

Acoustic correlates distinguish multiple levels of stress in 'ōlelo Hawai'i

THOMAS KETTIG, YORK UNIVERSITY

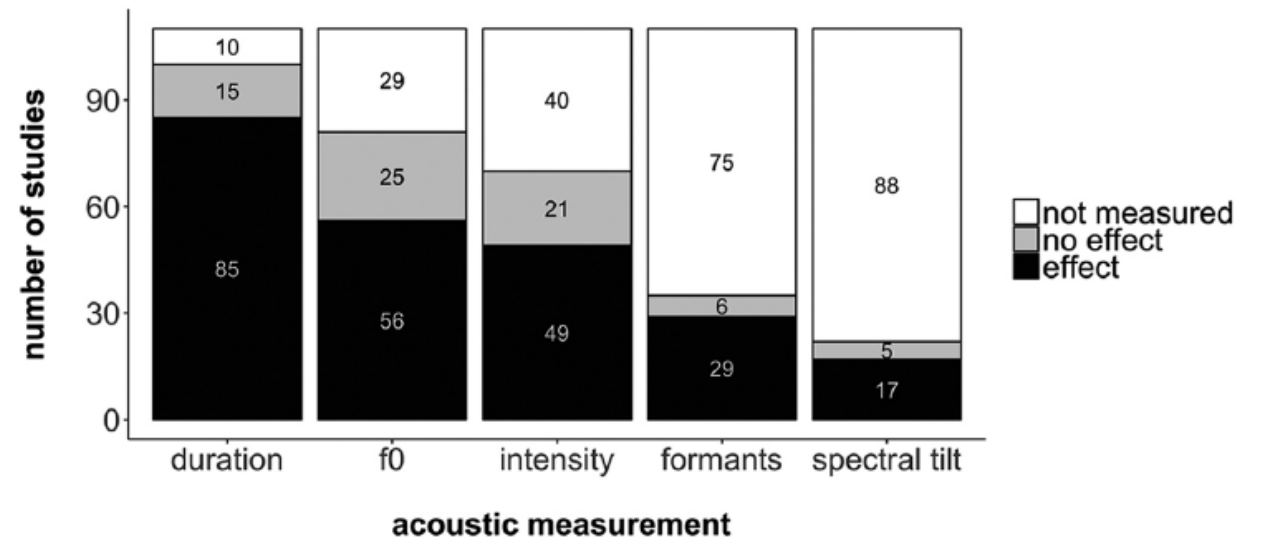
LISA DAVIDSON, NEW YORK UNIVERSITY

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Acoustic correlates of stress across languages

According to a meta-analysis of acoustic correlates to word stress, 5 correlates have been investigated most often (in decreasing order) (Gordon & Roettger 2017)

- *Duration*
- *Fundamental Frequency (F0)*
- *Intensity*
- Formants
- Spectral Tilt



Duration, F0, Intensity

Duration: In 65/72 (90%) languages, stressed syllables were longer than unstressed ones (Gordon & Roettger 2017)

F0: In 46/63 (73%) languages, F0 distinguished stressed from unstressed syllables

Intensity: Studies using mean/peak/midpoint intensity found that it distinguished stress in 39/52 (75%) languages

Primary vs. secondary vs. unstressed

Evidence for the existence of secondary stressed as distinguished from both primary and unstressed is tenuous

- Some evidence from Chickasaw and Dutch (Gordon 2004, Rietvald et al. 2004)

In several languages, no distinction found between secondary and unstressed syllables

- Erzya Mordvin (Uralic, Lehiste et al. 2003), Pitjantjatjara (Pama-Nyungan, Tabain et al. 2014), Polish (Dogil 1999; Newlin-Łukowicz 2012), Brazilian Portuguese (Barbosa et al. 2013)

Stress in Polynesian languages: Tongan

Acoustic correlates (Garellek and White 2015): No direct comparisons of primary and secondary

- **Duration**: Primary > Unstressed, Unstressed > Secondary (!). Probably no difference between primary-secondary.
- **F0**: Primary > Unstressed, Secondary > Unstressed. Magnitude for secondary-unstressed was much smaller than primary-unstressed.
- **Intensity (RMS energy)**: Primary > Unstressed, Secondary > Unstressed (but only for 3 of 5 vowels). Primary probably higher than secondary.

‘Ōlelo Hawai‘i (Eastern Polynesian)

	Bilabial	Labiodental	Alveolar	Velar	Glottal
Stop	p			k	ʔ
Fricative		v			h
Nasal	m		n		
Lateral			l		

	Front	Central	Back
High	i i:		u u:
Mid	e e:		o o:
Low		a a:	

Short diphthongs: /ae/, /ai/, /ao/, /au/, /ei/, /eu/, /iu/, /oi/, /ou/

Long diphthongs: /a:e/, /a:i/, /a:o/, /a:u/, /e:i/, /o:u/

(Parker Jones 2010, 2018; Elbert & Pukui 1979; Pukui & Elbert 1986; Schütz 1981, Kettig 2021)

Functional load hypothesis re: duration

Hypothesis: Languages that have a phonemic duration contrast will not use duration as a cue to stress (Berinstein 1979)

Mixed evidence has been reported (though much of it seems to be impressionistic, not measured)

Duration **is not** a cue to word-level stress:

- Hungarian (Vogel et al. 2016)

Duration **is** a cue to word-level stress:

- Aleut (Taff et al. 2001), Chickasaw (Gordon 2004)

Goals for analysis of 'ōlelo Hawai'i stress

1. 'Ōlelo Hawai'i is said to have primary, secondary and no stress. How many levels of stress are acoustically distinguished in spontaneous speech data?
2. Which acoustic correlates are most reliable in distinguishing levels of stress?
3. 'Ōlelo Hawai'i has a phonemic vowel length distinction: does it conform to the Functional Load Hypothesis and not use duration as a correlate to word stress (in words with only short vowels)?

Stress in 'Ōlelo Hawai'i

For words with only short vowels with up to 4 syllables, stress is trochaic with **primary stress** on the rightmost foot and **secondary stress** on the preceding foot (Schütz 1981, Parker Jones 2010):

- $/('σ_Lσ_L)/$: /('pu.ke)/ 'book', /('ki.ʔi)/ 'picture'
- $/σ_L('σ_Lσ_L)/$: /ʔe('li.ma)/ 'five', /ma('ku.a)/ 'parent'
- $/(_,σ_Lσ_L)('σ_Lσ_L)/$: /(_,ma.ka)('hi.ki)/ 'year', /(_,a.nu)('he.a)/ 'soft fragrance'

Stress and Prosodic Words in 'Ōlelo Hawai'i

Beyond 4 syllables, stress is not predictable:

- /ma(,ku.a)('hi.ne)/: 'mother', */(,ma.ku)a('hi.ne)/
- /(,pu.le)le('hu.a)/: 'butterfly', */pu(,le.le)('hu.a)/

In this talk, we focus on 2, 3, and 4 syllable words with only short vowels to establish a baseline

Speakers

Data from Kettig (2021): comprised of 8 speakers from the Ka Leo Hawai'i Hawaiian language radio program that aired from 1972-1988 (Kani'āina, ulukau.org, Larry Kimura, producer)

Speakers were fluent childhood speakers of 'ōlelo Hawai'i who spoke a variety of languages, including English and Hawai'i Creole

Passages were in 'ōlelo Hawai'i with no code-switching, except for occasional names or place names

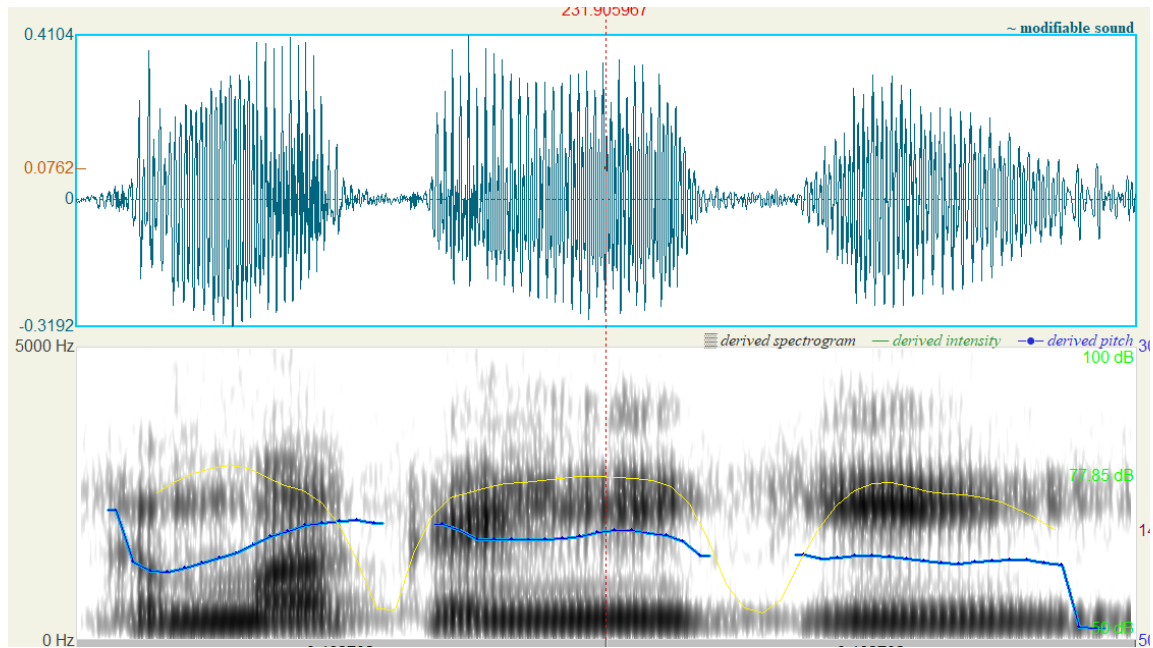
Materials

Data was force-aligned using the Montreal Forced Aligner (McAuliffe et al. 2017) trained on 'ōlelo Hawai'i

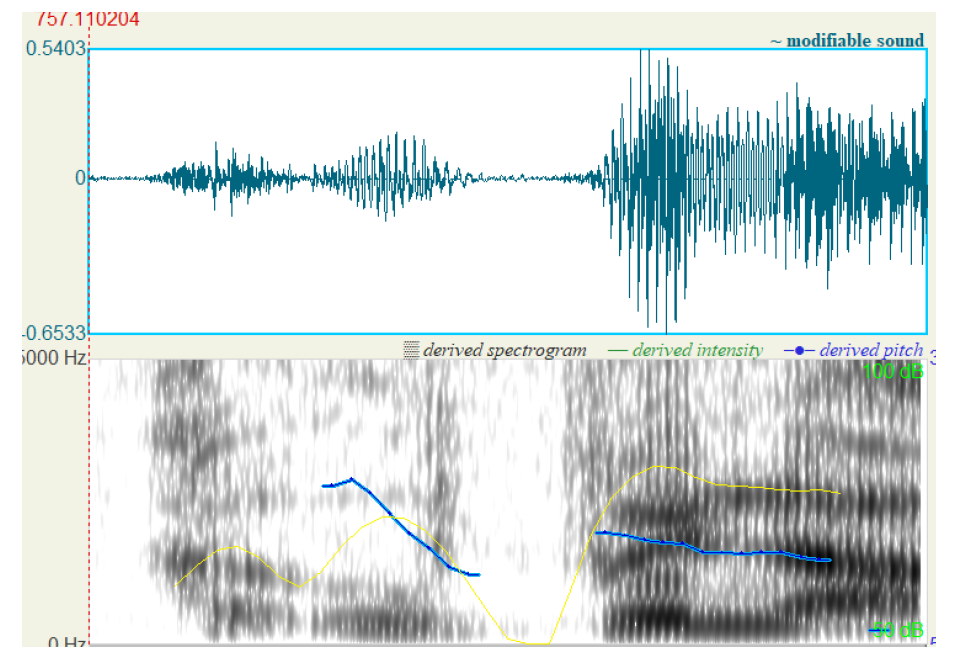
Two-, three- and four-syllable words containing only short vowels surrounded by consonants were identified in the transcripts

Pre-pausal, phrase-final and phrase-initial words were excluded

Examples



k a m a k a h i k i
'the year'



k a ? u p e n a
'the net'

Measures and analysis

For each vowel interval, three measures commonly associated with stress were extracted:

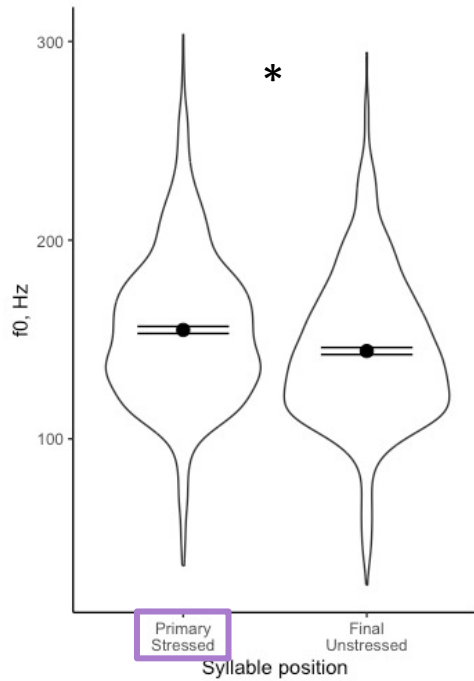
- **Vowel duration** and **median intensity (RMS amplitude)** using the FastTrack Praat plug-in (Barreda 2021)
- **Mean F0** using REAPER

Linear mixed effects models for each word length (2-4 syllables)

- Fixed effect of assumed stress level (primary, secondary, unstressed)
- Vowel, unique word and speaker as random intercepts
- Pairwise estimated marginal means reported here

Results: F0

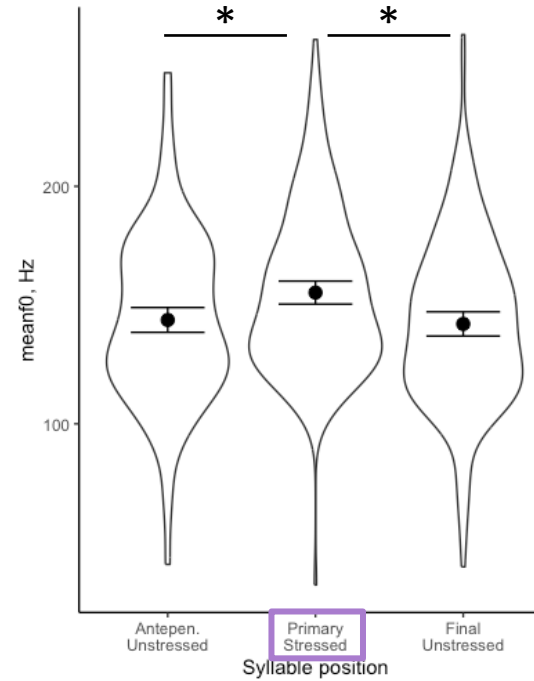
TWO SYLLABLE WORDS (N=1545)



Primary significantly higher than unstressed

[¹pu.ke]

THREE SYLLABLE WORDS (N=155)

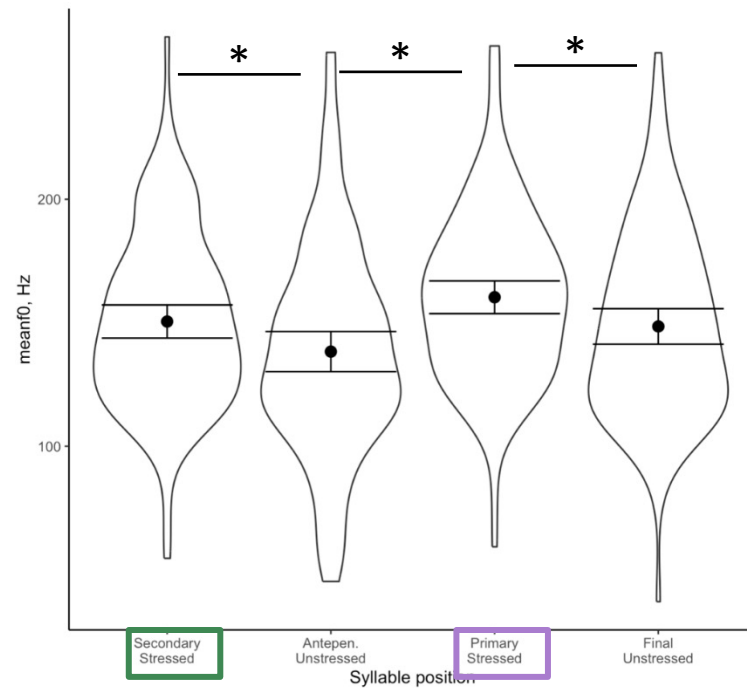


Primary significantly higher than both unstressed

[ʔe.¹li.ma]

Results: F0

FOUR SYLLABLE WORDS (N=108)



[,ma.ka.'hi.ki]

- Primary and secondary significantly higher than unstressed
- No difference between primary and secondary

F0 DISTINGUISHES TWO LEVELS OF STRESS

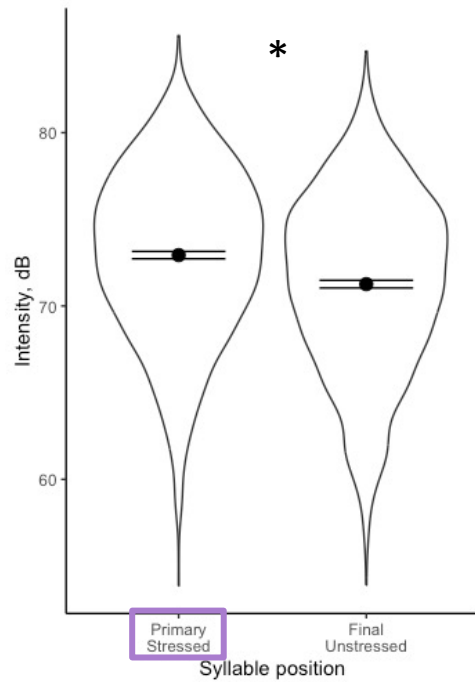
Primary and secondary both have higher F0 than both unstressed positions

- (4 syllables: secondary not different from final unstressed)

No other differences

Results: Intensity

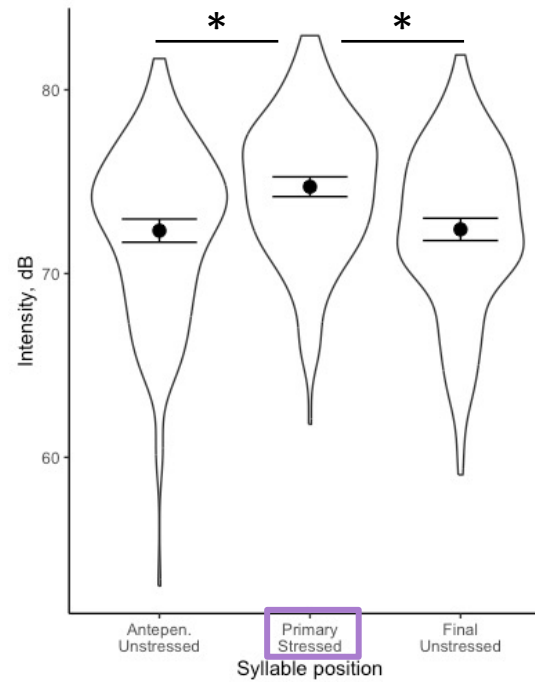
TWO SYLLABLE WORDS (N=2023)



[¹pu.ke]

Primary significantly higher intensity than unstressed

THREE SYLLABLE WORDS (N=206)

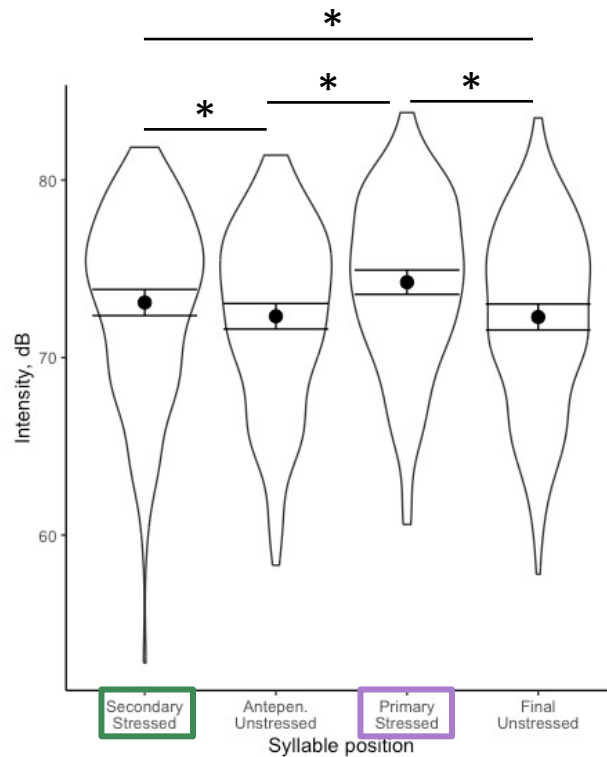


[ʔe.¹li.ma]

Primary significantly higher intensity than both unstressed

Results: Intensity

FOUR SYLLABLE WORDS (N=191)



- Primary and secondary significantly higher intensity than unstressed
- No difference between primary and secondary

INTENSITY DISTINGUISHES TWO LEVELS OF STRESS

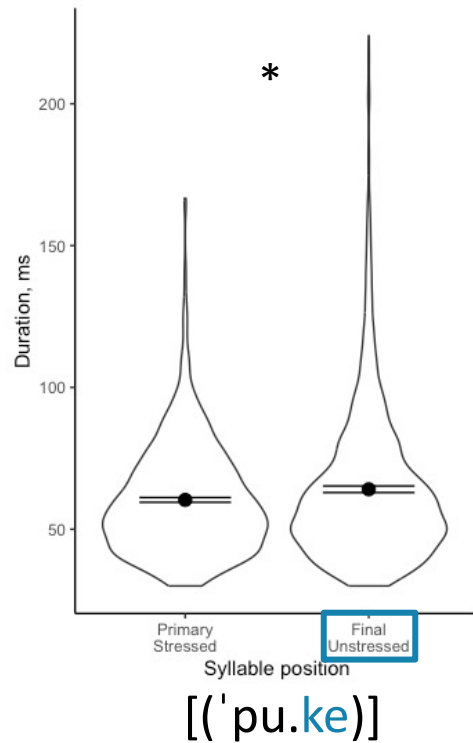
For all word lengths:

- Primary and secondary are both more intense than both unstressed positions
- No other differences

[,ma.ka.'hi.ki]

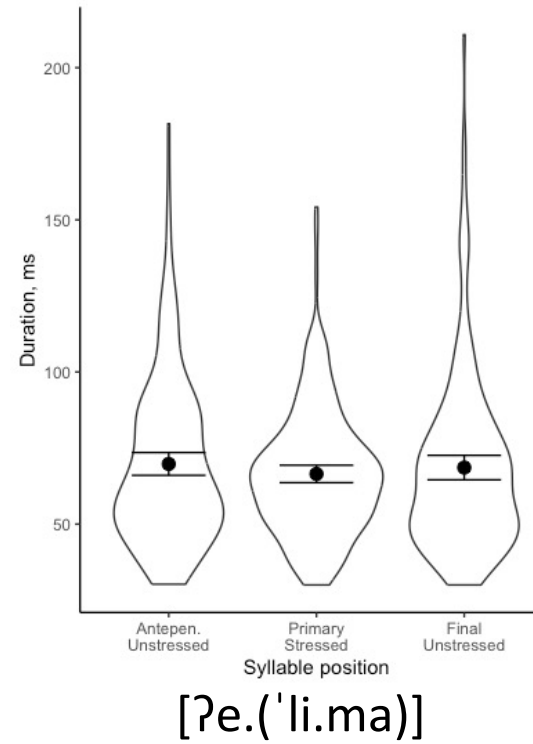
Results: Duration

TWO SYLLABLE WORDS (N=1998)



Final unstressed is longer than stressed

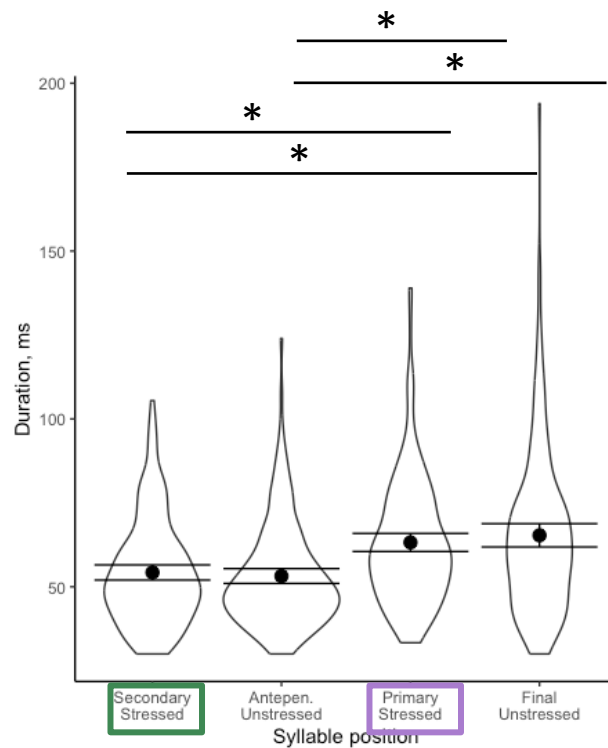
THREE SYLLABLE WORDS (N=205)



No significant differences

Results: Duration

FOUR SYLLABLE WORDS (N=190)



- No difference between secondary and antepenultimate unstressed
- No difference between primary and final unstressed

[(,ma.ka)('hi.ki)]

DURATION DOES NOT DISTINGUISH STRESS

Two syllable words

- Last syllable significantly longer than first

Four syllable words

- Syllables in second foot significantly longer than those in first

Three syllable words

- No differences (but final unstressed is numerically longer than stressed)

Summary of results

F0 and **Intensity**: Primary and secondary stressed syllables are higher than unstressed syllables, but no difference between primary and secondary stress.

Duration: Increase pertains to the final syllable (in 2 syllable words) or final foot (in 4 syllable words) rather than to the stressed syllable itself

- Two levels of stress in 'ōlelo Hawai'i are distinguished by F0 and intensity: **primary/secondary** vs. **unstressed**
- Duration is not a correlate of stress in 'ōlelo Hawai'i

Discussion: Acoustic correlates to levels of stress

The neutralization of primary with secondary, vs. unstressed may be less common compared to other languages with assumed 3 levels of stress when acoustic correlates are extracted:

- Gordon and Roettger (2017): “The most tenuous distinction in most cases was between secondary stress and lack of stress”
- Some languages are said to collapse assumed primary and secondary stress, but there is little instrumental evidence, e.g. Creek (Muskogean, Martin 2011) or Karitiana (Tupian, Everett 2006)

Discussion: Duration and FLH

‘Ōlelo Hawai‘i does not use duration to distinguish between any levels of stress (including primary vs. unstressed)

This happens to be consistent with the functional load hypothesis, but other languages violate the FLH (e.g., Chickasaw, Aleut)

Lunden et al. (2017): of 82 languages with contrastive vowel duration, 55% are said to use duration as a stress correlate

- 72% of Austronesian languages use duration as a correlate, though not all have contrastive length
- Even when limiting their analysis to studies w/instrumental evidence (N=25), 68% of languages w/a duration contrast also use duration to signal stress

Discussion: Role of duration

Instead of marking stress, duration in 'ōlelo Hawai'i may be prosodically marking final syllables or feet

Evidence for pre-boundary lengthening is strongest at higher prosodic boundaries, but some effects exist at the word level

- E.g. longer /ə/ in 'poppa posed' than 'pop opposed' (Beckman and Edwards 1990, Turk & Shattuck-Hufnagel 2000)

Conclusion

‘Ōlelo Hawai‘i marks two levels of stress: primary/secondary vs. unstressed

Duration is not a correlate of stress, but may instead indicate word edges

Future directions

- Are the correlates to stress for long vowels the same as those for short vowels?
- Are there other cues to stress, such as F1/F2?

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