Acoustic vowel space expansion in Panãra: Evidence for hyper-articulated long vowels

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The acoustic formant space of vowels has been shown to undergo two forms of prominence strengthening: sonority expansion [5] and hyperarticulation [4]. The sonority expansion hypothesis predicts that the acoustic space of prominent vowels is lowered, resulting in greater vowel sonority, as observed for Tongan [3], Catalan [11], and Russian [12]. The hyperarticulation hypothesis predicts that the acoustic space of prominent vowels is expanded overall, with peripheral vowels showing a more extreme articulation, as observed for American English [4]. This paper investigates the vowels of Panãra (Jê, Brazil), comparing the F1-F2 space of vowels along two dimensions of phonological prominence: stressed vs. unstressed, and short vs. long vowels [1, 13]. We find an overall expansion of the acoustic F1-F2 space for long compared to short vowels, but not for stressed compared to unstressed vowels. This expansion is observed as a raising and backing of the acoustic space of long vowels, consistent with the predictions of hyperarticulation.

Panãra has one of the world's largest vowel inventories: 28 contrastive vowels, which can be short or long, and oral or nasal ([6], Table 1). This paper focuses on oral vowels. Word stress generally falls on the last syllable of the phonological word [7], and the language exhibits no phonological process of unstressed vowel quality or duration reduction.

We recorded 21 native speakers of Panãra (f=11) in the village of Nãnsêpotiti using a Shure-Beta 54 hypercardioid headset microphone connected to a Zoom h4n Pro. The stimuli included 62 disyllabic words covering every vowel contrast in both stressed and unstressed position. Due to low levels of speaker literacy, target words were presented orthographically, visually, and auditorily using the recorded speech of one speaker, with one slide per target word. Words were produced inside the carrier phrase [ĩŋkjẽ hẽ kasũ X], where X is the target word. Speakers produced four repetitions of each target word in semi-randomized blocks. The data presented here comes from 4 speakers (f=2), for a total of 1,211 vowel tokens.

We extracted F1 and F2 values at ½ of the duration for each vowel token using a Praat script. Formant values were z-score normalized and preliminarily manually inspected for erroneous measurements, which were discarded if, for the given vowel category, the token belonged to a clear and unexpected bimodal distribution (n=81). We calculated the polygon area of the acoustic space using phonR [9], as defined by the mean values of each vowel.

Figure 1 presents the acoustic space area of stressed and unstressed, short and long vowels. Short unstressed vowels have an area of 3.48; short stressed vowels, 3.53; long unstressed vowels, 4.60; and long stressed vowels, 4.91. Thus, long vowels have an expanded vowel space compared to short vowels, where the effect of stress appears to be negligible or absent. This expansion is observed as a raising of high vowels and a backing of back vowels.

A Bayesian linear regression with weakly informative normal priors was fit to the data to predict F1 and F2 (separate models) as a function of length*stress and vowel quality. Marginal contrasts were then computed using emmeans [8]. F1 was significantly lower for long vs. short high /i, ɯ, u/, regardless of stress position ($p<.05$). F1 was significantly lower for long vs. short mid /e, ɤ, o/ in stressed position ($p<.05$). F2 was significantly lower for long vs. short back /o, ɔ, a/ ($p<.05$) and mid /ɤ/ ($p<.001$) in stressed position. Finally, F2 was significantly lower for long vs. short high back /u/ and low /a/ in unstressed position ($p<.05$).

Taken together, our results suggest that long vowels in Panãra show prominence strengthening when compared to short vowels. Curiously, the effect of stress on the acoustic space of Panãra vowels appears negligible or absent. In particular, we find that the overall acoustic space of long vowels is expanded in comparison to that of short vowels: High long vowels are raised, and back long vowels are backed compared to their short counterparts. These findings are compatible with the Hyperarticulation hypothesis, where long peripheral vowels show a more extreme articulation. Our presentation will include data from all speakers and discuss data exclusion methods, and the stress and vowel length interaction.

References

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Table 1: Phonemic vowel inventory of Panãra

Short oral		
i	ɯ	u
e	ɤ	o
ɛ	a	ɔ

Short nasal		
ĩ	ɯ̃	ũ
ẽ	ɤ̃	õ

Long oral		
i:	ɯ:	u:
e:	ɤ:	o:
ɛ:	a:	ɔ:

Long nasal		
ĩ:		
ẽ:	ɤ̃:	õ:

Figure 1: Acoustic space area of stressed (bright points, black lines) and unstressed (muted points, gray lines) short (circles, dashed line) and long (squares, solid lines) vowels.