schwa vowel is abundantly available (Anderson 1982; Flemming 2009). Therefore, following the principle of Occam's Razor – I propose not to assume any complex interaction between distinct metrical planes. Instead, the avoidance of stress placement on a schwa vowel is to be analyzed as an independent phonotactic constraint which pertains only to the metrical plane of stress.

This tableau presents the account for the inconsistency of stress pattern between the contextual and the pausal forms of CV.CV.CV words (see (42) in §5.1). The contextual form surfaces with ultimate stress due to the reduction of the penultimate vowel to schwa and the inability of schwa to bear stress. Consequently, the attested form surfaces with an iambic primary stress foot, instead of the expected trochee.

5.3.6 Derivation of pausal CV.CV-final forms

The following tableau presents an analysis of the pausal form of the word /ʃɔmɔru/ 'kept $_{3mp}$'. The constraint $*V^{\mu}]_{\omega}$ is omitted from the tableau, and all candidates feature bi-moraic weight assignment to the vowel in the ultimate syllable on the vowel reduction plane. The constraint ***ə^{HEAD}** is omitted here as it is not functional.

(58) [ʃɔmɔru] שָׁמָרוּ 'kept $_{3MPL}$'

/ ʃɔmɔru /]$_{IP}$	*ˈV$^{\mu}$]$_{IP}$	DEP-μ	*V/WEAK		TROCHEE	IDENTV
			[MID]	[F]		
s μ [μ μ] a. ʃɔ . ˈmɔ . ru *vr* μ μ] [μμ]	*!	 *	*	*		
s μ [μ μ] ☹ b. ʃɔ . ˈmɔ . ru *vr* μ [μμ] [μμ]		 **!				*
s μ [μ μ] ☞ c. ʃɔ . mə . ˈru *vr* [μ μ] [μμ]		 *				*

Attempting to use the same constraint grammar developed so far fails for the pausal form of /ʃɔmɔru/. The actual attested form is [ʃɔ.ˈmɔ.ru], however in this tableau the optimal candidate is [ʃɔ.mə.ˈru] – which is identical to the contextual form. Candidate (a) does not adhere to the scheme of weight assignment, as its penultimate stressed syllable is mono-moraic on the vowel reduction plane – it is eliminated by $*ˈV^{\mu}]_{IP}$. Candidates (b) and (c) resolve this violation by two different repair strategies. Candidate (b) satisfies $*ˈV^{\mu}]_{IP}$ by the insertion of an additional mora to the penultimate vowel. However, the insertion of an additional mora adds another crucial violation of DEP-μ. Candidate (c) avoids the violation of $*ˈV^{\mu}]_{IP}$ by alternation of stress position. The ultimate vowel is already bi-moraic due to the requirement of the undominated $*V^{\mu}]_{\omega}$. Therefore, if the ultima is stressed instead of the penultima, the violation of both $*ˈV^{\mu}]_{IP}$ and DEP-μ are avoided at the same time. Finally, candidate (c) is chosen as optimal instead of the actual attested form (b).

The missing element in the grammar presented so far is the avoidance of absolute phrase-final stress, which was discussed with reference to minor pausal forms in §3.7. The generalization is that pausal forms are never stressed on a final open syllable (CV). In the terminology of the Optimality Theory, this phenomenon is called Non-Finality (McCarthy & Prince 2004). Originally devised as a superseding theory for extrametricality, it propagates the avoidance of stress on final constituents. In contrast to extrametricality, the effect of Non-Finality is restricted to the position of stress, but not to alternative metrical parsing. For example, given a prosodic word such as

/ʃɔmɔru/, and assuming that the final syllable is never stressed - an extrametricality based account would create a metrical structure where the final syllable is not parsed into the stress foot, i.e. {[ʃɔ.mɔ].ru}. However, under a Non-Finality based account, the metrical parsing is not affected, the final foot incorporates the ultimate syllable, i.e. {ʃɔ.[mɔ.ru]}. However, a separate constraint propagates against stress placement on the final syllable. Since its inception, the theory of Non-Finality was further developed, allowing it to reference any kind of prosodic constituent. Hyde (2007) extends non-finality into a parameterizable constraints family of the scheme: NONFIN(CAT1, CAT2). The first parameter, CAT1, defines the prosodic category on which stress is avoided – e.g. the last syllable, mora, segment etc. The second parameter, CAT2, defined on which level of the prosodic hierarchy this Non-Finality effect operates – e.g. the syllable, prosodic word, phrase, utterance etc. The formal definition for the example above, where stress is avoided on the final syllable in a prosodic word is NONFIN(σ, PRWD).

Minor pausal forms were shown to avoid stress on a final CV, but otherwise allow stress on a final CVC. To capture this pattern the Non-Finality can be defined to reference the mora. At the metrical plane of stress, closed syllables are heavy, i.e. the final coda consonant is moraic. Therefore, the avoidance of stress on the final mora would yield exactly the attested pattern – ultimate stress for CVC-final forms, but penultimate stress for CV-final forms. Given that both minor and major pausal forms exhibit this pattern of stress – it can be assumed that this non-finality effect operates on the prosodic hierarchy levels of the phonological phrase and above. Finally, the proposed non-finality constraints are:

(59) Phrase-level non-finality constraints

a. **NONFIN[μ, φ]** – The final mora of a phonological phrase is not stressed (McCarthy & Prince 2004; Hyde 2007)

b. **NONFIN[μ, IP]** – The final mora of a intonational phrase is not stressed (McCarthy & Prince 2004; Hyde 2007)

The NONFIN[μ, φ] constraint operates at the level of the phonological phrase. Thus, it is irrelevant in the case of contextual forms, but relevant for both minor pausal forms. As major pausal forms are the main focus of this study, only the intonational phrase variant of the proposed non-finality constraints, NONFIN[μ, IP], is employed below. Incorporating this constraint into the grammar resolves the problem that emerged in the previous tableau.

(60) [ʃɔmɔru] שָׁמָ֫רוּ ‘kept$_{3MPL}$’

/ ʃɔmɔru /]$_{IP}$	*ˈV$^{\mu}$]$_{IP}$	NONFIN [μ, IP]	DEP-μ	*V/WEAK [MID]	*V/WEAK [F]	TROCHEE	IDENTV
s μ [μ μ] a. ʃɔ . ˈmɔ . ru *vr* [μ μ] [μμ]	*!		*	*	*		
s μ [μ μ] ☞ b. ʃɔ . ˈmɔ . ru *vr* μ [μμ] [μμ]			**				
s μ [μ μ] c. ʃɔ . ˈma . ru *vr* μ [μμ] [μμ]			**				*!
s μ [μ μ] d. ʃɔ . mə . ˈru *vr* [μ μ] [μμ]		*!	*				*

Ranking that can be derived from this tableau:

(61) Constraint ranking after inclusion of non-finality

***ˈV$^{\mu}$]$_{IP}$, NONFIN[μ, IP] » DEP-μ , IDENTV**

The newly introduced constraint NONFIN[μ, IP] eliminates candidate (c). Allowing candidate (b) to violate DEP-μ twice, as required by the two weight assignment constraints *ˈV$^{\mu}$]$_{IP}$ and *V$^{\mu}$]$_{\omega}$, without being disqualified. Now, the winning candidate (b) is the correct attested pausal form for the pausal form of /ʃɔmɔru/.

5.3.7 Grammar overview

The previous sections have presented formal accounts for weight assignment, metrical parsing, stress placement and vowel reduction for both contextual vs. pausal allomorphs. This section summarizes the grammar and highlights the crucial constraint interactions.

5.3.7.1 Weight assignment

The metrical planes of stress and vowel reduction were defined on the basis of their differences with regard to weight assignment (see §4.1). Following the Cophonology Theory (Inkelas 1998, 2008), these differences are formalized in the following different rankings:

(62) *Weight assignment grammar (co-phonologies)*

a. *Stress*

W-BY-P » DEP-μ » $*ˈV^{\mu}]_{IP}$, $*V^{\mu}]_{\omega}$

b. *Vowel reduction*

$*ˈV^{\mu}]_{IP}$, $*V^{\mu}]_{\omega}$ » DEP-μ » W-BY-P

The alternative Constraint Indexing Theory (Pater 2009) would yield the following constraint ranking, where [S] is the index for stress, and thus conn[s] refers only to weight assignment in the stress plane:

(63) *Weight assignment grammar (indexed constraints)*

W-BY-P[S] » DEP-μ[S] » $*ˈV^{\mu}]_{IP}$, $*V^{\mu}]_{\omega}$ » DEP-μ » W-BY-P

Under either representation, the two metrical planes have different sources for bi-moraicity. The stress plane is sensitive to syllable structure, assigning extra weight to closed syllables (via W-BY-P). The vowel reduction plane is sensitive to phonetic duration, assigning extra weight to vowels affected by domain-final lengthening (via $*ˈV^{\mu}]_{IP}$ and $*V^{\mu}]_{\omega}$).

5.3.7.2 Metrical parsing

Contrary to weight assignment, the grammar of metrical parsing is similar for the two planes. See §5.1.2 and §5.2.2 for detailed expositions.

(64) *Metrical parsing grammar for stress and vowel reduction*

FTBIN , TROCHEE , W-TO-S » PARSE-σ » ALIGNR(FT,PRWD)

There is only one technical difference to these grammars, which is the absence of W-TO-S from the vowel reduction plane. This is obvious because W-TO-S refers explicitly to stress, which is irrelevant for vowel reduction. The similarity in the grammars of metrical parsing supports the notion that these two metrical planes differ only in their scheme of weight assignment, as postulated by phenomenon-specific prominence (see §2.4). Consequently, the proposed metrical system is more consistent than earlier proposals (Rappaport 1984), which employed different feet types for the two metrical planes.

5.3.7.3 *Crucial constraint interactions*

The pause-context data presented in this study (see §3.4) include phenomena that pertain to alternation in vowel quality and stress position. The proposed grammar accounts for this allomorphy through the following main points of interaction among the constraints:

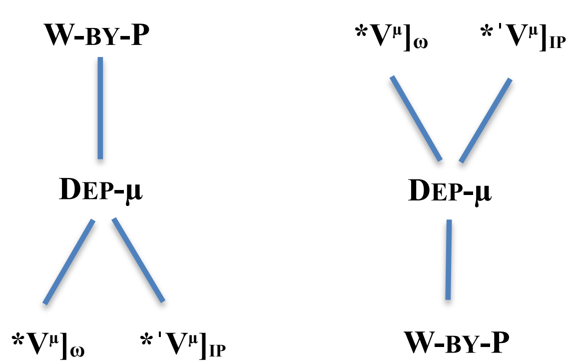
(65) *Crucial constraint interaction accounting for major phenomena*

Phenomenon			***Constraint ranking***
a.	Vowel reduction in CV	[V] => [ə]	***V[F]/WEAK » IDENTV**
b.	Vowel reduction in CVC	[V] => [a]	***ə^{HEAD} » *V[MID]/WEAK » IDENTV**
c.	Final stress in context form	CV.CV.CV	***ə^{HEAD} » *V[F]/WEAK » TROCHEE**

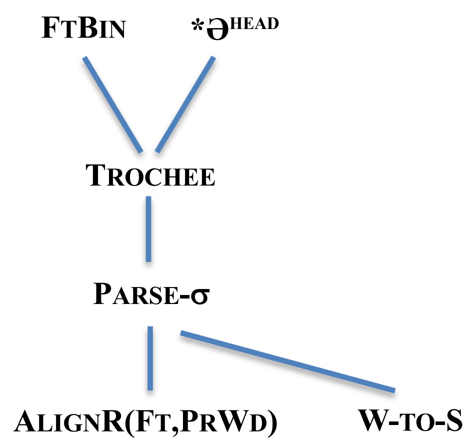
(66) *Tree representations of constraint rankings*

a. Weight assignment

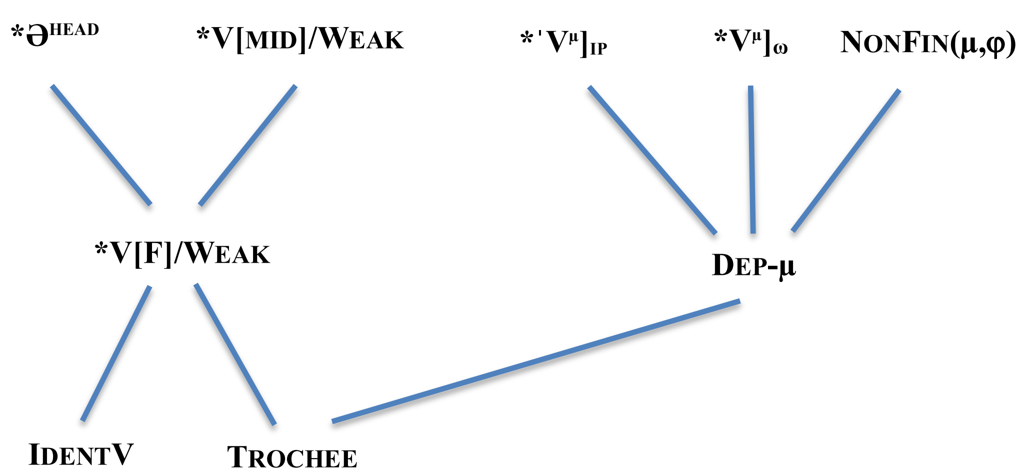
Stress *Vowel reduction*



b. Metrical parsing



c. The interaction of stress and vowel reduction



To conclude, the proposed analysis employs a uniform reduction scheme that applies to both contextual and pausal forms and yields all attested surface forms in both allomorphs. The system is metrically consistent as it employs only trochaic feet (unlike earlier analyses). Crucially, the analysis is grounded in the universally attested phenomena of vowel reduction and domain-final phonetic lengthening.

6 Summary

This thesis is an exploration of pausal-contextual allomorphy in Tiberian Hebrew, where the alternation is conditioned by the word's position in a phrase. As there is no semantic or morphological difference between pausal and contextual forms, this case presents an opportunity to examine a phenomenon which is purely phonological and provide an insightful glimpse both into the phonological grammar of Tiberian Hebrew and the nature of the interaction between stress, vowel reduction and phrase final lengthening in general.

Regarding the study of Tiberian Hebrew, the proposed analysis improves upon its predecessors by incorporating universally attested phenomena into the account. First, vowel reduction patterns which are cross-linguistically common are shown to match the segmental alternations exhibited by pausal allomorphy (§3.4). Second, phrase final lengthening provides a simplified account to the reduction-resistant nature of pausal forms (§4.4), which finds parallels in many other languages (Barnes 2006). Third, the employment of phenomenon-specific prominence (Gordon 2006) to account for the metrical conflict of reduction in stressed syllables reinforces the conceptual core of multi-planar metrical systems (Rappaport 1984; §4.1). Vowel reduction in Tiberian Hebrew is argued to operate independently of stress, where the positions where it applies and the induced vowel quality alternation are determined by prosodic factors such as the word's position in the phrase, the syllable's position in the word and syllable structure.

Regarding linguistic theory, the most significant proposal put forward in this thesis is the idea of a proprietary weight sensitivity scheme for the phenomenon of vowel reduction. The strong link between vowel reduction and phonetic vowel duration has been demonstrated and widely accepted for some time now (Lindblom 1963; *inter alia*). In the common case, the metrical systems of stress and vowel reduction are harmonically interweaved, creating an alternating pattern of stressed and reduced syllables which does not justify assuming there are two separate metrical systems at all. However, some exceptional cases where these metrical system do not align, like Northern Welsh (Bosch 1996; see §2.3.5.3) and hereby Tiberian Hebrew, suggest that these mechanisms may operate independently. In fact, languages with vowel reduction but no secondary stress, e.g.

Russian (§2.3.5.1), are clear cases of such metrical misalignment. In these languages, vowel reduction typically targets all non-stressed positions, resulting in two fundamentally different metrical domains. Typically, stress assignment metrics employ a single foot, while the domain of vowel reduction spans throughout the entire remainder of the prosodic word. While the segmental and phonetic realms of vowel reduction have been widely studied (Crosswhite 1999; Beckman 1997; Flemming 2005; Padgett & Tabain 2005; *inter alia*), the nature of metrical alignment between stress and vowel reduction seems like a promising endeavor for future research. Natural candidates for such research would be languages where the main phonetic correlate of stress is not phonetic vowel duration.

References

Aartun, K., 1981. Noch einmal zum Problem der Haupttondehnung beim Nomen im Althebräischen. *Zeitschrift der Deutschen Morgenländischen Gesellschaft*, *131*(1), 28-41.

Anderson, S.R., 1982. Where's morphology?. *Linguistic Inquiry, 13*(4), 571-612.

Anttila, A., 2002. Morphologically conditioned phonological alternations. *Natural Language & Linguistic Theory*, *20*(1), 1-42.

Anstey, M.P., 2005. Towards a typological presentation of Tiberian Hebrew. *Hebrew Studies*, *46*(1), 71-128.

Bat-El, O. 1994. Onset violation in Tiberian Hebrew. *Phonology at Santa Cruz* v.3, 1-12. The Linguistic Research Center, UCSC.

Bat-El, O. 1995. On the apparent ambiguity of the schwa symbol in Tiberian Hebrew. *Langues Orientales Anciennes Philologie et Linguistique*, 5-6, 79-96.

Bat-El, O. 2008. Morphologically conditioned V–Ø alternation in Hebrew: Distinction among nouns, adjectives & participles, and verbs. In S. Armon-Lotem, G. Danon, and S. Rothstein (eds), *Current Issues in Generative Hebrew Linguistics,* 27-60. Amsterdam: John Benjamins.

Bat-El, O., Cohen, E.G. and Silber-Varod, V., 2019. Modern Hebrew stress: Phonology and phonetics. *Brill's Journal of Afroasiatic Languages and Linguistics*, *11*(1), 96-118.

Balcaen, M. J. (1995). *The prosody of Tiberian Hebrew*. MA thesis, University of Saskatchewan.

Ball, M.J. and Williams, B.J., 2001. *Welsh phonetics*. Lampeter: The Edwin Mellen Press.

Bauer, H., Leander, P., Kahle, P. and Bauer, H., 1922. *Historische Grammatik der hebräischen Sprache des alten Testaments*. Georg Olms Verlag.

Barnes, J., 2006. *Strength and weakness at the interface: Positional neutralization in phonetics and phonology*. Berlin: Walter de Gruyter.

Barnes, J., 2007. Phonetics and phonology in Russian unstressed vowel reduction: A study in hyperarticulation. Ms. Boston University.

Becker, M., 2003. Hebrew Stress: Can't you hear those trochees?. *University of Pennsylvania Working Papers in Linguistics*, *9*(1), 45-57.

Becker-Kristal, R., 2010. *Acoustic typology of vowel inventories and Dispersion Theory: Insights from a large cross-linguistic corpus*. PhD dissertation, University of California, Los Angeles.

Beckman, J.N., 1997. Positional faithfulness, positional neutralization and Shona vowel harmony. *Phonology*, *14*(1), 1-46.

Beckman, M.E. and Edwards, J., 1987. The phonological domains of final lengthening. *The Journal of the Acoustical Society of America*, *81*(S1), 67-S67.

Beckman, M.E. and Edwards, J., 1992. Intonational categories and the articulatory control of duration. In Tohkura, Y., Vatikiotis-Bateson, E., Sagisaka, Y (eds), *Speech perception, production, and linguistic structure*, 359-375. Amsterdam: IOS Press.

Ben-David, I., 1990. The capacity of grammatical patterns to generate contextual and pausal forms in Biblical Hebrew. *Leshonenu*, *55*, 279-299.

Ben-David, I., 1995. *Context and Pause forms in Biblical Hebrew: Syntax and Cantillation marks* (*Tsurot heḳsher ṿe-tsurot hefseḳ ba-ʻIvrit sheba-Miḳra*). Publications of the Perry Foundation for Biblical Research in the Hebrew University of Jerusalem. Magnes, The Hebrew University Press.

Beyer, K., 1984. *Die aramäischen Texte vom Toten Meer: aramaistische Einleitung, Text, Übersetzung, Deutung, Grammatik/Wörterbuch, deutsch-aramäische Wortliste, Register*. Vandenhoeck & Ruprecht.

Birkeland, H., 1940. Akzent und Vokalismus im Althebräischen: mit Beiträgen zur vergleichenden semitischen Sprachwissenschaft (No. 3). det Norske Videnskaps-Akademi.

Blevins, J., 2004. *Evolutionary phonology: The emergence of sound patterns*. Cambridge University Press.

Berkovits, R., 1994. Durational effects in final lengthening, gapping, and contrastive stress. *Language and Speech*, *37*(3), 237-250.

Bosch, A., 1996. Prominence at two levels: Stress versus pitch prominence in North Welsh. *Journal of Celtic Linguistics*, *5*, 121-165.

Bosch, A. and Wiltshire, C., 1993. The licensing of prosodic prominence in Tamil. *Proceedings of the Third Annual Meeting of the Formal Linguistics Society of Midamerica*, 1-15.

Byrd, D., 2000. Articulatory vowel lengthening and coordination at phrasal junctures. *Phonetica*, *57*(1), 3-16.

Byrd, D., and Saltzman, E., 2003. The elastic phrase: Modeling the dynamics of boundary-adjacent lengthening. *Journal of Phonetics*, *31*(2), 149-180.

Byrd, D., Krivokapić, J. and Lee, S., 2006. How far, how long: On the temporal scope of prosodic boundary effects. *The Journal of the Acoustical Society of America*, *120*(3), 1589-1599.

Byrd, D., Kaun, A., Narayanan, S. and Saltzman, E., 2000. Phrasal signatures in articulation. *Papers in laboratory phonology V*, 70-87.

Byrd, D. and Saltzman, E., 1998. Intragestural dynamics of multiple prosodic boundaries. *Journal of Phonetics*, *26*(2), 173-199.

Cambier-Langeveld, T., Nespor, M. and Heuven, V.J.V., 1997. The domain of final lengthening in production and perception in Dutch. In *Fifth European Conference on Speech Communication and Technology*.

Cho, T., 2004. Prosodically conditioned strengthening and vowel-to-vowel coarticulation in English. *Journal of Phonetics*, *32*(2), 141-176.

Cho, T., 2006. Manifestation of prosodic structure in articulatory variation: Evidence from lip kinematics in English. *Laboratory phonology*, *8*, 519-548.

Cho, T., 2016. Prosodic boundary strengthening in the phonetics–prosody interface. *Language and Linguistics Compass*, *10*(3), 120-141.

Cho, T. and Jun, S.A., 2000. Domain-initial strengthening as enhancement of laryngeal features: Aerodynamic evidence from Korean. In Albright, A. and Cho T. (eds.), *UCLA working papers in phonetics*, *4*, 57-70.

Cho, T. and Keating, P.A., 2001. Articulatory and acoustic studies on domain-initial strengthening in Korean. *Journal of phonetics*, *29*(2), 155-190.

Chomsky, N. and Halle, M., 1968. The sound pattern of English. New York: Harper & Row.

Churchyard, H., 1999. Topics in Tiberian Biblical Hebrew metrical phonology and phonetics. PhD dissertation, University of Texas.

Cinque, G., 1993. A null theory of phrase and compound stress. *Linguistic inquiry*, *24*(2), 239-297.

Crosswhite, K.M., 2000. Vowel reduction in Russian: a unified account of standard, dialectal, and "dissimilative" patterns. *University of Rochester working papers in the language sciences*, *1*, 107-172.

Crosswhite, K., 2004. Vowel reduction. *Phonetically based phonology*, 191-231.

Crosswhite, K. and Jun, A., 2001. Vowel reduction in optimality theory. Psychology Press.

Dauer, R.M., 1980. The reduction of unstressed high vowels in Modern Greek. *Journal of the International Phonetic Association*, *10*(1-2), 17-27.

Dawson, W. 1980. Tibetan phonology. PhD dissertation, University of Washington.

DeCaen, V., 2003. Moveable nun and intrusive nun: the nature and distribution of verbal nunation in Joel and Job. *Journal of Northwest Semitic Languages*, *29*(1), 121-132.

DeCaen, V., 2005. On the distribution of major and minor pause in Tiberian Hebrew in the light of the variants of the second person independent pronouns. *Journal of Semitic Studies*, *50*(2), 321-327.

DeCaen, V. and Dresher, B.E., 2019. Pausal Forms and Prosodic Structure in Tiberian Hebrew.

Dresher, B.E., 1981. Accentuation and Metrical Structure in Tiberian Hebrew in Theoretical Issues in the grammar of Semitic Languages. *MIT Working Papers in Linguistics*, *3*, 180-208.

Dresher, B.E., 1994. The prosodic basis of the Tiberian Hebrew system of accents. *Language*, 1-52.

Dresher, B.E., 2009. The Word in Tiberian Hebrew. *The nature of the word: Essays in honor of Paul Kiparsky*, 95-111.

Dresher, B.E., 2009. Stress assignment in Tiberian Hebrew. *Contemporary Views on Architecture and Representations in Phonology*. 213-224.

Flemming, E., 2001. Vowel reduction and duration-dependent undershoot. *Paper presented at the Conference on the Phonetics-Phonology Interface, ZAS, Berlin.*

Flemming, E., 2005. A phonetically-based model of phonological vowel reduction. Ms. *Cambridge: MIT*.

Flemming, E., 2009. The phonetics of schwa vowels. *Phonological weakness in English*, 78-98.

Fougeron, C., 2001. Articulatory properties of initial segments in several prosodic constituents in French. *Journal of phonetics*, *29*(2), 109-135.

Fougeron, C. and Keating, P.A., 1997. Articulatory strengthening at edges of prosodic domains. *The journal of the acoustical society of America*, *101*(6), 3728-3740.

Gauthiot, R., 1913. *La fin de mot en indo-européen*. P. Geuthner.

Garcia, G.D., Goad, H. and Guzzo, N.B., 2017. Footing is not always about stress: Formalizing variable high vowel deletion in Québec French. In *Proceedings of the Annual Meetings on Phonology* (Vol. 4).

Gesenius, W., Kautzsch, E. and Cowley, A.E., 2006. *Gesenius' Hebrew Grammar*. Courier Corporation.

Goerwitz, R.L., 1993. *Tiberian Hebrew Pausal Forms*. PhD dissertation, University of Chicago.

Goldsmith, J., 1989. Licensing, inalterability, and harmonic rule application. *In CLS 25, ed. by Caroline Wiltshire & et al*, 145–156. Chicago: Chicago Linguistic Society

Gordon, M., 1998. The phonetics and phonology of non-modal vowels: a cross-linguistic perspective. In *Annual Meeting of the Berkeley Linguistics Society,* 24(1), 93-105.

Gordon, M., 2007. *Syllable weight: phonetics, phonology, typology*. Routledge.

Gordon, M., and Roettger, T., 2017. Acoustic correlates of word stress: A cross-linguistic survey. *Linguistics Vanguard*, *3*(1).

Gouskova, M., Newlin-Łukowicz, L. and Kasyanenko, S., 2015. Selectional restrictions as phonotactics over sublexicons. *Lingua*, *167*, 41-81.

Gussenhoven, C., 1992. Sentence accents and argument structure. *Thematic structure: Its role in grammar*, 79-106.

Hale, M. and Reiss, C., 2008. *The phonological enterprise*. Oxford University Press.

Hannahs, S.J., 2007. Constraining Welsh vowel mutation. *Journal of Linguistics*, *43*(2), 341-363.

Hannahs, S.J., 2013. *The phonology of Welsh*. Oxford University Press.

Hankamer, J. and Aissen J., 1974. The sonority hierarchy. *Papers from the Annual Regional Meeting. Chicago Linguistic Society: Parasession on natural phonology*, 131–145.

Harris, J., 1969. *Spanish Phonology*. Cambridge, MA: MIT Press.

Harris, J. and Lindsey, G., 1995. The elements of phonological representation. *Frontiers of phonology: Atoms, structures, derivations*, 34-79.

Harris, J. and Lindsey, G., 2000. Vowel patterns in mind and sound. *Phonological knowledge: Conceptual and empirical issues*, 185-205.

Harris, J., 2005. Vowel reduction as information loss. *Headhood, elements, specification and contrastivity*, 119-132.

Hayes, B., 1986. Inalterability in CV phonology. *Language*, 62, 321-351.

Hayes, B., 1989. Compensatory lengthening in moraic phonology. *Linguistic inquiry*, *20*(2), 253-306.

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

Hyde, B., 2007. Non-finality and weight-sensitivity. *Phonology*, *24*(2), 287-334.

Hyman, L.M., 1976. Phonologization. *In Linguistic Studies Offered to Joseph Greenberg on the Occasion of his Sixtieth Birthday*, ed. by Juilland A., 107-118. Saratoga: Anma Libri.

Hyman, L.M., 1984, October. On the weightlessness of syllable onsets. In *Annual Meeting of the Berkeley Linguistics Society*, 10, 1-14.

Inkelas, S., 1998. The theoretical status of morphologically conditioned phonology: a case study of dominance effects. In *Yearbook of Morphology,* 121-155. Springer, Dordrecht.

Inkelas, S., 2008, December. The morphology-phonology connection. In *Annual Meeting of the Berkeley Linguistics Society*, 34(1), 145-162.

Iosad, P., 2016. Prosodic structure and suprasegmental features. *The Journal of Comparative Germanic Linguistics*, *19*(3), 221-268.

Ito, J. and Mester, A., 2008. Lexical classes in phonology. *The Oxford handbook of Japanese linguistics*, 84-106.

Keating, P., 1988. *The Phonology–Phonetics Interface*. Linguistics: The Cambridge Survey ed. by Frederick Newmeyer, 281-302.

Keating, P.A., 1996. The phonology-phonetics interface. *UCLA Working Papers in Phonetics*, 45-60.

Keating, P., Cho, T., Fougeron, C. and Hsu, C.S., 2004. Domain-initial articulatory strengthening in four languages. *Phonetic interpretation: Papers in laboratory phonology VI*, 143-161.

Khan, G., 1987. Vowel length and syllable structure in the Tiberian tradition of Biblical Hebrew. *Journal of Semitic Studies*, *32*(1), 23-82.

Khan, G., 1994. The historical background of the vowel ṣere in some Hebrew verbal and nominal forms. *Bulletin of the School of Oriental and African Studies*, *57*(1), 133-144.

Khan, G., 2013. Shewa: pre-modern Hebrew. *Encyclopedia of Hebrew Language and Linguistics, Leiden: Brill*, *3*, 543-554.

Kirchner, R., 1998. *An effort-based approach to consonant lenition*. PhD. dissertation, University of California, Los Angeles.

Klatt, D.H., 1976. Linguistic uses of segmental duration in English: Acoustic and perceptual evidence. *The Journal of the Acoustical Society of America*, *59*(5), 1208-1221.

Lehiste, I., 1960. Segmental and syllabic quantity in Estonian. *American studies in Uralic linguistics*, *1*, 21-82.

Liberman, M. and Prince, A., 1977. On stress and linguistic rhythm. *Linguistic inquiry*, *8*(2), 249-336.

Liljencrants, J. and Lindblom, B., 1972. Numerical simulation of vowel quality systems: The role of perceptual contrast. *Language*, *48*(4), 839-862.

Lindblom, B., 1963. Spectrographic study of vowel reduction. *The journal of the Acoustical society of America*, *35*(11), 1773-1781.

Lombardi, L., 1991. *Laryngeal features and laryngeal neutralization*. PhD dissertation, UMass.

Lombardi, L., 1995. Laryngeal neutralization and syllable wellformedness. *Natural Language & Linguistic Theory*, *13*(1), 39-74.

Major, R.C., 1985. Stress and rhythm in Brazilian Portuguese. *Language*, 61, 259-282.

McCarthy, J.J., 1981. Stress, Pretonic Strengthening, and Syllabification in Tiberian Hebrew in Theoretical Issues in the grammar of Semitic Languages. *MIT Working Papers in Linguistics, 3*, 73-100.

McCarthy, J.J., Al-Mozainy H.Q., and Bley-Vroman, R., 1985. Stress Shift and Metrical Structure. *Linguistic Inquiry*, *16*(1), 135-144.

McCarthy, J. and Prince, A., 1990. Prosodic morphology and templatic morphology. In *Perspectives on Arabic linguistics II: papers from the second annual symposium on Arabic linguistics*, 1-54. John Benjamins Amsterdam.

McCarthy, J.J. and Prince, A., 1995. Faithfulness and reduplicative identity. *Linguistics Department Faculty Publication Series, 10*.

McCarthy, J.J. and Prince, A., 2004. Generalized Alignment: The Prosody-Morphology Interface. *Optimality Theory in phonology: A reader*, 451-463.

Moon, S.J. and Lindblom, B., 1994. Interaction between duration, context, and speaking style in English stressed vowels. *The Journal of the Acoustical society of America*, *96*(1), 40-55.

Nespor, M. and Vogel, I., 2007. *Prosodic phonology: with a new foreword* (Vol. 28). Walter de Gruyter.

Ohala, J.J., 1981. The listener as a source of sound change. *In Papers from the Parasession on Language and Behavior, Chicago Linguistic Society*, ed. by Masek C.S., Hendrick R.A. and Miller M.F., 178–203. Chicago: CLS.

Ohala, J.J., 1993. The phonetics of sound change. *Historical linguistics: Problems and perspectives*, 237-278.

Oller, D.K., 1973. The duration of speech segments: The effect of position in utterance and word length. *Journal of the Acoustical Society of America*, 54, 1235–1273.

Padgett, J., 2004. Russian vowel reduction and Dispersion Theory. *Phonological studies*, *7*, 81-96.

Padgett, J. and Tabain, M., 2005. Adaptive dispersion theory and phonological vowel reduction in Russian. *Phonetica*, *62*(1), 14-54.

Pater, J., 2000. Non-uniformity in English secondary stress: the role of ranked and lexically specific constraints. *Phonology*, *17*(2), 237-274.

Pater, J., 2009. *Morpheme-specific phonology: Constraint indexation and inconsistency resolution*. Equinox Publishing Ltd.

Pierrehumbert, J. and Talkin, D., 1992. Lenition of/h/and glottal stop. *Papers in laboratory phonology II*, ed. by Docherty G. and Ladd D.R., 90-117.

Plüschke, M. and Harrington, J., 2013. The domain of phrase-final lengthening in Estonian. *Nordic Prosody XI*, 293-302.

Prince, A.S., 1975. *The phonology and morphology of Tiberian Hebrew*. PhD dissertation, MIT Cambridge.

Prince, A.S., 1980. A metrical theory for Estonian quantity. *Linguistic inquiry*, 11(3), 511-562.

Prince, A. and Smolensky, P., 1993. Constraint interaction in generative grammar. *Malden, MA, and Oxford, UK: Blackwell*.

Prince, A. and Smolensky, P., 2004. Optimality Theory: Constraint Interaction in Generative Grammar. *Optimality Theory in Phonology: A Reader*, pp.1-71.

Qimron, E., 1986. Interchanges of e and a vowels in accented closed syllables in Biblical Hebrew. *Leshonenu, 50*, 77-102.

Qimron, E., 2006. The Pausal Patah in Biblical Hebrew. In Fassberg S.E. and Hurvitz A., Winona Lake (eds), *Biblical Hebrew in its Northwest Semitic Setting*, 305-314. Jerusalem: Hebrew University Magnes Press.

Qimron, E., 2008. Pausal forms – what is their nature? *Sha'arei Lashon (Vol.I) - Biblical Hebrew, Masorah, and Medieval Hebrew,* 92-106. Jerusalem: Bialik Institute.

Selkirk, E., 1984. On the major class features and syllable theory. *Language sound structure*. MIT Press.

Smith, J.L., 1999. Noun faithfulness and accent in Fukuoka Japanese. In *Proceedings of WCCFL XVIII*, 519-531. Cascadilla Press.

Smith, J.L., 2001. Lexical category and phonological contrast. In *Papers in experimental and theoretical linguistics 6: Workshop on the Lexicon in Phonetics and Phonology*, 61-72. Edmonton: University of Alberta.

Steriade, D., 1991. Moras and other slots. *Proceedings of the Formal Linguistics Society of Midamerica*, *1*, 254-280.

Steriade, D., 1994. Positional neutralization and the expression of contrast. Ms,. *UCLA*.

Steriade, D., 1997. Phonetics in phonology: the case of laryngeal neutralization. Ms,. *UCLA*.

Tabain, M., 2003. Effects of prosodic boundary on/aC/sequences: articulatory results. *The Journal of the Acoustical Society of America*, *113*(5), 2834-2849.

Tabain, M. and Perrier, P., 2005. Articulation and acoustics of /i/ in preboundary position in French. *Journal of Phonetics*, *33*(1), 77-100.

Trubetzkoy, N.S., 1969. Principles of phonology (trans. Baltaxe C.). *Berkeley: University of California Press*.

Truckenbrodt, H., 2006. Phrasal stress. *The encyclopedia of languages and linguistics*, *9*, 572-579.

Turk, A.E., 1999. Structural influences on boundary-related lengthening in English. In *Proceedings of the 14th International Congress of Phonetic Sciences*, 2, 1117-1120.

Turk, A.E., and Shattuck-Hufnagel, S., 2007. Multiple targets of phrase-final lengthening in American English words. *Journal of Phonetics*, *35*(4), 445-472.

Rappaport, M., 1984. *Issues in the phonology of Tiberian Hebrew*. PhD dissertation, MIT.

Revell, E.J., 1980. Pausal forms in Biblical Hebrew: their function, origin and significance. *Journal of Semitic Studies*, *25*(2), 165-179.

Revell, E.J., 1981. Pausal forms and the structure of biblical poetry. *Vetus Testamentum*, *31*(2), 186-199.

Revell, E.J., 1984. Stress and the "WAW Consecutive" in Biblical Hebrew. *Journal of the American Oriental Society*, *104*(3), 437-444.

Revell, E.J., 2012. The Occurrence of Pausal Forms. *Journal of semitic studies*, *57*(2), 213-230.

Revell, E.J., 2015. *The Pausal System: Divisions in the Hebrew Biblical Text as Marked by Voweling and Stress Position*. Sheffield Phoenix Press.

Revell, E.J., 2016. Terminal Markers in the Masoretic Text. *Journal of Semitic Studies*, *61*(1), 67-84.

Robar, E., 2013. Nunation. *Encyclopedia of Hebrew Language and Linguistics, ed. by Geoffrey Khan*. Leiden: Brill.

Roettger, T. and Gordon, M., 2017. Methodological issues in the study of word stress correlates. *Linguistics Vanguard*, *3*(1), 1-11.

Ryan, K., 2016. Phonological weight. *Language and Linguistics Compass*, *10*(12), 720-733.

Ryan, K., 2019. Prosodic end-weight reflects phrasal stress. *Natural Language & Linguistic Theory*, *37*(1), 315-356.

Van Bergem, D.R., 1993. Acoustic vowel reduction as a function of sentence accent, word stress, and word class. *Speech communication*, *12*(1), 1-23.

Watkins, A., 1954. The accent in Cwm Tawe Welsh. *Zeitschrift für celtische Philologie*, *24*(1), 6-9.

Wightman, C.W., Shattuck-Hufnagel, S., Ostendorf, M. and Price, P.J., 1992. Segmental durations in the vicinity of prosodic phrase boundaries. *The Journal of the Acoustical Society of America*, *91*(3), 1707-1717.

Williams, B., 1983. *Stress in modern Welsh*. PhD dissertation, University of Cambridge.

Zhang, J., 2001. *The effects of duration and sonority on contour tone distribution--typological survey and formal analysis*. PhD dissertation, UCLA.

Zoll, C., 1998. Positional asymmetries and licensing. Ms. *MIT, Cambridge.*

תוכן עניינים

תקציר

בהתבסס על נוסח המסורה, בעברית הטברנית ישנה אלומורפיה התלויה בעמדה. כלומר, למילה נתונה ישנן צורות הגיה *שונות כפונקציה של העמדה* אותה היא תופסת בפסוקית: צורת *ההפסק* בסוף הפסוקית, וצורת *ההקשר* באמצע (או תחילת) הפסוקית (Revell 1981, 2012, Goerwitz 1993, Dresher 2009).

	צורת הפסק		*צורת הקשר*	
א.	כָּתָב	kɔ.tɔ́v	כָּתַב	kɔ.táv
	אָמָרְתְּ	ʔɔ.mɔ́r.tɔ	אָמַרְתְּ	ʔɔ.már.tɔ
ב.	שָׁמָרוּ	ʃɔ.mɔ́.ru	שָׁמְרוּ	ʃɔ.mə.rú
	לֵכוּ	lé.xu	לְכוּ	lə.xú

חילופי התנועות בנתונים המוצגים לעיל מנותחים כפועל יוצא של הפחתת תנועות (vowel reduction). הסוגיה העיקרית שעולה בהקשר לאלומורפיה של צורות ההפסק וההקשר היא שבמקרים מסוימים, התנועה המופחתת נמצאת בהברה מוטעמת – אשר מהווה, בדרך כלל, עמדה פרוזודית בולטת (ולכן חזקה) שלא עוברת הפחתה. מחקרים קודמים הציעו כי שתי התופעות עושות שימוש בסוגים שונים של רגליים מטריות – רגל טרוכאית עבור הטעמה ורגל יאמבית עבור הפחתה (Rappaport 1984). המחקר הנוכחי עושה שימוש עקבי ברגל טרוכאית עבור שתי התופעות, ומפתח סכימה מורכבת של משקל הברה תלוי-תופעה (phenomenon-specific syllable weight), ובה משקל ההברה נקבע על בסיס היררכיית בולטות עמדתית (positional prominence) המאומתת אוניברסלית בשפות רבות. ספציפית, קביעת המשקל משתנה כתלות במבנה ההברה, מיקום התנועה במילה, מיקום המילה בפסוקית ולבסוף ביחס לתופעה הרלוונטית - טעם או הפחתת תנועות. מערכות משקל הברה תלויות-תופעה כאלו נמצאו בשפות רבות (Gordon 2006).

לצורכי הטעמה, קביעת המשקל מתייחסת אך ורק למבנה ההברה (הברת CVC סגורה היא כבדה). לעומת זאת, לצורכי הפחתת תנועות, קביעת המשקל מתבססת על היררכיית הבולטות הבאה, המבוססת על מניעים פונטיים ותפיסתיים:

מוטעמת, בסוף פסוקית > סוף מילה > מוטעמת > לא מוטעמת, לא סופית

הבולטות המוגברת של הברות בעמדות סופיות נובעת מתופעות של הארכה פונטית אשר פועלת על קצוות של יחידות פרוזודית (Turk & Shattuck-Hufnagel 2007). הארכת התנועה מובילה למבנה בו התנועות חסינות להפחתת תנועה (Barnes 2006) וכך בסופו של ענין להיווצרותן של צורות ההפסק. הניתוח הפורמלי המוצג במחקר זה מבוצע במסגרת תיאוריית האופטימליות (Prince & Smolensky 1993).

הניתוח המוצע מאפשר הסבר קונסיסטנטי מבחינה מטרית לתופעות ההטעמה והאלומורפיה של צורות ההפסק וההקשר במערכת הפועל בעברית הטברנית, בעודו מושתת על תופעות אוניברסליות בשפות העולם – הארכה סופית והפחתת תנועות.

TEL AVIV UNIVERSITY אוניברסיטת תל-אביב
הפקולטה למדעי הרוח ע"ש לסטר וסאלי אנטין
בית הספר לפילוסופיה, בלשנות ולימודי מדע
החוג לבלשנות

אלומורפיה עמדתית

צורות הפסק והקשר בעברית הטברנית

חיבור זה הוגש כעבודת גמר לקראת התואר
"מוסמך אוניברסיטה" - M.A. באוניברסיטת ת"א

על ידי
רומן הימלרייך

העבודה הוכנה בהדרכת:

פרופ׳ אוּתי בת-אל פוֹקס
אוניברסיטת תל-אביב

פרופ׳ ג׳פרי קהאן
אוניברסיטת קמברידג׳

ספטמבר 2019