ACOUSTIC CORRELATES OF METRICAL PROMINENCE IN MOJEÑO TRINITARIO

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ABSTRACT

This paper reports results of a phonetic study of acoustic exponents of metrical prominence in Mojeño Trinitario, an Arawak language of lowland Bolivia. Mojeño Trinitario displays a rhythmic syncope pattern that deletes vowels in non-final open syllables in metrically weak positions. The acoustic properties of duration, amplitude, and fundamental frequency are consistent with the predominantly iambic metrical parse predicted by rhythmic syncope, although there is interspeaker variation in how these properties are deployed to signal metrical prominence. Phonetic evidence overall supports a tripartite distinction between primary stressed, secondary stressed, and unstressed syllables, where the rightmost metrically strong syllable carries primary word stress.

Keywords: Mojeño Trinitario, Arawak, stress, syncope, prosody.

1. INTRODUCTION

Mojeño Trinitario is an Arawak language spoken in lowland Bolivia by several thousand speakers [8]. Underlying syllable structure is simple, consisting of only CV, where word-initial syllables may lack an onset consonant. Surface syllable structure is more complex, featuring complex onsets, coda consonants, and long vowels due to a process of syncope that rhythmically targets alternating vowels [9]. Mojeño Trinitario morphology is highly agglutinating, allowing for long words containing multiple instances of syncope and paradigmatic alternations in the vowel targeted by syncope. For example, the root /ʧunusihi/ surfaces as [ʧnushi] when unprefixed, e.g. [ˌʧnusˈhi-re] 'cushion-NPSD', but as [ʧunsihi] when prefixed, e.g. [ˌn-ʧunˈsihi] '1SG-cushion'.

Syncope is not restricted by phonotactic considerations and may yield virtually any type of cluster. Its application is instead governed by prosody, failing to affect word-final vowels or to vowels in metrically strong syllables according to an iambic (weak-strong) parse from left to right [9]. For example, in the word (ʧu̲n**u**)(si̲h**i**)-re 'cushion-NPSD' → [ˌʧnusˈhi-re], syncope targets the weak first and third vowels (underlined) but does not apply to the strong second and fourth vowels (in bold) or to the final vowel. Metrically-governed syncope of weak vowels has parallels in other languages [2, 3, 4, 5] and may be viewed as a strategy complementary to lengthening of strong syllables for enhancing the prominence of metrically strong syllables relative to weak ones. In Mojeño, the final syllable never falls in a metrically strong position; disyllabic words thus display a trochaic pattern and do not undergo syncope, e.g. (ˈjuku) 'fire'. There are also forms in which syncope of weak vowels underapplies [9].

Under the assumption that metrically strong syllables are stressed and thus phonetically prominent [3], the metrically-driven nature of syncope in Mojeño Trinitario predicts the existence of a distinction in acoustic prominence between strong and weak syllables, only the latter of which are targeted by syncope. Auditory impressions of both authors are consistent with this prediction and additionally suggest that the rightmost strong syllable is the most prominent in a word [9]. This paper aims to corroborate these impressionistic observations through acoustic analysis, thereby increasing cross-linguistic knowledge of the mapping between metrical prominence and phonetic correlates of stress, particularly secondary stress, which has been subject to sparse phonetic documentation [1].

2. METHODOLOGY

A list of Mojeño Trinitario words was recorded in medial position of a semantically neutral carrier sentence using a Q8 handy video recorder at a sampling rate of 44.1kHz via a head-mounted Shure Beta 53 microphone. The embedding of target words in a phrase reduced the likelihood of interference of phrase boundary effects on word level prosody but did not eliminate the possibility of the target word being implicitly focused [7]. The present study is based on 41 words varying in syllable structure (CV or CVC, no CVV), number of syllables (2-5), the application of syncope and the location of primary stress (antepenult or penult). Each word (and its associated carrier phrase) was repeated three times after being prompted by the second author. The sound files were imported into Praat where a script extracted for each vowel a series of acoustic measurements that have been demonstrated to diagnose word stress in the cross-linguistic literature [1]. Measured parameters for this study included vowel duration, and mean (RMS) amplitude of the vowel, and a series of fundamental frequency measurements of the vowel. The amplitude values were calculated relative to a reference vowel in the carrier phrase to normalize for different gain levels between and within recordings. Fundamental frequency was measured at the beginning, middle and end of the vowel, and minimum, maximum and mean values for the entire vowel were calculated. Spurious F0 values triggered by non-modal phonation were discarded. F0 patterns were also visually inspected to determine whether stress might be associated with particular F0 contours. The results for each acoustic parameter were subsequently subjected to statistical analysis in R [6]: either ANOVAs (where assumptions of the test were satisfied) accompanied by pairwise Tukey HSD tests or Welch's t-tests (where an ANOVA was not indicated). Results are drawn from four speakers (three male and one female), who were middle-aged and proficient (in varying degrees) in Spanish in addition to Mojeño Trinitario.

3. RESULTS

Figures 1 (from speaker F1) and 2 (from speaker M1) contain spectrograms, F0 traces (in blue) and amplitude curves (in red) for representative trisyllabic words of the form ˌCVCˈCVCCV with secondary stress on the first syllable and primary stress on the second syllable. As is evident, unstressed vowels are most reliably differentiated from stressed vowels in having lower amplitude and greater duration. F0 values on the other hand, differ between the two speakers (possibly as a result of different prosodic phrasing or a delayed F0 peak), being highest on the primary stressed vowel for speaker M1 but highest on the unstressed vowel for speaker F1. Amplitude distinguishes primary and secondary stress, although to different degrees depending on speaker. In general, neither F0 level nor F0 slope proved to be reliable cues to stress; to simplify the presentation of F0 results, mean values are thus provided as a proxy for other F0 parameters.

Figure 1: Spectrogram, F0 (blue) and amplitude (red) of [ˌetˈhopka] 'if there is' (speaker F1).

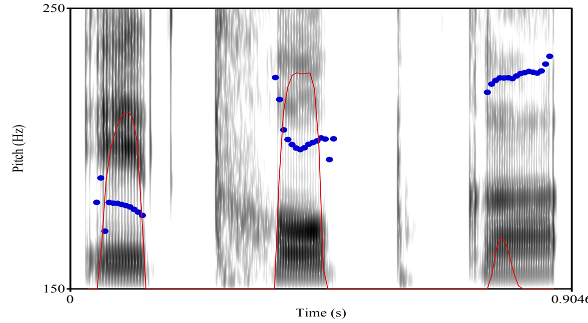
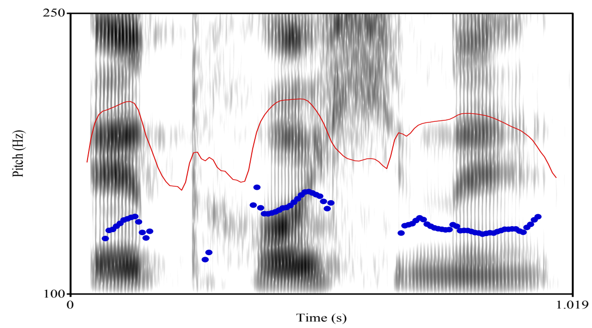


Figure 2: Spectrogram, F0 (blue) and amplitude (red) of [ˌetˈhoçne] 'there really is' (speaker M1).



3.1. Primary stressed vs. unstressed vowels

As a first step in the quantitative analysis, words containing a single metrically strong syllable and displaying regular application of syncope were analysed. In practice, this amounts to disyllabic words consisting of a stressed followed by an unstressed syllable since any pretonic unstressed vowel (not lexically marked as being resistant to syncope) is predicted to delete. Figures 3, 4, and 5 contain boxplots illustrating results for amplitude, fundamental frequency, and duration, respectively, for the four speakers, who diverge in their patterns and are thus considered separately.

Amplitude patterns are most consistent: stressed vowels are more intense than unstressed ones for all speakers, though the magnitude of the difference varies between speakers (Welch's t-tests: Speaker F1: t=4.74, df=76.83, p<.001; M1: t=14.84, df=102.43, p<.001; M2: t=9.40, df=84.19, p<.001; M3: t=5.02, df=123.86, p<.001).

F0 results differ between speakers. Speaker M3 has higher F0 values for stressed vowels (t=6.6858, df=119.93, p<.001). M1 displays a similar general pattern but the range of values for his unstressed vowels overlaps almost completely with those of his stressed vowels. Speaker F1 displays the opposite pattern: higher F0 values for *unstressed* vowels

(t=3.6576, df=57.27, p<.001). Speaker M2 does not distinguish F0 as a function of stress.

Turning to duration, only one speaker (F1) makes a clear distinction between stressed and unstressed vowels (t=3.76, df=71.49, p<.001). It is conceivable, though, that the lack of a difference for the other speakers is due to a final lengthening effect targeting the unstressed vowel.

Figure 3: Amplitude of primary stressed (light gray) and unstressed (dark gray) vowels in disyllables.

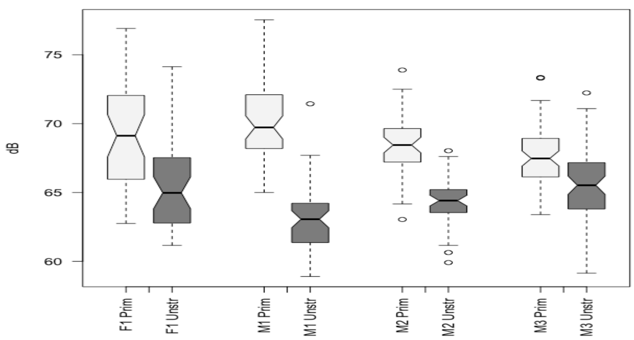


Figure 4: Mean F0 of primary stressed and unstressed vowels in disyllables.

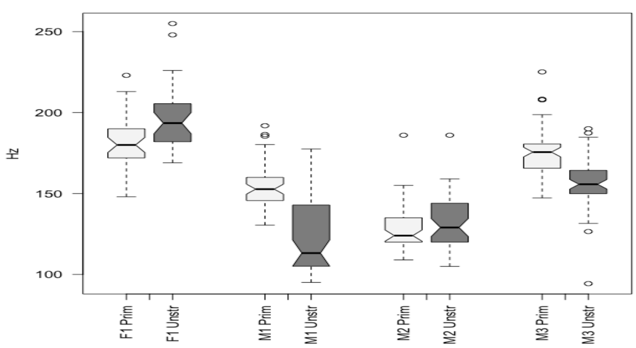
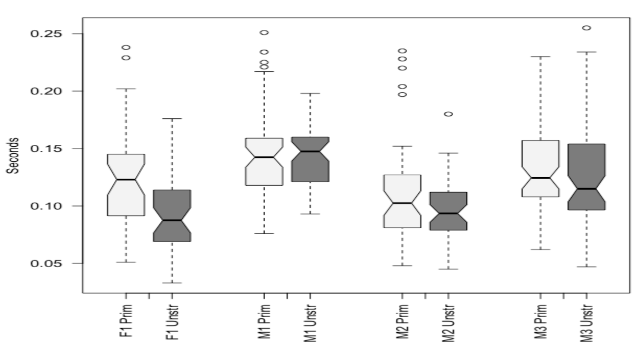


Figure 5: Duration of primary stressed and unstressed vowels in disyllables.



3.2. Secondary stress

The next phase of the study explored the acoustic evidence for a secondary level of prominence below primary stress but above lack of stress. By targeting metrically weak vowels, syncope ensures that the majority of strong syllables before the primary stress are closed (see section 1). Metrically weak vowels only surface in non-final syllables that are lexically marked as resistant to syncope, where likelihood of underapplication is probabilistically determined based on various phonological properties [9]. It is a priori unclear whether vowels that are resistant to syncope display this behavior because they are lexically specified as blockers of syncope or whether this resistance is an indirect consequence of being lexically marked as stressed, which imbues them with immunity to syncope. Only words with regular application of syncope were thus included in the present analysis, meaning that all vowels with secondary stress occurred in closed syllables and all unstressed vowels were word-final.

Figures 6, 7, and 8 contain boxplots illustrating results for amplitude, fundamental frequency, and duration, respectively. As in disyllables, amplitude most reliably differentiates vowels by stress level. For all speakers amplitude is greatest in primary stressed vowels, lowest in unstressed vowels and intermediate in secondary stressed vowels. The robustness of distinctions, both overall and between pairs of stress levels, differs between speakers, as inspection of the R^2 values (equivalent to effect sizes in the models employed) in monofactorial ANOVAs (independent variable=stress level) confirm: speaker F1: $F_{2,84}$=10.432, p<.001, adjusted R^2=0.178; Tukey's posthoc tests: primary vs. unstressed, p<.001, primary vs. secondary, p=.067, secondary vs. unstressed, p=.060; M1: $F_{2,69}$=44.907, p<.001, adj. R^2=0.553; posthoc tests: primary vs. unstressed, p<.001, primary vs. secondary, p=.002, secondary vs. unstressed, p<.001; M2: $F_{2,78}$=12.702, p<.001, adj. R^2= 0.226; posthoc tests: primary vs. unstressed, p<.001, primary vs. secondary, p=0.002, secondary vs. unstressed, NS; M3: $F_{2,63}$=3.218, p=0.047, adj. R^2=0.064; posthoc tests: primary vs. unstressed, p=0.039, primary vs. secondary, NS, secondary vs. unstressed, NS.

Turning to F0, only one speaker (M3) displays an overall effect of stress level but he does not distinguish secondary stressed from unstressed vowels: $F_{2,63}$=23.238, p<.001, adjusted R^2=0.406; posthoc tests: primary vs. unstressed, p<.001, primary vs. secondary, p<.001, secondary vs. unstressed, NS. Speaker M1 displays a similar tripartite hierarchy but sizable variance among unstressed tokens.

Figure 6: Amplitude of primary stressed (light gray), secondary stressed (medium gray), and unstressed (dark gray) vowels.

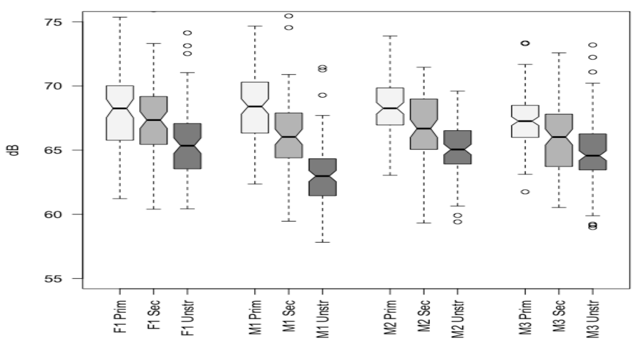


Figure 7: Mean F0 of primary stressed, secondary stressed, and unstressed vowels.

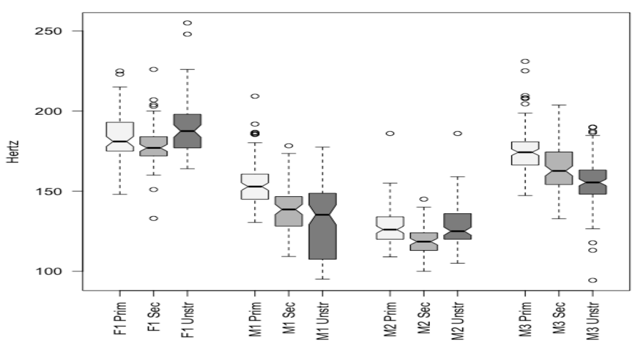
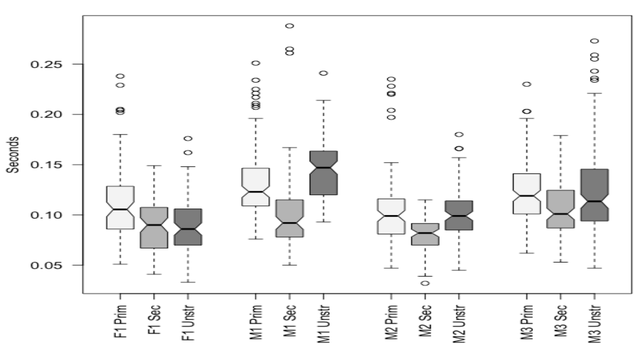


Figure 8: Duration of primary stressed, secondary stressed, and unstressed vowels.



For duration, the most prevalent pattern is for primary stressed and unstressed vowels to be longer than secondary stressed vowels. Only for speaker M1, however, are durational distinctions statistically robust according to an ANOVA: $F_{2,69}$=13.705, p<.001, adjusted R^2=0.264. Pairwise comparisons for M1 indicate, however, that not only are primary stressed vowels longer than secondary stressed ones but also that unstressed vowels are longer than stressed ones: Tukey's posthoc tests: primary vs. unstressed, p=0.021, primary vs. secondary, p=0.039, secondary vs. unstressed, p<.001).

4. DISCUSSION

Of the measured parameters, amplitude is the most robust correlate of stress in Mojeño Trinitario and the only property that supports a tripartite distinction between primary stressed vowels, secondary stressed vowels, and unstressed vowels for a majority of speakers. Duration and F0 are less reliable diagnostics for stress, showing considerable interspeaker variation and failing to reliably distinguish three degrees of stress. The inconsistent role of F0 and duration in signalling word stress potentially owes to interference from independent prosodic effects: preboundary lengthening of unstressed vowels in the case of duration and the reservation of F0 as a cue to pitch accent or phrase boundaries [1]. It may also be noted that duration is in a sense already recruited as a marker of stress through syncope itself, which plausibly arose through gradual durational reduction of unstressed vowels that eventually became phonologized.

Evidence for secondary stress was in general less compelling than support for primary stress, a result that mirrors results from other languages in which secondary stress has been acoustically investigated [1]. Amplitude data were nevertheless consistent with the secondary stresses predicted by the metrical parses hypothesized to motivate syncope patterns.

5. SUMMARY

Acoustic examination of stress correlates offers general support for the metrical patterns adduced by rhythmic syncope in Mojeño Trinitario. Vowels that are resistant to syncope because they occur in metrically strong positions are characteristically more prominent acoustically (inferable as stressed) than those in weak positions, although this prominence is subject to interspeaker and interparameter variation. Future work taking into account prosodic phrasing and other potential cues to stress (e.g. vowel quality, spectral tilt), also in words in which syncope unexpectedly fails to apply to metrically weak vowels, might yield further into the acoustic manifestation of stress and its relationship to the metrical structures predictive of syncope.

6. REFERENCES

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