Statistical Reanalysis of Munster Irish Stress: M3

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Abstract

This paper presents a new statistical analysis of Blum (2018)'s Munster Irish (MI) acoustic data that uses linear mixed effects models. MI has been described as presenting a stress pattern that current metrical and non-metrical theories of stress, such as in Hayes (1995); deLacy (2002); deLacy (2004); deLacy (2006), cannot account for: the ternary stress attraction hierarchy of V < /ax/ < Vː. Blum (2018)'s acoustic study collected new data in order to reevaluate evidence for the MI stress pattern. Blum (2018)'s statistical analysis of the data from a single speaker of MI utilized t-tests to show that previous work did not accurately decribe the stress pattern produced by an MI speaker. Using linear mixed effects models provides a more accurate measure of significance and variance while avoiding Type 1 errors (Winter, 2013) and this paper uses them to show that previous descriptions may not have been so far off.

Statistical Reanalysis of Munster Irish Stress: M3

Introduction

The goal of this paper is to provide a statistical reanalysis of data from a single native speaker of Munster Irish (MI) using linear mixed effects models (Winter, 2013). Blum (2018)'s statistical analysis of the speaker (M3)'s productions utilized t-tests to determine the significance of the described stress pattern, syllable position, and frame sentence for various acoustic properties. Using linear mixed effects models provides a more accurate measure of significance and variance while avoiding Type 1 errors.

Impressionistic descriptions of MI (Blankenhorn, 1981; Breatnach, 1947; Gussman, 2002; Hickey, 2014; O'Rahilly, 1932; O'Siadhail, 1989; ÓCuív, 1944; Sé, 1989) agree that when a word consists of only short vowels primary stress is on the first syllable. They also agree that if the second syllable contains a long vowel, it will be stressed. In addition, descriptions agree that the syllable [ax] can also attract stress, as in [bəˈkax], but not away from a long vowel (i.e. [ˈCVː.Cax], *[CVːˈCax]); and that coda consonants do not otherwise contribute to stress attraction. The MI stress pattern has thus been described as having a three-way weight distinction between short vowels, /ax/, and long vowels, as shown in (1) below (Doherty 1991, Bennett 2015).

(1) V < /ax/ < Vː

Blum (2018)'s statstical analysis found that stress did fall on the second vowel in CVCax words and it was confirmed that the first vowel reduces: i.e. /CVCax/ → [CəˈCax]. However, in all other word forms, it was argued that stress falls on the initial syllable, even in words with the shape [CVCVː]. In addition, it was argued that /a/ never reduces before [x]: i.e. [ˈCax.Cax], *[Cax.Cəx]. Evidence for stress and resistance to vowel reduction was found in the first formant (F1).

The current paper will reevaluate M3's data using linear mixed effects models. It will show that for two short vowels, [a] and [ə], F1 varies based on an interaction between described stress and syllable positions. The new analysis will find that when these two vowels are stressed F1 is often higher, but the degree to which they are distinguished from unstressed vowels differs based on syllable position.

Experimental Methods

Participant

The single subject (M3) was a 74 year old male native speaker of Irish from the Corca Dhuibhne Gaeltacht on the Dingle Peninsula. M3 spoke only Irish until age 10, at which time he had a cleft palate repaired and learned English during his hospital stay. M3 had a minor speech impediment which made it difficult for him to produce coronal stops ([t]s were often fricated) and he has had limited contact with MI in day-to-day life over the past 50 years. While his speech impediment does not likely affect potential correlates of stress, it is possible that the way he speaks is no longer the norm or understood by anyone outside his family. Analyzing data from only one speaker has the possibility of describing an idiolectal difference that is not representative of the stress pattern produced more widely in MI, as it is used daily. However, if the speaker is cognitively intact, his phonological system represents a possible state of the Phonological Module, and so is relevant to evaluating theories of that module's representational and computational properties. I have reproduced the same experiment in multiple gaeltachtaí of the Munster region of Ireland and in future work I plan to analyze those field recordings for comparison and to determine the stress correlates of MI across speakers and across counties in Munster.

Stimuli

The target words were existing MI words, initially collected from the online pronunciation database at www.teanglann.ie (2013). The target words were verified by two consulting native speakers of a Connacht dialect and one native speaker of MI. The shapes of the target words allowed comparison of the acoustic properties of [ɤ], [a], [aː], and other short and long vowels in both initial and peninitial positions. I assumed that comparing properties of these segments in different environments would be sufficient to identify acoustic properties that differed significantly between these three segments, and thus could be ascribed to phonological metrical prominence.

MI stress has been described to fall mainly on the first or second syllable of a word, so the target list was restricted to roots with two syllables. Wug words were used when stimuli shapes were rare in the www.teanglann.ie (2013) database. Vowel length and syllable shape were controlled so as to test only the forms that are crucial to the described stress pattern. The default stress pattern should be easily detectable in words with two short vowels, as in (Table 1a). In order to determine the acoustic properties that differentiate stress on long and short vowels in MI, roots with a long vowel in each position of a disyllabic word were also included, as in (Table 1b). Lastly, the properties of the [ax] syllable were tested in each position adjacent to a short and a long vowel, as in (Table 1c). The word shapes in (Table 1) are also marked with the expected position of stress, based on traditional descriptions.

Table 1

Stimuli Shapes

(a) ˈCV.CV	(b) ˈCVː.CV	(c)CV.ˈCax
	CV.ˈCVː	ˈCax.CV
	ˈCVː.CVː	ˈCVː.Cax
		Cax.ˈCVː
		ˈCax.Cax

The vowel and consonant qualities in each position were restricted to include the vowels [i] and [u] (the most common vowels) and crucially [a], which occurs in the [ax] sequence. Some shapes were rare, so a few words with [o] were also included. Vowel identity was included as a factor in the statistical analysis since the vowels vary in inherent duration and inherent F0.

While long vowels are reported to attract stress in MI, coda consonants are not claimed to contribute to syllable weight. For this reason and to restrict the number of shapes tested, no syllables with coda consonants were included, except for the [Cax] syllables in (1c). Consonant voicing and manner can affect a preceding vowel's length (vanSanten, 1992), so medial consonants were limited to the voiceless stops ([p], [t], and [k]) and fricatives ([f], [s], and [x]). Voiceless intervocalic obstruents are both easy to segment and have a smaller effect on preceding vowel duration than do voiced obstruents (vanSanten (1992); p.528-9 and others cited therein). Words with medial fricatives were also included in order to increase the number of real-word stimuli.

There were a total of 69 target words. Seven words of each shape were included, except for CV.Cax words – 13 words were included because this shape is crucial to the issue under contention. The target word list was copied three times and randomized (using Microsoft Excel's RAND function) to create three sets of stimuli, each with different orders. The three sets of words were combined into a single list. Filler sentences were inserted after every five stimuli.

Procedure

PsychoPy2 (Pierce, 2009, 2015) was used to generate a presentation of the stimuli such that each target word appeared alone on a computer screen. The subject produced each target word within the two frame sentences in (Table 2). The subject saw the sentences and practiced using them with a few words before the experiment began. Target words were produced phrase-medially in order to avoid phrase-final lengthening effects (vanSanten, 1992). Two sentences were used to vary any prosodic (intensity) effects of focus on new vs. old information, following Shih (2016). M3 was recorded in his home and was given the frame sentences to learn. He then began recording with non-target words in order to familiarize himself with the task. He read individual target words written in standard Irish orthography on a computer screen. He then said the word out loud within each of the two frame sentences, and pressed the space bar in order to move on to the next word, continuing at his own pace.

Table 2

Frame Sentences

Frame 1:	Dúirt	Bríd	an	focal	X	sular	imigh	sí
	duːɹ^{h}t^{j}.	bɹiːd^{j}.	an.	fʌ.kl.	X	sʌ.lɪ.	ɪ.mɪg.	ʃiː
	"Brid	said the word X before leaving"						
Frame 2:	Abair	X	faoi	d'anáil				
	a.bɹ.	X	fsuper wi.	d'a.nal^{j}				
	"Say	X under your breath"						

Recordings were made using a head-mounted AKG C420 condenser microphone in order to maintain a constant distance between the mouth and the microphone, with the goal of eliminating amplitude variation due to head movement. The microphone was connected to a Marantz PMD670 solid state recorder, which recorded using 44.1 kHz sample rate and 16 bit quantization rate in mono. The data was saved as a RIFF (.wav) file to ensure that no information was lost due to a lossy compression codec. The participant's recordings were saved in a coded file, which was then segmented manually using Praat (Boersma & Weenink, 2013).

Segmentation was done by hand using primarily the waveform and secondarily F2 to determine where segments began and ended. Vowels were taken to begin at the zero-crossing of the first upswing of the first non-deformed period and ended at the zero-crossing of the last downswing of the last non-deformed period. If the boundary was unclear based on the waveform, vowel boundaries were determined by the presence of a robust F2 in the spectrogram, as long as there was a robust F1 underneath. Fricatives were taken to begin at the zero-crossing of the first downswing of the last non-deformed period of the preceding vowel and ended at the zero-crossing of the first upswing of the first non-deformed period of the following vowel. Fricatives boundaries were confirmed by the onset and offset of noise in the spectrogram.

Statistical Analysis

Previous Findings

Blum (2018)'s statistical analysis utilized Student's t-tests in Microsoft Excel to determine where there was variation within the M3 data. The t-tests were used to determine which acoustic properties correlate with word-level stress. The previous analysis assumed a restricted p-value threshold of 0.01 rather than the more generous standard of 0.05 in order to adjust for family-wise error and avoid capitalizing on chance, but the possibility of committing a Type 1 error remained due to the high number of tests run on the single dataset.

Blum (2018)'s t-test analysis found that stress did fall on the second vowel, but only in CVCax words and it was confirmed that the first vowel reduces: i.e. /CVCax/ → [Cəˈ Cax]. In all other word forms, it was argued that stress falls on the initial syllable, even in words with the shape [CVCVː]. In addition, it was argued that /a/ never reduces before [x]: i.e. [ˈCax.Cax], *[Cax.Cəx]. Evidence for stress and resistance to vowel reduction was found in the first formant (F1). The vowels [a] and [ə] were found to significantly differ in height, but their distribution was not indicative of the traditionally described stress pattern. For example, an initial short [a] adjacent to a long vowel did not reduce, but adjacent to an [ax] syllable it did. Crucially, F1 was also claimed to indicate that the vowel in an [ax] syllable does not reduce to generate [əx].

Reanalysis Methods

The current analysis of M3's data uses linear mixed effects models in R (R Core Team, 2016) via the lmer function of the lme4 package (Bates, Mächler, Bolker, & Walker, 2015). Separate models were built for each of two vowels ([a] and [ə]) and each of three acoustic properties (vowel duration, F1, and F2). Data was organized in long format such that each variable occupied a separate column and each row contained a single vowel's data. Rows were labeled with the word, syllable shape, and vowel (as it was segmented) in separate columns in that order. To the right of the vowel label were the continuous variables duration, F1, F2, F3 in order. Each vowel was also coded for the categorical variables frame sentence (1 or 2), syllable position (1 or 2), and stress (0 or 1 according to the descriptions).

Results

The lmer() function was used to separately model each of the continous dependent variables (duration, F1, and F2) as a function of the three fixed effects (frame, syllable, and stress). In addition, the mixed effects models encoded a random effect of word, which was labeled by the file name. Statistical significance was assessed using hierarchical partitioning of variance via nested model comparisons. Models were compared using the anova() function. Visual inspection of residual plots revealed both normal distribution and homoskedasticity.

Short [a] vowels

Short [a] vowels include all vowels marked as [a] during segmentation. These include both those in /ax/ syllables and those that are not. Whether or not they were marked as stressed (1), depends upon the other vowel present in the word. So [a] vowels, whether or not they are in an /ax/ syllable, would be marked as unstressed (0) if the other vowel in the word is long, for example.

Duration. Stress and syllable position were shown to have a significant effect on the duration of [a] vowels ($p < 0.05$), but frame sentence did not. There was a main effect of stress on duration ($\chi^2(1)=0.97$, p=3.255e-01) and syllable position on duration ($\chi^2(1)=26.443$, p=2.714e-07). No effect of frame sentence was found. The interaction between stress and syllable position was found not to have a significant effect on duration ($\chi^2(1)=3.4548$, p=0.06307).

F1. Stress was shown to have a significant effect on the F1 of [a] vowels, but neither syllable position nor frame sentence did. There was a main effect of stress on F1 ($\chi^2(1)=27.966$, p=1.235e-07). The effect of syllable position on F1 was shown not to be significant ($\chi^2(1)=0.2704$, p=0.6031). No effect of frame sentence was found. The interaction between stress and syllable positions was found to significantly effect F1 ($\chi^2=14.977$, p=0.0001088).

F2. No categorical factors were shown to have a significant effect on F2. The effects of both stress ($\chi^2(1)=1.337$, p=0.25) and syllable position ($\chi^2(1)=2.89$, p=0.089) were found not to be significant. No effect of frame sentence was found. The interaction between stress and syllable position was found not to significantly affect F2 ($\chi^2=0.0061$, p=0.93756).

[ə] **Vowels**

[ə] vowels include all vowels marked as [ə] during segmentation. These include both [ə] in /ax/ syllables and those that are not. There are stressed [ə] vowels in the two CəCə words, which were also extremely common words—[ˈpətə] "(cooking) pot" and [ˈkəpə] "(drinking) cup". According to Green (1996:4) it is possible that the schwas in stressed syllables are underlying and not the result of vowel reduction.

Duration. All three categorical predictors were shown to have a significant effect on ə duration. There was a main effect of stress ($\chi^2(1)=29.827$, p=4.723e-08), syllable position ($\chi^2(1)=48.692$, p=2.996e-12), and frame sentence ($\chi^2(1)=15.954$, p=6.489e-05). The interaction between stress and syllable position was found to significantly affect [ə] duration ($\chi^2=17.022$, p=3.695e-05).

F1. All three categorical predictors were also shown to have a significant effect on the F1 of ə. There was a main effect of stress ($\chi^2(1)=9.5367$, p=0.002014), syllable position ($\chi^2(1)=6.4637$, p=0.01101), and frame sentence ($\chi^2(1)=40.431$, p=2.036e-10). The interaction between stress and syllable position was shown to significantly affect F1 of ə ($\chi^2=10.6015$, p=0.00113).

F2. Only frame sentence significantly affected the F2 of ə vowels. The effect of stress ($\chi^2(1)$=0.4965, p=0.481) and syllable position ($\chi^2(1)$=0.0069, p=0.9338) on F2 were shown not to be significant. There was, however, a main effect of frame sentence ($\chi^2(1)$=22.432, p=2.177e-06). The interaction between stress and syllable position was found not to have a significant effect on ə F2 (χ^2=0.9324, p=0.3342).

Summary

The described stress pattern was shown to be a significant predictor of duration and F1 for both short [a] and [ə] vowels. Duration of [a] as well as duration and F1 of [ə] were predicted by syllable position. F2 was not predicted by any of the categorical factors for [a], but was predicted by frame sentence for [ə] vowels. The interaction between stress and syllable position was shown to be a significant predictor of F1 for [a] as well as duration and F1 for [ə] vowels.

Discussion

Blum (2018) claims that F1 is the only significant acoustic correlate of stress such that stressed [a] vowels are more peripheral and unstressed [a] vowels are reduced to [ə]. Blum (2018) further claims that F1 only varies based on syllable position so stressed vowels are always initial, except in CVCax words and this is due to some pressure against reducing an [a] vowel before [x]. Blum (2018)'s analysis thus suggests that traditional descriptions may have been right about CVCax words, but otherwise the acoustic measures showed more variation based on syllable position.

The linear mixed effects model analysis in this paper shows that particularly F1 of both [a] and [ə] vowels was significantly affected by an interaction between the described stress pattern and syllable position. Figure 1 demonstrates the interaction between stress and syllable position because while durations don't necessarily differ by stress, the distribution of stressed [ə] durations (the blue boxes) is constrained by syllable position. So, in the first syllable there are more stressed [ə] that have a longer average duration than unstressed [ə], but in the second syllable there are more unstressed [ə] vowels that have a longer average duration. A similar distribution can be seen for [a] durations in Figure 2, which shows that there are stressed [a] in an initial syllable which are shorter than any unstressed [a].

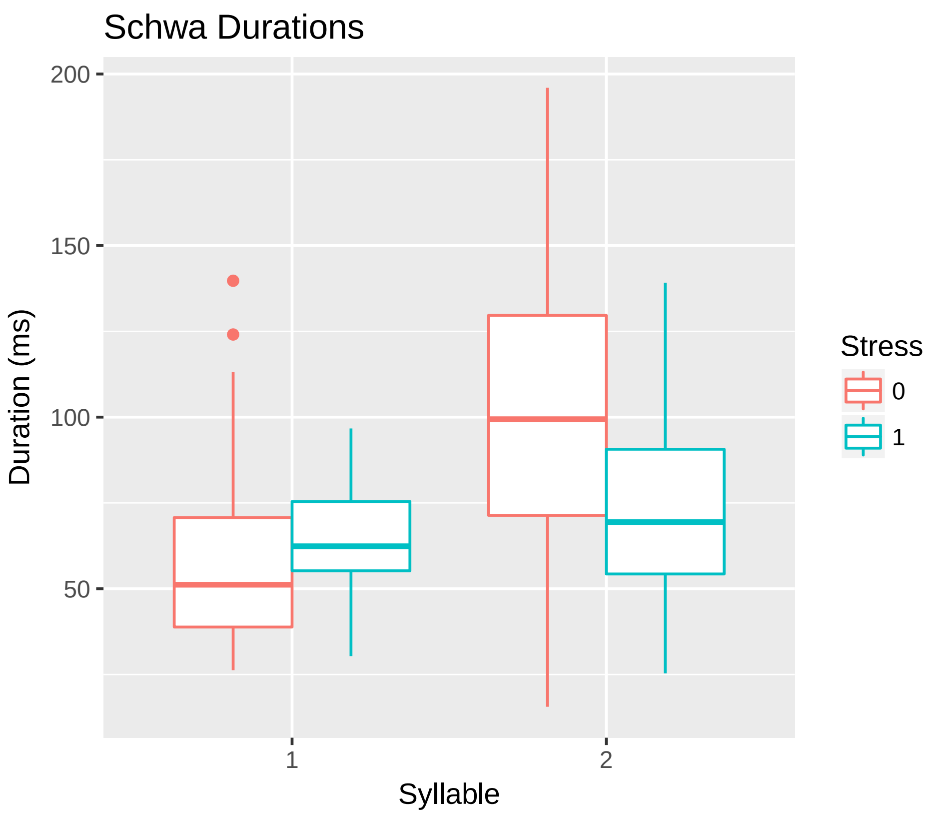

Figure 1

A similar distribution can be seen for [a] durations in Figure 2, which shows that there are stressed [a] in an initial syllable which are shorter than any unstressed [a].

F1, on the other hand, show a distribution more like what one might expect for the perceptual saliency of stressed vs. unstressed vowels. There is much less overlap in the F1 values of stressed and unstressed vowels and the stressed vowels have higher F1, which means they are lower (i.e. more peripheral) than unstressed vowels. For example, Figure 3 shows that F1 of stressed [ə] was higher on average than unstressed [ə]. While this generalization holds in both syllable positions the difference between stressed and unstressed [ə] is more pronounced in initial syllables.

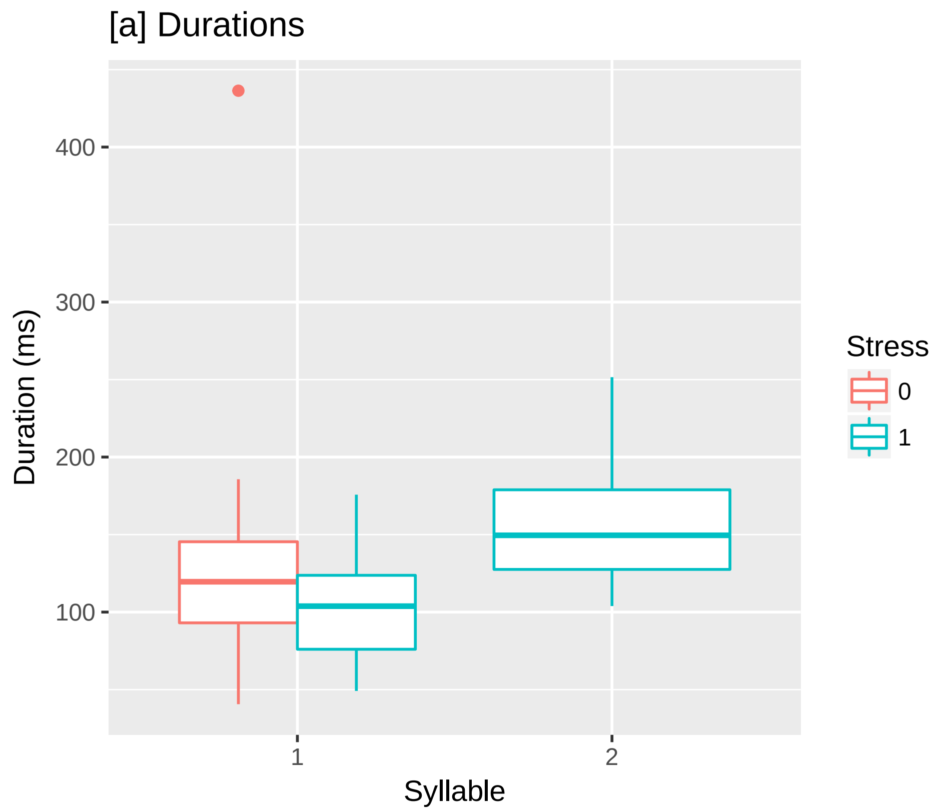

Figure 2

Figure 4 shows the same pattern for F1 values of [a], which are noticably higher for stressed than unstressed vowels in initial syllables.

F2 was only affected by frame sentence, which does not provide information relevant to determining M3's stress pattern.

Conclusion

This paper provides a new statistical analysis of Blum (2018)'s acoustic production data from a single speaker of Munster Irish. Blum (2018) utilized Student's t-tests to show that vowel reduction indicated by F1 demontrated a stress pattern that differs from the pattern that has been described. This paper uses linear mixed effects models to show that for two short vowels, [a] and [ə], an interaction between the described stress pattern and syllable position constrains the distribution of F1 values such that stressed [a] and [ə] are lower when stressed. In addition, stress affected vowel duration, but whether stressed vowels

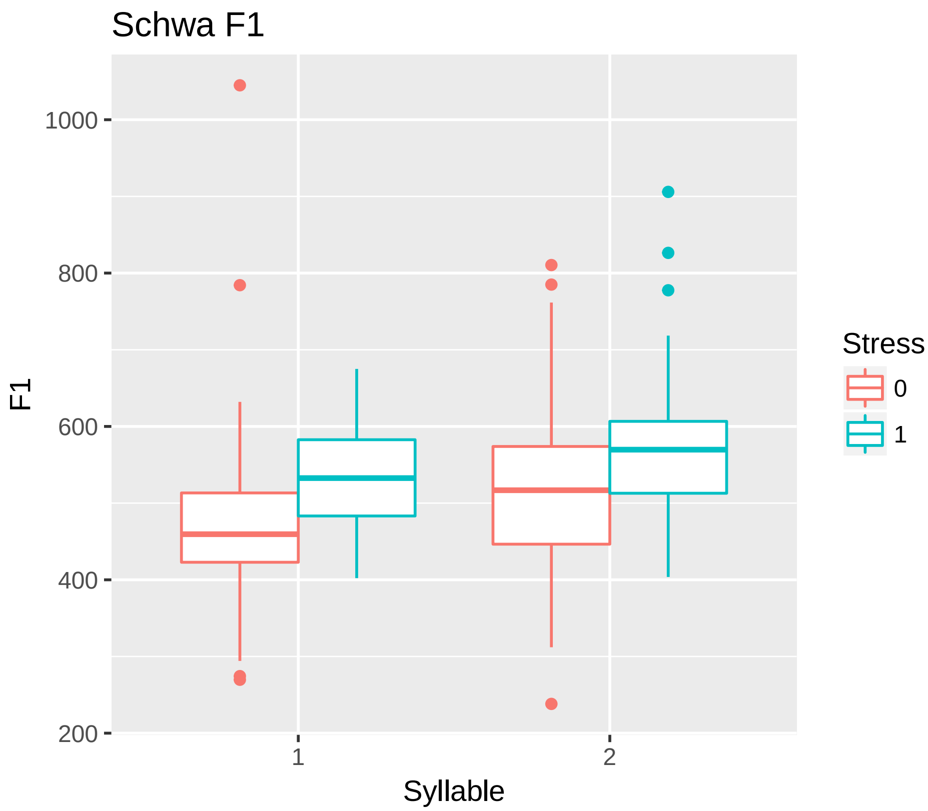

Figure 3

were longer or shortered differed depending upon the syllable position. In short, the stress pattern described by previous impressionistic work may not be as inaccurate as Blum (2018) suggests.

Further work remains to determine M3's complete stress pattern. The next steps for this analysis will be to determine the effect of stress, syllable position, and frame sentence on high vowels. In addition, future work will include analysis of long vowels and independently testing short vowels and /ax/ vowels in order to determine if there is any difference in the effects of stress and syllable position on those two type of vowels.

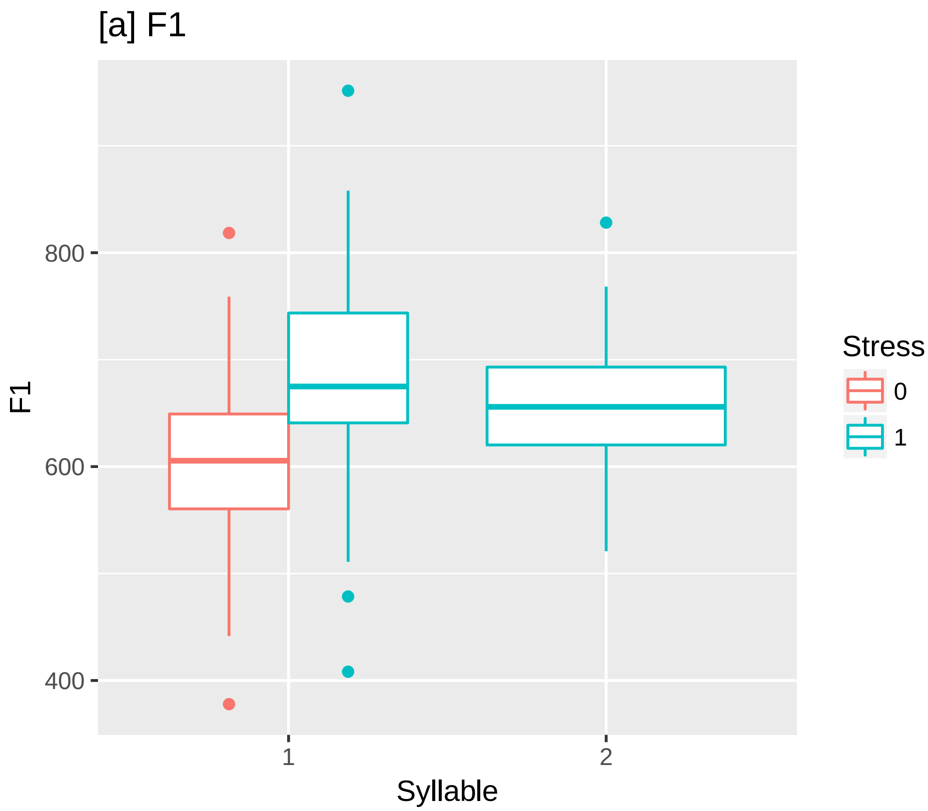

Figure 4

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