

## **Prosodic properties of Hebrew word-level stress: high-low or long-short?**

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Word-level stress is a prosodic phenomenon in spoken language, which functions, in many cases, to allow the listener to distinguish between words with the same segmental sequence [1]. For example, in English, the stress distinguishes between a noun and a verb in words such as: 'address', in which a penultimate stress assigns the nominal meaning (an 'address) while an ultimate stress assigns the verbal meaning (to add'ress). In Hebrew, there are also such minimal pairs, for example: ['oxel] "food" versus [o'xel] "dining" and even between two nouns, such as: ['boker] "morning" versus [bo'ker] "cowboy". Although it is well established that word stress is part of the Hebrew phonology (among others, [2], the question of how Hebrew speakers realize the word-level stress – whether by lengthening and shortening syllables or by increasing and decreasing the pitch – has been only recently studied. Moreover, previous phonological studies suggest that secondary stress in Hebrew is assigned to every other syllable from the primary stressed syllable (among others, [3]), but if Hebrew speakers do not perceive it, what is its realization?

The main findings of [4] on the (primary) word stress were that the main cue for Hebrew stress is duration. Intensity was found as significant but weaker cue. Fundamental frequency (F0), on the other hand, plays a minor role in indicating stress. Regarding secondary stress in mid-sentence position, [5] found inconsistent and sporadic evidence for secondary stress, which supports the claim that secondary stress in Hebrew is not acoustically realized.

Following those findings, we investigated the realization of the two word-level stress patterns – final and penultimate, at utterance-*final* position. The recording settings was the same as in [4] – target words were naturally embedded in syntactically coherent sentences. Overall, the study is based on 26 disyllabic minimal pairs, which are identical in their phoneme sequence but differ phonemically in their stress pattern, giving 52 different commonly used lexemes. The sentences were read aloud by thirty participants, gender balanced, resulting in 2,040 productions. We then extracted three acoustic parameters – duration, F0 and intensity – from the two vowels of the target word at utterance-final position, following numerous experiments on the relations between the intonational phrase (IP) and word-level stress (e.g., [6], [7], [8]).

Statistical analysis revealed that vowel duration is a significant and stable cue for word-level stress at utterance-final position (Figure 1a). Our findings contrast previous studies on Hebrew [9] that reported on lengthened syllables at utterance-final position regardless of stress. Nevertheless, the second vowels – the unstressed in the penultimate pattern ("p2" in Figure 1) and the stressed in the final pattern ("u2\*" in Figure 1) – lengthen to a higher degree compared to the first vowels ("p1\*" and "u1") and utterance-final vowels lengthen to a higher degree compared to mid-position vowels.

As to intensity in final-position, lower intensity is assigned to the utterance-final vowels regardless of the stress pattern, but the degree of lowering does depend on the stress pattern (Figure 1b). These findings are somewhat not in line with mid-position behavior, in which we found that unstressed vowels are significantly weaker than stressed vowels [4].

Lower F0 values are assigned to the utterance-final vowels, and the degree of lowering is similar to both stress patterns (Figure 1c). In mid-position, second vowels always have higher F0 than first vowels, regardless of the stress pattern. This suggests that F0 cues the falling terminal boundary-tone of a declarative type of utterances.

To summarize, F0 is a phrase level cue, while duration is the word-level cue in Hebrew. Naturally, the word-level stress in spoken Hebrew is not realized through a single prosodic cue but is the result of a combination of cues. To fully understand the combinatory acoustic-prosodic system of the word-level stress, examination of how stress is produced in non-read speech is required. Moreover, a more balanced vowel representation than in the current study would be necessary for inspecting spectral traits of word stress.

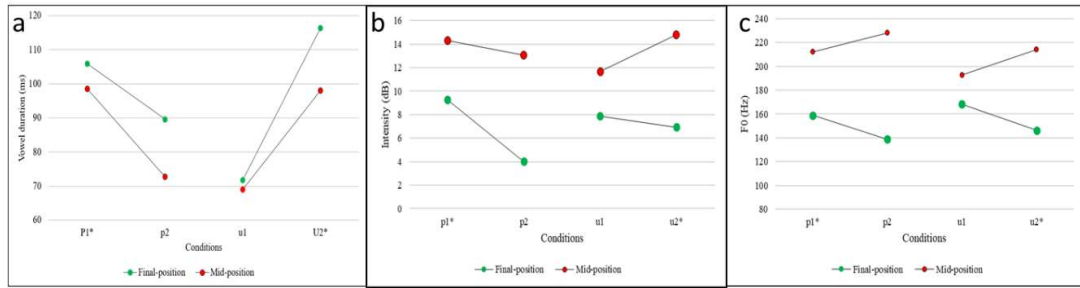


Figure 1. Behavior of the word-level stress in Hebrew according to average values of vowel duration (a), Intensity (b), and F0 of female speakers (c) in two positions – middle of utterance and utterance final position. X-axis legend: P represents the penultimate pattern; U – the final (ultimate) pattern. First vowel = 1, second vowel = 2. The stressed vowel is marked with an asterisk (\*).

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