PAUSAL VS. CONTEXT FORMS IN TIBERIAN HEBREW
A multi-planer analysis of vowel reduction and stress

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Abstract: In this study, we analyze the pause–context allomorphy in Tiberian Hebrew, manifested by alternation in stress and vowel reduction. The challenging aspect of this allomorphy is that vowels in stressed syllables do not resist reduction, contrary to universal typology. We argue that stress and vowel reduction in Tiberian Hebrew are not directly related, and propose a multi-planer metrical structure – a separate metrical plane for each phenomenon. Foot assignment in the two planes is identical (right-aligned trochaic foot), but mora assignment is minimally distinct. This minimal contrast is phonetically and phonologically supported and fits within universal typology.

Keywords: Tiberian Hebrew, pausal forms, vowel reduction, stress, phenomenon-specific phonology, multi-planer metrical structure, phrase final lengthening.

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 elsewhere (Revell 1981, 2012; Goerwitz 1993; Dresher 2009). As shown in (1), the two allomorphs may appear within the same phrase.

(1) *Pausal and context forms within the same phrase*[1]

אֶת־זֶה֙ **תֹּֽאכְל֔וּ** מִכֹּ֖ל אֲשֶׁ֣ר בַּמָּ֑יִם כֹּ֣ל אֲשֶׁר־ל֛וֹ סְנַפִּ֥יר וְקַשְׂקֶ֖שֶׂת **תֹּאכֵֽלוּ**: (דברים יד, ט)

ʔɛθ-ˈzɛ	**toχəˈlu**	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)

[1] 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 co-occur with any specific cantillation mark, their appearance is nevertheless largely predictable on the basis 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).

There are two types of alternation between the allomorphs: either in vowel quality alone (2a), or in vowel quality and stress (2b).[2]

(2) *Pausal vs. context forms*

	Pausal form		***Contextual form***		
a.	kɔ.ˈt**ɔ**v	כָּתָב	kɔ.ˈt**a**v	כָּתַב	'wrote 3MSG'
	ʔɔ.ˈm**ɔ**r.tɔ	אָמָרְתָּ	ʔɔ.ˈm**a**r.tɔ	אָמַרְתָּ	'said 2MSG'
b.	ʃɔ.ˈm**ɔ**.r-u	שָׁמָרוּ	ʃɔ.m**ə**.ˈr-u	שָׁמְרוּ	'guarded 3MPL'
	ˈl**e**.x-u	לֵכוּ	l**ə**.ˈx-u	לְכוּ	'go! 2MPL'

The two types of alternation result from vowel reduction. In (2a), the output of reduction is [a] and stress persists in its position; in (2b) the output of reduction is schwa [ə] and stress shifts to the final syllable. That is, the reduced vowel in the contextual form is either stressed (2a) or corresponding to a stressed vowel (2b). Such interaction between stress and vowel reduction is typologically odd and theoretically problematic; stressed syllables are prosodically strong and vowels in strong positions tend to resist alternation, let alone reduction (Beckman 1997; Crosswhite 2001, 2004; Padgett & Tabain 2005; Barnes 2006).

In this paper we solve this discrepancy with biplanar metrical structure, allocating one plane for stress assignment and another for vowel reduction. Crucially, the two planes do not interact directly, thus allowing vowel reduction to apply in a weak position in its own metrical structure.

The difference between the two metrical planes stems from different schemes of syllable weight. The stress plane is sensitive to syllable structure, assigning extra weight to closed syllables; thus, the syllables that are heavy for the purpose of stress are CVC. The vowel reduction plane is sensitive to phonetic duration, assigning extra weight to vowels in domain final positions; thus, the syllables that are heavy for the purpose of vowel reduction are those which feature a vowel which is lengthened due to its final position in the word or the phrase.

(3) *Syllable weight in the two metrical planes*

Syllable structure	***Stress assignment***	***Vowel reduction***	
		Word medial	***Word final***
CV	Light	Light	*Heavy*
CVC	*Heavy*	Light	

[2] Vowel alternation is oblivious to morphological structure, thus applying also within a suffix (e.g. [jirɔˈʃ-**ɛ**χɔ]P – [jirɔʃ-**ə**ˈχɔ]C 'inherit 3MSG you').

The paper's roadmap is as follows: We start with generalizations regarding the pause-context alternation (§2), and then introduce the theoretical problem addressed here: while cross-linguistically vowel reduction targets vowels in unstressed syllables, in Tiberian Hebrew vowels in stressed syllables undergo reduction (§3). The path towards resolving this problem goes through the concept of phenomenon-specific syllable weight (§3.2) which is extended to the realm of vowel reduction (§3.3). Detailed expositions of the derivation of contextual and pausal forms are presented in §4. Finally, the conclusion is given in §5.

2 PAUSE-CONTEXT ALTERNATION: DATA AND GENERALIZATIONS

We start this section with two basic assumptions, one regarding the Tiberian Hebrew vowel system and the other addressing the base of the derivation.

There is an ongoing debate in the literature regarding the vowel system in Tiberian Hebrew, whether it is a 5-vowel system with length contrast, or a 7-vowel system with quality contrast only (Khan 1987; Churchyard 1999; Anstey 2005). Here we adopt Khan's (1987) 7-vowel system, attributing vowel length contrast to a late phonetic effect. Tiberian Hebrew vowel system thus includes one low vowel [a], two high vowels [i, u] and four mid vowels; two tense [e, o] and two lax [ɛ, ɔ]. The schwa, although transcribed here as [ə] is phonetically a low vowel (Khan 2013) and thus the output of vowel reduction in both (2a) and (2b) is phonetically [a].[3] We will, however, maintain the [ə] symbol, which reflects the phonological behavior of the vowel.

The second assumption concerns the base of derivation. Although pausal forms exhibit more vowel contrasts and are often identical to the base of derivation, pentasyllabic words (4) show that both pausal and contextual forms undergo reduction. Therefore, we assume that the base of derivation is an abstract form comprised of the non-reduced vowels in both allomorphs.

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[3] The Shewa diacritic אְ in Tiberian Hebrew correlates with two phonological realizations: either a syllable coda (silent Shewa) or a reduced vowel (vocalic Shewa). For example, in תִּשְׁמְרוּ [tiʃ.mə.ˈr-u] 'keep 3MPL', the first Shewa diacritic marks the /ʃ/ in the coda and the other indicates the reduced vowel [ə] following /m/. We employ the term 'schwa' to refer to the vocalic Shewa.

(4) *Pausal forms missing segmental information w.r.t to Contextual forms*

Pause		***Context***		***Base***	
lə.hɔ.rə.ˈʁɛ.χɔ	לְהָרְגֶךָ	la.hă.rɔ.ʁə.ˈχɔ	לַהֲרָגְךָ	lə.hɔ.rɔ.ʁɛ.χɔ	‘to kill you’
lə.χal.kə.ˈlɛ.χɔ	לְכַלְכְּלֶךָ	lə.χal.kɛ.lə.ˈχɔ	לְכַלְכֶּלְךָ	lə.χal.kɛ.lɛ.χɔ	‘to support you’

With these assumptions in hand, the rest of this section displays the pause–context alternation in CV (§2.1) and CVC (§2.2) syllables; as shown, the structure of syllable is a crucial factor in determining the nature of the alternation.

2.1 Open syllables (CV)

The vowel in a penultimate CV syllable alternates between a full mid vowel in the pausal allomorph, and a schwa in the contextual allomorph. As shown in (5a), the mid vowels [o, ɔ, e, ɛ][4] in the pausal allomorph correspond to [ə] in the contextual forms; the high vowels [i, u] resist alternation (5b).

(5) *Alternation in open syllables (CV)*

	Pause		***Context***			***Alternation***
a.	tiʃ.ˈm**o**.r-u	תִּשְׁמֹרוּ	tiʃ.m**ə**.ˈr-u	תִּשְׁמְרוּ	‘keep 2MPL’	o ~ ə & stress
	hɔ.ˈj**ɔ**.θ-ɔ	הָיָתָה	hɔ.j**ə**.ˈθ-ɔ	הָיְתָה	‘was 3FSG’	ɔ ~ ə & stress
	to.ˈχ**e**.l-u	תֹּאכֵלוּ	to.χ**ə**.ˈl-u	תֹּאכְלוּ	‘eat 2PL’	e ~ ə & stress
b.	jɔ.ˈm**u**.θ-u	יָמוּתוּ	jɔ.ˈm**u**.θ-u	יָמוּתוּ	‘die 3MSG’	—
	jag.ˈg**i**.ð-u	יַגִּידוּ	jag.ˈg**i**.ð-u	יַגִּידוּ	‘say 3MSG’	—

There is a clear correlation between vowel alternation and stress alternation, i.e. stress shift; neither apply in (5b) while both apply in (5a). This correlation is due to the prohibition on a stressed schwa in Tiberian Hebrew (Gesenius-Kautzsch-Cowley 2006; Prince 1975), as in many other languages (Flemming 2009; Becker-Kristal 2010; Gordon 2017). Thus, where a vowel is reduced to schwa stress must shift, and since stress in Tiberian Hebrew can be either final or penultimate, stress shifts to the final syllable.[5]

[4] The vowel /ɛ/ is included in this list on the basis of the alternation found in the possessive/accusative suffix /ɛχɔ/, as in [jirɔˈʃ-**ɛ**χɔ]$_{P}$ – [jirɔʃ-**ə**ˈχɔ]$_{C}$ ‘inherit 3MSG you’.

[5] Antepenultimate stress is possible in the exceptional case where phrasal stress clash (*nesiga*) prohibits a final stressed syllable and the penultimate syllable cannot bear stress because it contains a schwa; e.g. /hɔrɔʁ-u ʔiʃ/ ⇒ [ˈhɔ.rə.ʁu ˈʔiʃ] ‘killed 3PL a man’ (Dresher 2009).

The patterns of vowel quality alternation in (5b) mirror prototypical patterns of vowel reduction in the world's languages. First, mid vowels are the most commonly attested targets of vowel reduction due to their low contrastivity and distinctiveness in compare to corner vowels [i, a, u]; see Dispersion Theory (Lindblom 1963; Padget & Tabain 2005). Second, schwa is the most common output of vowel reduction cross-linguistically (Crosswhite 2001; Barnes 2006), structurally represented as an empty V-slot (Anderson 1982; Clements & Kayser 1983). In Tiberian Hebrew, this featureless representation is supported by the *hataf* vowels which acquire their features from neighboring consonants or vowels. For example, in [ʔă.vaq.ˈqeʃ] אֲבַקֵּשׁ 'ask 1SG' the vowel [ă] is an empty V-slot, i.e. a schwa, that gets its features from the glottal stop.

2.2 Closed syllables (CVC)

Unlike in CV syllables, where the reduced vowel in context forms surfaces as schwa [e], in CVC syllables the output of reduction is [a].

(6) Alternation in closed syllables (CVC)

	Pause		***Context***			***Alternation***
a.	jo.ˈχ**e**l	יֹאכֵל	jo.ˈχ**a**l	יֹאכַל	'eat 3MSG'	e ~ a
	hɔ.ˈr**ɔ**ʁ	הָרָג	hɔ.ˈr**a**ʁ	הָרַג	'killed 3MSG'	ɔ ~ a
b.	ʔɔ.ˈm**ɔ**r.-ti	אָמָרְתִּי	ʔɔ.ˈm**a**r.-ti	אָמַרְתִּי	'said 1MSG'	ɔ ~ a
	mɔ.ˈr**ɔ**ð.-nu	מָרָדְנוּ	mɔ.ˈr**a**ð.-nu	מָרַדְנוּ	'rebelled 1PL'	ɔ ~ a
c.	jɔ.ˈmuθ	יָמוּת	jɔ.ˈmuθ	יָמוּת	'die 3MSG'	–
	jag.ˈgið	יַגִּיד	jag.ˈgið	יַגִּיד	'say 3MSG'	–

As in CV syllables, the high vowels resist alternation (6c), and the mid vowels [ɔ] and [e], whether in the final (6a) or the penultimate (6b) syllable, alternate with [a]. Thus, contextual allomorphs exhibit less structural complexity, and it is in this sense that they can be considered reduced (Bosch & Wiltshire 1993).[6]

Similar pattern of vowel reduction is found in Belarusian (7), where high vowels do not alternate, and mid vowels alternate with [a].

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[6] Unlike in CV syllables, the alternation in CVC syllables is not exception-free; that is, mid vowels do not always alternate in CVC syllables and consequently the pausal and contextual forms can be identical, e.g. [tir.ˈdof]$_{C/P}$ 'chase 2MSG', [ʔă.vaq.ˈqeʃ]$_{C/P}$ 'ask 1SG'. Such exceptions are commonly attributed to diachronic phenomena (Qimron 1986, 2006; Khan 1994).

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

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

The same reduction pattern is also attested in certain southern dialects of Russian (Crosswhite 2000) and in Shimakonde (Barnes 2006).

3 A CONFLICT IN PROMINENCE

The following table 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.

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

	Position	***Structure***	***Pause***		***Context***		
a.	Penultimate	CVC	ʔɔ.ˈmɔr.tɔ	אָמָ֫רְתָּ	ʔɔ.ˈmar.tɔ	אָמַ֫רְתָּ	'said 2MSG'
b.	Penultimate	CV	ʃɔ.ˈmɔ.ru	שָׁמָ֫רוּ	ʃɔ.mə.ˈru	שָׁמְרוּ	'kept 3MPL'
c.	Final	CVC	kɔ.ˈθɔv	כָּתָב	kɔ.ˈθav	כָּתַב	'wrote 2MSG'
d.	Final	CV		*not attested*			

The data in (8) exhibit a typologically a-typical reduction pattern and thus poses a theoretical problem. Cross-linguistically, vowel reduction tends to affect unstressed syllables, as stressed syllables are prosodically strong positions, thus exempt from reduction (Beckman 1997; Crosswhite 2004; Barnes 2006). Here, contrary to cross-linguistic tendencies, vowels in stressed syllable are reduced.

However, it is not the case that stress is isomorphic with prosodic strength, nor that vowel reduction always targets unstressed syllables. Indeed, vowel reduction does not affect strong positions, but stressed syllables are only one of several strong positions in the word (Bosch & Wiltshire 1993; Bosch 1996; Barnes 2006). Thus, vowel reduction in Tiberian Hebrew could as well be independent of stress, as it is the case in French and Northern Welsh. French lacks word-level stress, but it does exhibit alternating pattern of vowel reduction in casual speech, attributed to a phrase-level foot structure (Garcia et al. 2017). In Northern Welsh, as in Biblical Hebrew, vowel reduction applies in stressed syllables (9). All vowels, except the final one, are reduced to [ə], including the vowels in the stressed syllables, which are usually penultimate (Hannahs 2007).

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

Stem forms		***Suffixed forms***	
ˈkuχ	‘boat’	ˈkə.χɔd	‘boats’
ˈbrɨn	‘hill’	ˈbrə.nja	‘hills’
ˈmə.nið	‘mountain’	mə.ˈnə.ðɔɨð	‘mountains’

3.1 Multiple prominent positions

On the phonetic level, stress is not a homogenous phenomenon; its phonetic correlates are typically pitch contour, increased intensity, and/or prolonged duration (Hayes 1995). Different languages employ varying subsets of these acoustic characterizations to mark stress (Gordon & Roettger 2017). For example, Modern Hebrew marks stress mainly by duration (Silber-Varod et al. 2016, Cohen et al. 2018) while Welsh marks it by intensity. However, these same languages employ the other phonetic correlates of stress in different positions: in Modern Hebrew a peak of high pitch appears in the first pre-tonic syllable (Becker 2003), and in Welsh duration and pitch rise are associated with the word-final syllable (Ball & Williams 2001; Hannahs 2013).

Bosch (1996) proposes that prosodic words in Northern Welsh have two distinct prominent positions, one relevant to stress assignment and another determining the position of vowel reduction. The prominent position for stress assignment is determined by the metrical system – a right-aligned trochaic foot. The prominent position for vowel reduction is determined by the phonetic properties of the syllable – the final syllable is the longest in terms of duration (Ball & Williams 2001), thus resisting vowel reduction; all other syllables are reduced. Bosch’s analysis is in line with recent studies on 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 §3.2), why not for stress assignment vs. vowel reduction?

Dismantling stress to its phonetic correlates does not impeach its phonological prominence. However, it does show that on the phonetic level, there are multiple positions of prominence which correspond to different phonetic phenomena. These phonetically prominent positions coincide in some cases, while in others they do not. Therefore, given a phonological phenomenon other than stress, such as vowel reduction, which correlates with phonetic vowel duration – the relevant position(s) of prominence may be different to the ones which are relevant for the purposes of stress.

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, where VR-feet are trochaic and stress feet are iambic (Rappaport 1984). The superimposition of the two metrical planes, illustrated in (10), achieves the sought duality, where a single syllable occupies a strong position for stress and a weak position for reduction. Notice that this analysis assumes a 5-vowel quantity-sensitive vowel inventory, while in this study we assume a 7-vowel inventory.

(10) Analysis: Context forms (Rappaport 1984)

	a. ʃɔː.mə.ˈruː שָׁמְרוּ ‘guarded 3MPL’	b. kɔː.ˈθav כָּתַב ‘wrote 3MSG’
Stress plane	[* _]	[*]
Underlying base	ʃaː . ma . ru	kaː . tav
Reduction plane	[*] [_ *]	[*] [*]
Derived form	ʃaː . mV . rú	kaː . táv
Surface form	ʃɔː . mV . rúː	kɔː . θáv

The penultimate syllable in (10a) exemplifies the main idea of a multi-planar metrical system, with the co-occurrence of prosodic strength on the stress plane (marked with *) and prosodic weakness on the vowel reduction plane (marked with _). Since the vowel is reduced, stress must shift to the final syllable because a reduced vowel cannot be stressed in Tiberian Hebrew. Additional rules are applied to derive the surface representation, including word-final vowel lengthening, rounding of [aː] to [ɔː], and post-vocalic spirantization (Rappaport 1984). The surface form [ʃɔː.mV.rúː] contains the empty V-slot for the reduced vowel; the surface segmental content (or lack thereof) may be further conditioned by the adjacency of guttural consonants or set by default (see §2.1). In the case of (10b), there is no environment for vowel reduction to occur, i.e. no weak position.

Rappaport’s (1984) VR-feet are not compatible with the 7-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 §2). In a 7-vowel system, the underlying base of (10b) is not /kaːtav/ but rather /kɔtɔv/. With /kɔtɔv/ as the 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 7-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 5-vowel quantity-sensitive system. The admission of pausal lengthening into the account predicts that all stressed vowels in pausal forms will surface as 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]$_{\text{F}}$. 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 7-vowel system, the underlying quality of the penultimate vowel is /ɛ/. The surface form features a straightforward preservation of the underlying quality. Thus, no derivation process is required to account for /-ɛχɔ/ affixed words under the 7-vowel system. According to our analysis, vowel reduction does not apply to this vowel due to the effects of phrase final lengthening, which renders this vowel immune to vowel reduction (see §2.3).

Rappaport's (1984) analysis with multiple metrical planes has been reinforced in recent studies of phenomenon-specific prominence (Gordon 2006; Ryan 2019). The present study adopts and follows the general concept of this analysis, but proposes a novel architecture to the vowel reduction plane – one which is tightly grounded upon the cross-linguistically attested phenomenon of final lengthening (see §3.4).

3.2 Phenomenon-specific weight criteria

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. For example, Lhasa Tibetan exhibits three different syllable weight schemes corresponding to three phenomena: stress, compensatory lengthening, and contour tone (Dawson 1980; Gordon 2006). CVC syllables are light for the purposes of stress assignment, but heavy for the purposes of compensatory lengthening. As for contour tones, CVR syllables (where R stand for a sonorant) are heavy but CVO syllables (where O stands for an obstruent) are light.

(11) Phenomenon specific prominence in Lhasa Tibetan (data from Dawson 1980)

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

In the stress system, CVV syllables are heavy and CVC are light; in (11a) the initial CVV syllable is stressed but in (11c) the initial CVC is not stressed. In the tone system, both CVV and CVR are heavy as they license contour tone; there are no CVC syllables with contour tone where the coda is an obstruent. Finally, for compensatory lengthening, all CVC are heavy since any deleted consonant coda position is compensated via lengthening of the preceding vowel. Gordon (2006) provides a detailed analysis grounding this behavior in the phonetic manifestation of the different phenomena. In brief, the realization of a contour tone requires a long sequence of sonority, where a sonorous segment is a vowel or a sonorant consonant; therefore, CVR is heavy like CVV. Compensatory lengthening, on the other hand, is sensitive to prosodic structure and applies whenever a deleted consonant leaves an empty coda position. Stress as a metrical system is different from both, given no weight priority to coda consonants. Thus, Lhasa Tibetan exhibits three different syllable weight schemes for different phonological phenomena.

A similar case is reported for Early and Classical Greek, where different weight criteria are required for the pitch accent system as opposed to the systems of stress, poetic meter and minimal root requirement (Steriade 1991). The solution proposed in recent literature is to redefine weight distinction as *phenomenon-driven* rather than *language-driven* (Gordon 2006). In such a system, different phenomena can utilize distinct metrical planes within the same language, where each phenomenon determines its prominent (and weak) positions. The proposed system is restricted in the sense that all syllable weight schemes must adhere to the universal scale of syllable weight (Hyman 1984, Hayes 1989): CVV > CVR > CVC > CV. However, different schemes may place the borderline between light and heavy syllables in different positions along this universal scale. The different syllable weight schemes employed in Lhasa Tibetan are as follows (grayed cells represent bimoraic syllable types).

(12) 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
Compensatory Lengthening	CVV $\sigma_{\mu\mu}$	>	CVR $\sigma_{\mu\mu}$	>	CVO $\sigma_{\mu\mu}$	>	CV

Under such an analysis, each phenomenon adheres to a strict dichotomy of light vs. heavy, where heavy syllables are bimoraic.

3.3 Syllable weight criteria for vowel reduction

Introducing new phenomenon-specific weight criteria must be rigorously restricted because it is a powerful theoretical device that may easily over-generate; therefore, any phenomenon-specific syllable weight scheme must be well-supported. Following typological surveys (Gordon 2006; Ryan 2019), the following phenomena may have independent syllable weight schemes: stress, tone, minimal word restrictions, compensatory lengthening, syllabic template and poetic meter.

Previous studies propose three elements that are required to support a phenomenon-specific weight scheme (Gordon 2006; Ryan 2016, 2019):

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).

The following exposition uses the case of contour tone licensing 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 (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 bimoraic, while CVC and CV are monomoraic. Thus, the three required elements for postulating a proprietary weight scheme for contour tone are as follows:

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

Now, we turn to the argument supporting a phenomenon-specific weight scheme for vowel reduction. On the phonetic level, the main correlate of vowel reduction is vowel duration (Lindblom 1963; Moon & Lindblom 1994; Flemming 2005). Like in 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 this "sufficient" threshold. This effect is best seen in the cases of gradient reduction systems such as non-first-pretonic syllables in Russian, where vowel quality is gradually altered in direct correlation with phonetic duration (Crosswhite 2000; Barnes 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 comprises "sufficiency" is language specific (Barnes 2006) and also vowel specific, as some vowels are inherently longer than others (Becker-Kristal 2010). Therefore, we 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 bimoraic and reducible vowels are monomoraic.

The actual application of vowel reduction is further conditioned by metrical structure, which is again, 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 monomoraic vowel is not necessarily reduced, it is just *reducible*.

In this study we propose a new syllable weight scheme specific to vowel reduction, whereby moraic structure is assigned as a function of the vowel's phonetic duration: a short vowel is mono-moraic and a long vowel is bimoraic. This contrast distinguishes between reducible and non-reducible vowels respectively. Crucially, coda consonants do not contribute weight for the purpose of vowel reduction. Finalizing the argument, here are the three elements required to support the existence of a proprietary vowel reduction weight scheme:

i. Categorical phenomenon: The reducibility vs. reduction-resistance of a vowel.
ii. Phonetic manifestation: Vowel production over "sufficient" phonetic duration.
iii. 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 the literature. In general, the notion of bimoraic non-reducible vowels is a case of *inalterability* (Hayes 1986). Reformulated in the terminology of moraic and prosodic theories, it follows the same line of thought regarding the inalterability of segments which are associated with multiple prosodic slots, such as Tiberian Hebrew geminate stops, which do not undergo spirantization due to the one-to-many representation, one segment to two prosodic positions. 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 applicability of vowel reduction. In parallel, a separate prominence level, called "word-level" in her terms, determines the position of word stress. In our proposal, "word-level" prominence is simply called stress.

3.4 Final lengthening

Commonly attested vowel reduction systems target prosodically weak positions. The most widespread case being the licensing of a large vowel inventory in stressed syllables as opposed to a small vowel inventory in unstressed syllables. In such languages, stress correlates with increased phonetic duration of the stressed vowel (Hayes 1995; Gordon & Roettger 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. In languages with secondary stress, like English, this scheme is repeated in an alternating pattern throughout the entire word (e.g. [səˈrɛnəɾi] 'serenity'; Hammond 1997).

Resistance to vowel reduction is incurred by prolonged phonetic duration, regardless of the phenomenon that caused duration to increase. Acoustic studies exploring the durational effects of prosodic boundaries have shown that final lengthening manifests at all levels of the prosodic hierarchy; starting from the prosodic word and climbing up to the utterance. The amount of lengthening increases with higher prosodic boundaries (Cambier-Langeveld 1997; Byrd & Saltzman 1998; Cho 2006; Tabain 2003; Tabain & Perrier 2005). Final lengthening at the level of the prosodic word affects the final syllable, prolonging the duration of its vowel (Beckman & Edwards 1987; Wightman et al. 1992). However, phrase-final lengthening targets two distinct positions – the final syllable and the rightmost stressed syllable in the phrase (Berkovits 1994; Turk 1999; Turk & Shattuck-Hufnagel 2007).

In complete accordance to these observations, various languages exhibit the blocking of vowel reduction due to the increased phonetic duration of vowels in domain-final positions. This behavior is attested at the word-level, in languages such as Northern Welsh, Belarusian, Ukrainian, Central Eastern Catalan, English and Bonggi, and at the phrase-level, in Russian, Brazilian Portuguese, Yakan, Nawuri, Shimakonde, Murut (Barnes 2006).

4 A MULTI-PLANER ANALYSIS OF TIBERIAN HEBREW PAUSE-CONTEXT ALLOMORPHY

In light of the above discussion, we present in this section a detailed analysis of the context (§4.1) and pausal (§4.2) allomorphs, employing *phenomenon-specific syllable weight* scheme. We argue that vowel reduction in Tiberian Hebrew is independent of stress, by showing that stress does not block, license or determine the site of vowel reduction. Rather, the application of vowel reduction is determined by prosodic factors, which include: (i) the position of the word in the phrase, (ii) the position of the syllable in the word, and (iii) the syllable structure. The apparent correlation between stress and vowel reduction is attributed to the shared prosodic elements.

Additional support for the existence of separate metrical planes comes from the phenomenon of *minor pause*, which shows that stress and vowel reduction are independent phenomena (Revell 1981, 2012). For example, the word /ʔɔttɔ/ 'you 2MSG' has three surface forms: [ˈʔɔt.tɔ] in major pause, [ˈʔat.tɔ] in minor pause, and [ʔat.ˈtɔ] in context (DeCaen 2005). Notice that the reduced vowel, [a], appears in a stressed syllable in minor pause and an unstressed syllable in context. This phenomenon suggests that stress and vowel reduction are independent of each other, as vowel reduction (/ɔ/ ⇒ [a]) may apply in a stressed or unstressed syllable, depending on the phrase-level prosodic environment.

4.1 Vowel reduction in the *contextual* allomorph

This section begins the exposition of the core proposal of this study. In order to employ the metrical plane of vowel reduction developed above in §3.3, the distribution of phonetic vowel duration must be determined. Following Khan (1987), phonetic duration in Tiberian Hebrew is conditioned by stress and syllable structure:

(13) Tiberian Hebrew phonetic vowel duration

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

Stressed vowels ($C\acute{V}(C)]_\sigma$) are long regardless of syllable structure. When unstressed, vowels in open syllables ($CV]_\sigma$) are long while vowels in closed syllables ($CVC]_\sigma$) are short. Finally, reduced vowels ($C\check{V}]_\sigma$) are always short and never stressed. This yields the following vowel duration scale (a comma indicates an equal position in the hierarchy):

(14) Vowel duration hierarchy (first version)

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

However, this scale does not prove useful for predicting the alternation involved in pause-context allomorphy, because vowels in all syllable types can be reduced. As shown in (15) below (repeated from (8)), contextual forms display reduction in closed and open syllables, stressed or unstressed.

(15) 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*		

The only position that never allows reduction is word-final open syllable (15d). We propose that word-final vowels in Tiberian Hebrew are phonetically lengthened due to final lengthening on the word-level (see §2.4). The lengthened state of the final vowel renders it resistant to vowel reduction (see §2.3). Given the position-based behavior difference in CV syllables, i.e. final vs.

non-final position, the word-final open syllable, $CV]_{\omega}$, is added to the scale of phonetic vowel duration.

(16) Vowel duration hierarchy (revised version; cf. (14))

$CV]_{\omega}$	>	$C\acute{V}(C)]_{\sigma}$	,	$CV]_{\sigma}$	>	$CVC]_{\sigma}$	>	$C\check{V}]_{\sigma}$
Open word-final		Stressed		Open		Closed		Reduced

$CV]_{\omega}$ is the only syllable type that should be considered heavy (i.e. bimoraic) for the purposes of vowel reduction, since its vowel is never reduced (15d).

The claim that word final vowels in Tiberian Hebrew are long has already been made in Balcaen (1995) and Dresher (2009). However, we argue that this length is relevant only for the vowel reduction system, not for the stress system. The resulting state of affairs in similar to Northern Welsh, where the vowel in the final syllable is longer than the stressed vowel and never reduced (Ball & Williams 2001; Bosch 1996). The following table presents the proposed phenomenon-specific syllable weight for stress and vowel reduction, where monomoraic syllables are light and bimoraic (shaded) are heavy.

(17) Phenomenon-specific weight for stress and vowel reduction

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

For the purposes of stress, CV syllables are monomoraic while CVC syllables are bimoraic. For the purposes of vowel reduction, CVC syllables are monomoraic, while CV syllables vary – monomoraic when word-medial but bimoraic when word-final. That is, there are two types of heavy syllables, one for each phenomenon: CVC for stress and final CV for vowel reduction; all other syllables in all other positions are light. These differences in moraic structure yield different definitions of prominence (i.e. bimoracity): stress is sensitive to the complexity of syllable structure (CV vs. CVC), where coda consonants get an extra mora, while vowel reduction is sensitive to phonetic vowel duration (CV in word final position), where lengthened vowels receive an extra mora. These difference lead to a multi-planar metrical structure, illustrated below for the context forms [hɔ.ˈraʁ] הָרַג ‘killed 3MSG’ and [ʔɔ.ˈmar.tɔ] אָמַרְתָּ ‘said 2MSG’.

(18) Multi-planar analysis for Context forms

a. Stress assignment

Base	***Weight Assignment***	***Trochaic Footing***	***Stress***
hɔ.rɔʁ	hɔ^{μ}.rɔ^{μ}ʁ^{μ}	hɔ^{μ}.|rɔ^{μ}ʁ^{μ}|$_{F}$	hɔ.|ˈ**rɔʁ**|$_{F}$
ʔɔ.mɔr.tɔ	ʔɔ^{μ}.mɔ^{μ}r^{μ}.tɔ^{μ}	ʔɔ^{μ}.|mɔ^{μ}r^{μ}.tɔ^{μ}|$_{F}$	ʔɔ.|ˈ**mɔr**.tɔ|$_{F}$

b. Vowel reduction

Base	***Weight Assignment***	***Trochaic Footing***	***Reduction***
hɔ.rɔʁ	hɔ^{μ}.rɔ^{μ}ʁ	|hɔ^{μ}.rɔ^{μ}ʁ|$_{F}$	|hɔ.**raʁ**|$_{F}$
ʔɔ.mɔr.tɔ	ʔɔ^{μ}.mɔ^{μ}r.tɔ^{μμ}	|ʔɔ^{μ}.mɔ^{μ}r|$_{F}$.|tɔ^{μμ}|$_{F}$	|ʔɔ.**mar**|$_{F}$.|tɔ|$_{F}$

As emphasized above, the only difference between these two metrical systems is the assignment of an additional mora to coda consonants in (18a) vs. word-final vowels in (18b). Otherwise, the derivation follows 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 (18a), the *strong* position of the trochaic foot (in bold) is assigned with stress, whereas in (18b), the strong position resists reduction, and thus the vowel in the *weak* position of the trochaic foot (in bold) undergoes reduction (ɔ ⇒ a).

The forms in (18) 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 [ʃɔ.mə.ˈru] שָׁמְרוּ 'kept 3MPL', which 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}|$_{F}$]. 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}|$_{F}$.|ru^{μμ}|$_{F}$]. 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 bear 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 not surface with final stress; e.g. [jɔ.ˈmu.θu] יָמוּתוּ 'will die 3MPL'. The following scheme presents the multi-planar metrics for the context form [ʃɔ.mə.ˈru] שָׁמְרוּ 'kept 3MPL'.

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

Stress		s	w		
	μ	[μ	μ]		
Base	ʃɔ .	mɔ .	ru	⇒	[ʃɔ.mə.ˈru]
	[μ	μ]	[μμ]		
Vowel Reduction	s	w	s		

The alternation in stress position is explained by the generalization that schwa is never stressed in Tiberian Hebrew. In the cases presented above in (18), 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, and 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 §2.1). 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, re-parsing is imposed. 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 (see Himmelreich 2019), by posing a constraint which bans stress from schwa (Cohn & McCarthy 1998).

4.2 Vowel reduction in the *pausal* allomorph

In earlier studies, the pausal form is often assumed to be similar to the base (Prince 1975; Rappaport 1984; Revell 1981, 2012; Dresher 2009; Qimron 2008; *inter alia*). In this study we show that pausal forms resemble the base because they undergo less vowel reduction relative to context forms. 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 (Dresher 1994) and are thus affected both by *word-level* and *phrase-level* final lengthening (see §2.4). 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 (Berkovits 1994; Turk & Shattuck-Hufnagel 2007). This is the crucial phenomenon that distinguishes phrase-final vs. phrase-medial words. 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 (5), (6) and (8) suggest that the pausal form's stressed vowel never undergoes reduction – it is non-reducible. Conversely, the stressed vowel of a phrase-medial word is not protected by additional lengthening, and so it does undergo reduction, yielding the attested contextual forms.

In complete parallel to the analysis of word-final vowels as reduction resistant, in this study, we propose to analyze the pausal form's stressed vowel as reduction resistant, i.e. $\acute{V}]_{IP}$ and $CV]_{\omega}$ are analyzed as bimoraic 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.

(20) 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:

(21) 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 it is bimoraic.

The following tables present the application of the proposed multi-planar metrical structure for pausal forms: שָׁמָרְתִּי [ʃɔ.ˈmɔr.ti] 'kept $_{1MSG}$' and הָרָג [hɔ.ˈrɔʁ] 'killed $_{3MSG}$'. The data from (18a) is repeated below in (22a) for convenience, the metrical account for stress assignment in both context and pausal forms is identical.

(22) Multi-planar analysis for 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 (22b) contains only bimoraic feet. There are no metrically weak positions, and therefore there is no reduction (see inalterability in §3.3). This is the common state of affairs in pausal forms which span up to 4 syllables.

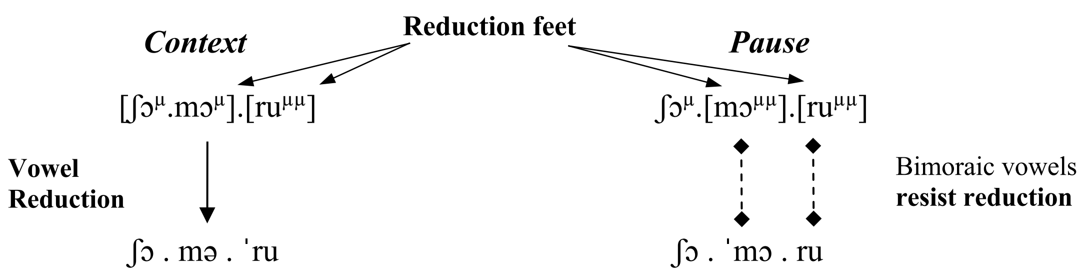
However, given a longer word such as /lə.hɔ.rɔ.ʁɛ.χɔ/ ‘to kill you’, which is long enough to host three feet, vowel reduction will manifest in a pausal form. The metrical parsing will result in lə$^{\mu}$.[hɔ$^{\mu}$.rɔ$^{\mu}$]$_F$.[ʁɛ$^{\mu\mu}$]$_F$.[χɔ$^{\mu\mu}$]$_F$, where the leftmost trochaic foot is disyllabic, thus targeting the antepenultimate syllable [rɔ] for vowel reduction. The derivation of both the contextual and the pausal allomorphs of /lə.hɔ.rɔ.ʁɛ.χɔ/ are given in (23) below:

(23) Derivation of long Context and Pausal forms

		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 weight assignment in VR. 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 right-aligned trochaic feet and application of vowel reduction at the weak positions. The same derivation process is illustrated in the following diagram:

(24) Derivation of long Context and Pausal forms



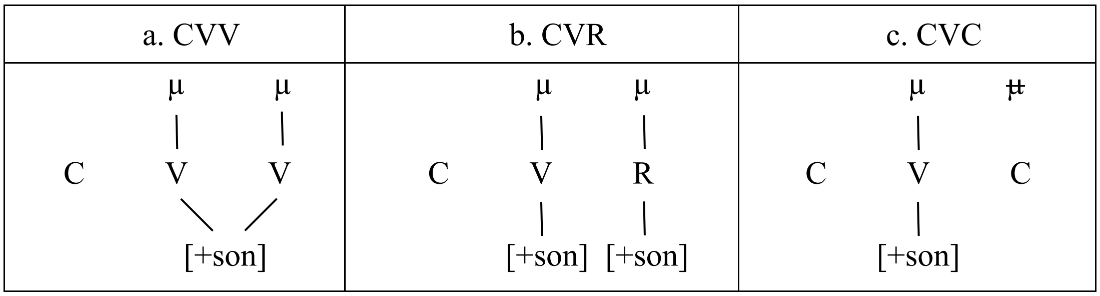
4.3 Moraic projection

To account for the complex pattern of the moraic projection required by phenomenon-specific syllable weight schemes, the grammar of weight assignment must be allowed to refer to other levels in the prosodic hierarchy.

For example, contour tone licensing in Lhasa Tibetan is licensed on CVV and CVR syllables (R=Sonorant), but not CVC syllables (C=Stop). This suggests that contour tone licensing requires a structure where two consecutive prosodic slots are associated with the segmental feature [+son].

In other words, weight assignment for the purposes of contour tone must refer to the segmental tier, in order to be able to distinguish between sonorant and non-sonorant consonants.

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

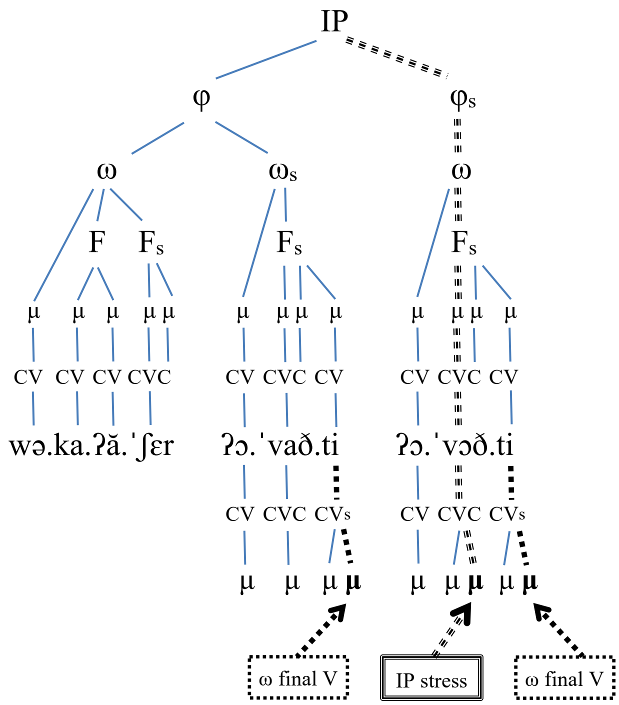


In the classic case, the moraic projection for each C and V slot is determined by its position within the syllable. However, if the projection of a mora can be conditioned by its association with segmental features, the grammar of weight assignment must refer to more complex structures. In the case of contour tone licensing, it is necessary to refer to both the CV tier and the segmental tier to determine whether a mora is to be projected. In (25), the conditions for the projection of two morae are met only in (a) and (b), thus contour tone is licensed only in these two structures. This type of analysis can be used to formalize the grammars of various phenomenon-specific weight assignment schemes (Gordon 2006; Rayan 2019).

For the purposes of weight assignment on the metrical plane of vowel reduction, we 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 (Beckman 1997), 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.

The tree representation in (26) presents the multi-planar prosodic parsing of an intonational phrase in Tiberian Hebrew. 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).

(26) Prosodic structure of an intonational phrase



… וְכַאֲשֶׁר אָבַדְתִּי אָבָֽדְתִּי (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 /ʔɔvɔðti/ ‘perished 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. This occurs because the word-final vowel is affected by final lengthening (see §3.4), and thus, it is assigned with the [strong] feature. Moreover, the pausal form’s stressed vowel also projects an additional mora. This occurs because this vowel is the rightmost stressed vowel in the intonational phrase, and thus it is also affected by final lengthening (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 dependency must be embodied by the rules or constraints employed in any formal account of these phenomena. Rules targeting a word-final vowel are straightforward, while for singling out the “rightmost stressed vowel” one can refer to 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). In an Optimality Theoretic (Prince & Smolensky 1993) account, one would use constraints such as **$*V^{\mu}]_{\omega}$** and **$*ˈV^{\mu}]_{IP}$** which propagate that a vowel associated with a word-final position or the rightmost stressed position in the IP – must not be monomoraic (see Himmelreich 2019 for OT analysis).

5 Conclusion

In this study, we analyzed the allomorphy between pausal and contextual forms 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 presented an opportunity to examine a phenomenon which is purely phonological and provide a glimpse 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 alternation exhibited by pausal allomorphy (§1). Second, phrase final lengthening provides a simplified account to the reduction-resistant nature of pausal forms (§3.2), 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). We argued that vowel reduction in Tiberian Hebrew operates independently of stress, where the positions it targets and the vowel alternation are determined by prosodic factors such as the position of the word in the phrase, the position of the syllable in the word, and syllable structure.

Regarding linguistic theory, we introduced the phenomenon-specific syllable weight scheme for vowel reduction (§2.3). The strong link between vowel reduction and phonetic vowel duration has been demonstrated and widely accepted for some time now (Lindblom 1963; Moon & Lindblom 1994; Flemming 2005). 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 two separate metrical planes. However, the cases where these metrical systems do not align, such as Northern Welsh (Bosch 1996) and hereby Tiberian Hebrew, suggest that these mechanisms can operate independently. In fact, languages with vowel reduction but no secondary stress (e.g. Russian; Crosswhite 2000) are clear cases of such metrical misalignment. In this type of languages, vowel reduction typically targets all non-stressed positions, resulting in two fundamentally different metrical domains. While stress assignment metrics employ a single foot, 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 2001; 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.

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