Hebrew stress: Can't you hear those trochees?*

Michael Becker

1. Introduction

In this paper, I look into the stress system of Modern Hebrew, offering new data from the intonational phonology. I examine the distribution of High tones at the phrasal level, and show that it is best understood in terms of trochaic foot structure.

The analysis supports the proposal made in Hayes (1995), that final-stress languages are trochaic. The traditional analysis of tone, in terms of Autosegmental theory, is shown to be less satisfactory or insightful.

2. The Stress System of Hebrew

The stress pattern of Modern Hebrew is rather well studied. The first overview of the facts within generative phonology is in Bat-El (1993). I offer here a slightly different typology, where nouns fall into two classes, rather than three as proposed by Bat-El.

One class of nouns is the **accented** class, where nouns have some lexical mark for stress. Within this class, suffixation doesn't shift the place of stress (unless the suffix itself is accented). This class includes most loan words and many native words. Stress usually appears inside the "three syllable window" with some exceptions. Some examples are in (1).

(1)	singular	plural	
	balon[1]	balonim	'balloon'
	tiras	tirasim	'corn, corn cob'
	ambulans	ambulansim	'ambulance'
	beybisiter	beybisiterim[2]	'babysitter'

* Thanks to my advisors, Outi Bat-El and Charles W. Kisseberth, for endless hours of guidance, discussion and tremendously helpful questions and comments. All remaining errors are my own.

[1] Throughout this paper, an underline marks stress. The acute accent (´) is reserved for High tone.

The other class of nouns is the **unaccented** type, where nouns have no underlying stress, and are assigned final stress by a general principle of the language. When suffixes are added, stress appears on the last suffix and not on the root. This type includes most native nouns and all of the various deverbal forms, as in (2).

(2)	maxšev	'computer'	
	maxševim	'computers'	(with the plural suffix *-im*)
	maxševon	'calculator'	(with the suffix *-on*)
	maxševonim	'calculators'	(with both *-on* and *-im*)
	xišuv	'calculation'	(from *xišev*, 'to calculate')
	xišuvim	'calculations'	(with the plural suffix *-im*)

A large number of native nouns, traditionally known as the 'segolates', follow a different pattern. In the singular they can be either accented or unaccented, but in the plural they take a templatic form. The fixed prosodic form of the plural overwrites the prosodic information of the singular.

The template of the plural is of the form σσ (i.e. disyllabic with final stress), with the vocalic pattern *a* and the plural suffix *-im* or *-ot*. Some examples are in (3).

(3)	semel	smalim	'symbol'	(plural suffix *-im*)
	simla	smalot	'dress'	(plural suffix *-ot*)
	ben	banim	'son'	(plural suffix *-im*)

In the verbal system, stress is predictable. Verb roots are maximally of the form σσ (i.e. at most two syllables with final stress, as in 4a). When consonant-initial suffixes are added, stress stays final on the root (4b).

Vowel-initial suffixes trigger the deletion of a stem-final non-high vowel in stems that have more than one vowel in them. The stem's stressed vowel does not surface, and final stress is assigned to the word (4c).

(4)					
	a.	amad	'he stood'	ya-amod	'he will stand'
	b.	amad-nu	'we stood'	na-amod	'we will stand'
	c.	amd-u	'they stood'	ya-amd-u	'they will stand'

[2] Where in the singular there is antepenult or pre-antepenult stress, in the plural some speakers shift the stress two syllables to the right, so the forms *ambulansim* and *beybisiterim* exist as well (Bat-El 1993).

In short, Hebrew has a general principle that assigns final stress to nouns and verb stems. Additionally, Hebrew tolerates lexical marking of stress (accent).

The analysis of Hebrew within the theoretical framework of metrical theory has been attempted in a number of works: Bat-El (1993), with right-headed unbounded feet and trochees; Graf (1999), with trochees and catalexis; and Ussishkin (2000), with iambs and trochees.

Hayes (1995, pp. 262-266) suggests that final-stress languages are trochaic, since iambs are incompatible with left-to-right parsing. Final stress languages, such as Turkish and Tübatulabal, are re-analyzed as trochaic. A successful analysis of Hebrew in terms of trochees will support Hayes' theory.

3. Hebrew Tonology

While the stress system of Hebrew is well studied, the phonetic realization of stress in Hebrew has not gotten much attention. For the purposes of this study, I rely on two sources:

One source is a series of laboratory experiments with four native speakers, excluding myself. The speakers, three males and one female, are all from Tel Aviv, and are in their twenties or thirties.

The second source consists of recordings of radio talk shows. In the chosen recordings, speakers were judged to be native speakers of Hebrew, speaking the same dialect as the laboratory-recorded speakers. The speech was fluent, unplanned, and every-day-like, not read aloud. The speakers were not professional media people.

The phonetic correlates of stress are elusive. Cross-linguistically, duration and pitch contrasts are known to be the best correlates of stress, more so than intensity (see Hayes 1995, pp. 5-8). In Hebrew, there is no phonemic vowel-length or consonant-length distinction, and there is no underlying tone. Therefore, the phonology is free to use these two aspects of the pronunciation as correlates of stress.

Vowel length straightforwardly marks the stressed syllable in Hebrew. Phonetic measurements show that vowels in stressed syllables are twice as long as vowels in stressless syllables (5), regardless of syllable structure.

(5)	ba<u>lo:n</u>	'balloon'
	<u>ye:</u>led	'boy'
	<u>a:m</u>bulans	'ambulance'
	<u>be:y</u>bisiter	'babysitter'

3.1. Tone Shift

In Hebrew, a stressed syllable is marked by a High tone. The High tone appears on the stressed syllable when it is final or penult in the phrase (6a). When the stress is farther to the left in the phrase, The High tone appears one syllable after the stress (6b). This is a fully productive post-lexical phenomenon, as can be seen in (6c).

(6)	a.	ba<u>ló:n</u>	'balloon'
		<u>yé:</u>led	'boy'
	b.	<u>a:m</u>búlans	'ambulance'
		<u>be:y</u>bísiter	'babysitter'
	c.	<u>yé:</u>led	'boy'
		<u>ye:</u>léd ma<u>tó:k</u>	'a sweet boy' lit. boy sweet

Hebrew assigns a High tone to every stressed syllable in a phrase. Some general principle of the language pushes High tones one syllable to the right. This principle does not apply when there is no syllable available after the stress, or when the syllable that follows the stress is final in the phrase.

3.2. Adjacent Stressed Syllables

Another factor that can block a High tone from shifting to the right is the presence of another stressed syllable, as in (7c,d).

(7)	a.	ro<u>ní:t</u>	'Ronit (proper name)'
	b.	ro<u>ni:t</u> hál<u>xá:</u>	'Ronit left'
	c.	ro<u>ní:t</u> <u>ká:</u>ma	'Ronit stood up'
	d.	ro<u>ní:t</u> <u>ka:</u>má la<u>lé:</u>xet	'Ronit stood up and left' lit. to-leave

As the examples in (7) show, the High tone from the subject noun shifts to the right when a non-final stressless syllable is available (7b). The High tone does not shift when the next available syllable is stressed (7c,d). The example in (7d) shows that it is not the adjacency of the two High tones that creates the problem; rather it is the adjacency of the two stressed syllables.

3.3 Crossing High Tones

A third factor that can block the shifting of a High tone is a word boundary. While High tones invariably shift if the next syllable is in the same word, shifting is *optional* when shifting would cross into a following word (8):

(8) a. yo:ní neelá:m 'Yoni (proper name) disappeared'
b. * yó:ni neelá:m
c. yaro:n néelá:m 'Yaron (proper name) disappeared'
d. yaró:n neelá:m 'Yaron (proper name) disappeared'

This phenomenon is probably not so common in stress languages, where High tones usually appear inside the word they belong to. This aspect of Hebrew results from the combination of two factors: The principle of tone shift and the occurrence of word-final stressed light syllables.

4. Against an Autosegmental Analysis

It is common practice in generative linguistics to describe intonational phenomena as involving tones that associate to the segmental string, starting mostly with Pierrehumbert (1980). In Hebrew, there should be a means to express the principle that shifts High tones one syllable to the right.

One possibility is to associate a L*H pitch accent to each stressed syllable, as in (9a). This approach makes the prediction that a Low tone is pronounced on the stressed syllable. This turns out not to be the case: there is no "elbow" on stressed syllables in the relevant pitch tracks. Rather, pitch rises smoothly into the syllable that has a High tone on it.

Another possibility is to assume a H* pitch accent and a tone shift rule, as in (9b)[3]. This kind of rule would derive the correct surface forms. It should be noted, however, that in Pierrehumbert's version of the theory, starred tones are not allowed to spread. A shifting rule as in (9b) has spreading in it, so it weakens the theory to some extent.

(9) a. L* H b. H*
te le fon te le fon 'telephone'

[3] I am proposing a rule-based account of the facts, since most literature about Autosegmental theory is rule-based. Certainly it is possible to express the same analysis in a non-serial approach such as Optimality Theory.

For concreteness, I adopt the H* pitch accent and shifting rule in (9b), despite its problematic implications for the theory. Now, I turn to the three cases presented in section 3, where the tone shift rule is blocked.

Extra-tonality would account for the behavior of the high tone at the right edge of the phrase[4]. Phrase-final syllables are marked as extra-tonal when not stressed (10a), so the tone shift rule cannot apply. In (10b), the last syllable of the noun *yeled* is not peripheral, so it is not extra-tonal.

(10) a. H* b. H* H*
ye<led> 'boy' yeled matok 'a sweet boy'

Tone shift does not apply when there is a following stressed syllable, as in (11). The High tone from the noun *ronit* does not shift to the first syllable of the verb *kama*. In a rule-based theory, this effect is easy to explain: The following syllable is taken by another High tone at the beginning of the derivation, and it is commonly assumed that tones may choose not to spread to an occupied position.

In an Optimality Theoretic analysis, one would have to account for this in some other way: The High tone from *ronit* does not spread to the next syllable, although this syllable is toneless on the surface, since its High tone has shifted to the right. I will not attempt to solve this problem here.

(11) H* H* H*
ronit kama lale<xet> 'Ronit stood up and left'

The third case that one has to account for is the optional application of tone shifting across a word boundary. The relevant examples are in (12) below. Recall that the High tone from *yeled* invariably shifts to the next syllable (12a), while shifting from *balon* is optional (12b).

(12) a. H* H* b. H* H*
ha-yeled neelam ha-balon neelam
'The boy disappeared' 'The balloon disappeared'

[4] It was proposed to me that a boundary Low tone might be responsible for blocking the High tone shift. This proposal could not be extended to the analysis of yes-no questions. In a yes-no question, extra-tonality does not apply, and a (super) High tone is pronounced on the final syllable: yelḗd 'a boy?'

There is nothing in the representation in (12) that predicts any interaction between the tonal rule and the lexical or syntactic structure of the phrase. Any interaction of this sort will have to be stipulated.

I conclude that the Autosegmental analysis in pressed hard in accounting for the presented data. The solutions come in form of stipulations that do not give much insight as to the nature of the phenomena involved.

5. A Metrical Analysis of Hebrew

In this section, I propose an analysis of Hebrew tonology in terms of metrical theory. I suggest that Hebrew is a trochaic language, and that a High tone is pronounced at the right edge of each trochaic foot.

The idea of understanding tone in terms of metrical structure goes back to Idsardi (1992) and Idsardi and Purnell (1997). A related analysis of Bantu tone in terms of phonological structure is in Kisseberth (1994), and an Optimality Theory version is in Cassimjee and Kisseberth (1997).

A standard analysis of a trochaic system within Optimality Theory (Prince and Smolensky 1993) would follow McCarthy and Prince (1993). I use the constraints in (13-15):

(13) FT-BIN
Feet must be binary under syllabic or moraic analysis.

(14) Foot-Form (TROCHAIC)
Feet must be left headed
$Ft \rightarrow \sigma_s\sigma_w >> \sigma_s$

(15) NON-FINALITY
Feet must not be final, or
A High tone must not be pronounced finally

In Hebrew, stress is present underlyingly for some items (see section 1), and final stress is assigned otherwise. To assure faithfulness to underlying stress, I adopt the constraint in (16) from Graf (2000).

(16) Max-Head-Ft (MAX-HDFT)
Every input foot-head has a correspondent output foot-head.

The constraints proposed so far are sufficient to derive the surface forms of inputs such as *ha-yeled* 'the boy' or *ha-beybisiter* 'the babysitter'. In tableau (17), I mark two language-specific aspects of Hebrew: a High tone on the rightmost syllable of a foot, and a long vowel on the head syllable of a foot. I suggest that these two aspects of the pronunciation are due to the effect of some undominated constraints that are of no great interest at this point.

(17)

F Input: /ha-yeled/	MAX-HDFT	NON-FINALITY	TROCHAIC	FT-BIN
F a. (hayé:)led			*!	
F ☞ b. ha(yé:)led				*
F c. ha(ye:léd)		*!		

F Input: /ha-beybisiter/	MAX-HDFT	NON-FINALITY	TROCHAIC	FT-BIN
F ☞ a. ha(be:ybí)siter				
F b. ha(bé:y)bisiter				*!
F c. (habé:y)bisiter			*!	

In the tableaux above, I only consider candidates that satisfy MAX-HDFT, i.e. candidates that are faithful to the underlying foot's head. The (a) candidates have a trochaic foot, the (b) candidates have a degenerate foot, and the (c) candidates have an iamb.

The ranking of NON-FINALITY above TROCHAIC and FT-BIN causes the degenerate foot to be optimal in the case of penultimate stress, but there is nothing to prevent a formation of a perfect trochee when stress is antepenult or farther to the left.

In Hebrew, nouns that have no underlying stress are assigned final stress (see section 1). In the literature, assignment of final stress was proposed to be the effect of a constraint that aligns a foot's head with the right edge of the prosodic word (Inkelas 1994 for Turkish, Ussishkin 2000 for Hebrew).

While this proposal is adequate for words in isolation, looking at the phrasal level shows that stress is assigned to the lexical word, rather than to the prosodic word (18).

(18) a. ha ba<u>xú:r</u> 'the lad'
b. ha ba<u>xu:r</u> há ze 'this lad' lit. the lad the this

In (18a), the underlyingly stressless *baxur* 'lad' is assigned final stress. In (18b), the demonstrative '*ze*' is normally stressless, much in the same way that the demonstrative 'this' is normally stressless in English. The binary trochee, whose right edge is marked by a High tone, includes a vowel that is not a part of the lexical word. According to the principles of the Prosodic Hierarchy (Selkirk 1994), feet have to be properly contained in prosodic words. It follows that the prosodic word *has* to include the syllable that has the High tone on it, and it probably includes the whole noun phrase. The proposed structure is shown in (19). The stress is on the final vowel of the lexical word, not on the final vowel of the prosodic word. The proposed constraint is formalized in (20).

(19) [ha ba(<u>xu:r</u> há)$_{F}$ ze]$_{PWd}$ 'this lad' lit. the lad the this

(20) FINAL-STRESS
Align (LexicalWord, R, σ́, R)
For every Lexical Word there is a foot head, such that the right edge of the Lexical Word is aligned with a right edge of a foot head.

The constraint FINAL-STRESS has to be ranked above NON-FINALITY, so it forces a violation when the finally-stressed word is final in the phrase. A derivation of *ha-baxur* 'the lad' is in tableau (21) below.

While candidates (a) and (c) violate none of the markedness constraints, they are ruled out by FINAL STRESS, either by having their foot misaligned (a), or missing altogether (c). Both (d) and (e) violate NON-FINALITY, and candidate (d), with the degenerate foot, is chosen due to the ranking between TROCHAIC and FT-BIN.

(21)

Input: /ha-baxur/	MAX-HDFT	FINAL STRESS	NON-FIN	TRO-CHAIC	FT-BIN
F a.(ha:bá)xur		σ!σ			
F b. ha(bá:)xur		σ!			*
c. habaxur		*!			
F ☞ d. haba(xú:r)			*		*
F e. ha(baxú:r)			*	*!	

Finally, we have to make sure that FINAL STRESS will not interfere with faithfulness to underlying stress. For this, we will need to complete our ranking with (22).

(22) UNIQUENESS
A lexical item cannot have more than one head foot in it

The ranking MAX-HDFT, UNIQUENESS >> FINAL STRESS will give the right results, as can be seen in (23). The lower ranking constraints were omitted for brevity.

(23)

F Input: /beybisiter /	MAX-HDFT	UNIQUENESS	FINAL STRESS
F ☞ a. (be:ybí)siter			*
F F c. (be:ybí)si(té:r)		*!	
F b. beybisi(té:r)	*!		

Two more issues of Hebrew tonology still need to be addressed. One is the case of two adjacent stressed syllables. Recall that a High tone from one stressed syllable never shows up on a following stressed syllable. Once tone is understood as a manifestation of foot structure, this simply follows from the principle of Proper Bracketing (Itô 1992). A relevant example is repeated in (24), with the assumed structure.

(24) a. ro(ní:t)$_F$ (ka:má)$_F$ la(lé:)$_F$xet 'Ronit stood up and left'
b. *ro(ni:t (ká:)$_F$má)$_F$ la(lé:)$_F$xet

Since universally feet may not overlap, the structure in (24b) is ruled out. A degenerate foot must be formed, as in (24a).

The last issue that has to be addressed is the optionality of tone shifting across a word boundary. The relevant examples are repeated in (25), with the assumed structure.

(25) a. (yo:ní)$_F$ nee(lá:m)$_F$ 'Yoni (proper name) disappeared'
b. * (yó:)$_F$ni nee(lá:m)$_F$
c. ya(ro:n né)$_F$e(lá:m)$_F$ 'Yaron (proper name) disappeared'
d. ya(ró:n)$_F$ nee(lá:m)$_F$ 'Yaron (proper name) disappeared'

We see that indeed there is no reason to expect a pronunciation such as (25b), which violates FT-BIN for no good reason. We also understand why we should expect (25c), which has a binary foot. But why is (25d), with its degenerate foot, a possible pronunciation?

Notice that in (25c), the foot from the first word extends into the next word, whereas the foot in (25d) is aligned with the edge of the word. Within the theory of the Prosodic Hierarchy, we assume that feet are contained in prosodic words. Prosodic word edges have to be aligned with lexical word edges. Formally, there is a universal constraint such as (26), cf. McCarthy & Prince (1993), Selkirk (1995).

(26) ALIGN(LexicalWord,L,ProsodicWord,L)
For every lexical word there is a prosodic word, such that the left edge of the lexical word is aligned with the left edge of a prosodic word.

Recall that so far, the lowest ranking constraint was FT-BIN. If the alignment constraint in (26) and FT-BIN are **crucially tied** (Anttila 1995), i.e. both possible rankings are given by the grammar, then we get exactly the observed optionality.

(27)

Input: /yaron ǀ neelam/	ALIGN(LexWd,L,PWd,L)	FT-BIN
☞ a. [ya(ró:n)$_F$]$_{PWd}$ [neela:m]$_{PWd}$		*
b. [ya(ro:n né)$_F$]$_{PWd}$[ela:m]$_{PWd}$	σ!	

Input: /yaron neelam/	FT-BIN	ALIGN(LexWd,L,PWd,L)
a. [ya(ró:n)$_F$]$_{PWd}$ [neela:m]$_{PWd}$	*!	
☞ b. [ya(ro:n né)$_F$]$_{PWd}$[ela:m]$_{PWd}$		σ

The two tableaux in (27) have the same input, same candidates and same constraints. The only difference is in the ranking between ALIGN(LexWd,L,PWd,L) and FT-BIN.

Note that the account that I provide for the two possible pronunciations in (26) follows naturally from what is assumed to be universal in the theory of the Prosodic Hierarchy. Nothing had to be added or stipulated in the account so far, since the relationship between prosodic structure and lexical structure is an inherent part of the theory. The only thing that had to be added was the crucial non-ranking between two of the proposed constraints.

7. Conclusion

In this paper I presented new facts about Hebrew intonation. I have shown that an analysis of the data in terms of Autosegmental theory faces some serious problems, and leads to no theoretical insight.

I suggested that the location of High tones in Hebrew should be understood as a realization of metrical structure, namely trochaic feet. Once tone was understood in terms of trochaic foot structure, the account followed easily from what is universally assumed about the Prosodic Hierarchy and metrical structure. No stipulations of any kind were needed.

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Department of Linguistics
Tel Aviv University
Tel Aviv, Israel
kuzum99@yahoo.com