Acoustic correlates to contrastive tone heights in two African languages

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1 Introduction

Lexical tone contrast may have multiple acoustic correlates. While the primary acoustic correlate of tone is traditionally thought of as F0, lexical tone may also be realized by changes in F0 and vowel length, amongst other phonetic cues (Zhang, 2002). It has been suggested that universal phonetic properties influence the relationship between F0 and vowel duration. Many studies have found a negative correlation between F0 and vowel duration: high tones correlate to shorter vowel durations, while low tones are correlated with longer vowels in Thai, Mandarin, and Medʉmba (Gandour, 1977; Dreher and Lee, 1968; Franich, 2016). Recently, however, the universality of this negative correlation has been questioned. Studies looking at languages with level tone have found a positive correlation between F0 and vowel duration, suggesting that the assumed universal correlation between F0 and vowel duration may be a language specific property rather than a universal phonetic constraint (Mamadou, 2018; Kpodo and Akpanglo-Nartey, 2018). Additionally, it has been argued that the phonological system of a language will impact what phonetic units are used to cue prominence (Remijsen, 2014). A language may not use vowel length to cue stress if vowel length is contrastive in the language. The present study examines the relationship between vowel length and tone in two underdocumented African languages, Nobiin (Nilo-Saharic) and Guébie (Kru), and finds evidence that the relationship between F0 and vowel length is a language specific phenomenon. Additionally, this study does not find evidence that having contrastive vowel length impacts the acoustic correlates to pitch. These findings have implications for the relationship between phonetics and phonology, and highlight the importance of including a broad range of languages in experimental phonetic studies.

1.1 Acoustic correlates of tone

The acoustic correlates are language specific, and in some cases, can interact with the phonological inventory of a language. In languages such as Rangi, contour tones are more likely to be realized on heavy syllables (Zhang, 2002). Therefore, long vowels may more often co-occur with contour tones. Because of this co-occurence, vowel length may become an acoustic or perceptual cue to a contour tone.

In languages that do not have restrictions on the quantity of a tone bearing, or a stress bearing, unit may make use of available acoustic cues to optimize the prominence of the unit. Stress is argued to be realized primarily through vowel lengthening, while

tone is realized primarily through pitch (Remijsen, 2014; Lunden et al., 2017). However, in languages such as Washo, Welsh, and Zapotec that have contrastive vowel length in addition to stress, other acoustic cues besides vowel lengthening will be primarily used as acoustic correlates to prominence (Remijsen, 2014). If a language has contrastive vowel duration, Remijsen (2014) posits that vowel lengthening is not optimal to cue stress. This implies that the acoustic correlates to prominence may be predictable based on the phonological system of a language, as optimal phonetic correlates to prominence may be in a one-to-one relationship with phonological information. The present study expands on this work to look at the acoustic cues to tone, rather than stress. Nobiin has contrastive vowel length, so if tone behaves similarly to stress languages such as Washo, Welsh, and Zapotec, it is expected that vowel length may not correlate with tone. Guébie, on the other hand, does not have contrastive vowel length, and we therefore do not predict the same restrictions on the use of both pitch and vowel length as correlates to tone contrasts.

Similar to prominence, languages may have multiple acoustic correlates to vowel length. Listeners may use changes in F0 as well as vowel duration as an acoustic cue to vowel length (Lehnert, 2010). In a perception study, listeners with varying language backgrounds identified vowels that differed in duration (Lehnert, 2010). Japanese listeners were found to exploit F0 as a cue to vowel length in addition to vowel duration (Lehnert, 2010). Lehnert (2010) argues that this is because F0 and vowel duration co-occur in Japanese. Although vowel duration is typically considered the acoustic cue distinguishing phonemically long and short vowels, secondary phonetic cues such as F0 are active in distinguishing the contrast. This perception study shows that multiple acoustic correlates can signal a single phonological contrast (in this case vowel length), and that multiple acoustic cues can be used by listeners to perceive a single phonological contrast.

1.2 Relationship between acoustic correlates of tone

Studies investigating the relationship between the acoustic correlates of tone and prominence have suggested that there may be a universal relationship between primary and secondary acoustic correlates to tone. H tones tend to be short, while L tones tend to be long. Evidence for a negative correlation between tone and vowel duration comes from studies looking at Thai, Mandarin, and Medʉmba, among others (Gandour, 1977; Dreher and Lee, 1968; Franich, 2016). Thai has contrastive vowel length and contrastive tone. However, vowel length has been lost in certain Thai dialects. Gandour argues that the loss of the phonological distinction of contrastive long vowels is condition by tone (Gandour, 1977). Gandour (1977) shows that there is a negative correlation between vowel duration and average F0 of tones. This study argues that there may be a physiological motivation for this correlation, which can additionally condition sound change.

Perception studies have also supported the claim that F0 and vowel duration are inversely related. Medʉmba is a Bantu language and contrasts H and L tones (Franich, 2016). Unlike Thai or Mandarin, F0 remains relatively constant throughout the level tones. In a perception study, speakers of Medʉmba participated in a word identification task, and vowel duration as well as F0 were cues to tone perception (Franich, 2016). Duration as a cue to tone perception was stronger for L tones (Franich, 2016). Additionally, this study found that vowels with short durations and low F0 were more likely to be identified as H tones than vowels with longer durations (Franich, 2016). These results show that in a language that has level tone, vowel duration is exploited to identify tonal contrasts in addition to F0. This Medʉmba data also expands the claim that there

may be a universal physiological negative correlation between vowel duration and F0 by looking at data from a level-tone language.

Medʉmba does not have contrastive vowel length, meaning duration is exclusively used as a cue to tonal contrasts. The present study will further address how vowel length and pitch interact, specifically by looking at a language that has contrastive vowel length and two level tones (Nobiin), and a language with no contrastive vowel length and four contrastive tones (Guébie).

The studies addressed above have found production and perception data to support the claim that vowel duration and F0 can be used as acoustic cues to tonal contrasts in both contour tone and level tone languages. However, recent studies looking at tone production in various level tone languages have shown that there may not be a negative correlation between pitch and duration. This calls into question whether or not the negative correlation between pitch and duration found in many languages is physiologically motivated.

In a production study, 2 speakers of Yoruba were found to produce H tone vowels with a longer vowel duration than M or L tone vowels (Mamadou, 2018). Yoruba has three level tones, and does not have contrastive vowel length. These results contest earlier assumptions that the negative correlation between pitch and vowel duration is a universal tendency, and suggests that perhaps it is a language specific property (Mamadou, 2018).

Similar results have been found for Ewe and Ga (Kpodo and Akpanglo-Nartey, 2018). Ewe and Ga are Kwa languages that have level and contour tones (Kpodo and Akpanglo-Nartey, 2018). Neither Ewe or Ga has contrastive vowel length. Acoustic data shows that duration and mean F0 are positively correlated in both Ewe and Ga (Kpodo and Akpanglo-Nartey, 2018). Furthermore, this work found that vowel duration may be an even stronger cue to tone contrasts than F0. In the presence of a voiced consonant, the average F0 of H tones is similar to the average F0 of L tones. In this environment, vowel duration alone remains as a cue distinguishing H and L tone contrasts. The effect of phonetic environment on pitch is consistent with studies of other languages. Voiced consonants can act as depressor consonants, lowering the F0 of a following vowel (Hombert, 1978; Hanson, 2009).

1.3 Phonological inventory of Nobiin and Guébie

The present study expands on work addressing the relationship between pitch and vowel duration to two underdocumented African languages; Nobiin and Guébie. Nobiin is a Nilo-Saharan language spoken in southern Egypt and northern Sudan. Because of geopolitical reasons, many Nobiin speakers have been displaced. Nobiin has two contrastive level tones: H and ∅. On the surface, ∅ is realized as L. Minimal pairs show level tone is lexically contrastive in Nobiin: [dawwí] 'elder' and [dawwi] 'path'. Nobiin has five short vowels and five long vowels: [i, iː, e, eː, a, aː, u, uː, o, oː]. All of the vowels can bear a H or L tone.

Guébie is a Kru language spoken by around 7,000 speakers in southwest Côte d'Ivoire. Guébie has four contrastive level tones, labeled here as tones 1-4, 1 being the low tone and 4 being the high tone (Sande, 2017). Contour tones are also contrastive in Guébie, with tone melodies 41, 31, 42, 32, 13, 23, and 24 attested. However, contour tones are not examined in the present study, as the primary goal is to compare the acoustic correlates to level tone in Nobiin and Guébie. Contour tones will thus not be discussed further here. There are 10 contrastive vowels in Guébie, [i, e, ɛ, u, ʊ, o, ɔ, ə, a], and vowel length is

not contrastive (Sande, 2017).

Work looking at the relationship between level tones and vowel duration have found that vowel duration is often an acoustic correlate of tone. However, the languages included in many of these studies do not have contrastive vowel length in their inventories. There is a possibility that a language with contrastive vowel length will not use vowel length as an acoustic correlate to tone. This study expands upon earlier work by comparing the acoustic correlates to tone in a language that has contrastive vowel length (Nobiin) and a language that does not (Guébie). Furthermore, previous studies have looked at languages with only have two contrasting level tone heights (Franich, 2016), or that primarily have contour tones (Gandour, 1977). A language that has more than two contrastive level tones may make use of additional phonetic cues to create tone contrasts. The present study examines the acoustic correlates to contrastive level tones in a language that has two contrastive tones (Nobiin) and a language that has four contrastive tone heights (Guébie) to better understand the relationship between level tone contrasts and their phonetic correlates.

This study seeks to answer the following research questions:

1. What are the acoustic correlates to tone in Nobiin and Guébie?
2. Do Nobiin and Guébie show evidence for a negative or positive correlation between F0 and vowel duration?
3. How does vowel length interact with tone?
    - Do languages with contrastive vowel length (Nobiin) also use vowel length to distinguish tonal contrasts? Does this differ from languages without contrastive vowel length (Guébie)?
    - Are acoustic correlates to tone independent from phonological inventories?

2 Methods

Two speaker groups completed a production task for the present study. In the first group, two Nobiin speakers were recorded in Washington, D.C. in a quiet classroom. Both speakers are male and over the age of 40. For the production task, a word list was designed to elicit H and L tones on vowels in object position. The word list controlled for vowel quality to the extent possible. Items on the word list had all ten Nobiin vowels with H and L tone. While an effort was made to include a token of H and L vowels for every Nobiin vowel, a few gaps remain. The present study does not include H tone tokens of /oo/, or L tone tokens of /o/.

Participants were given the lexical item in English and asked to translate it into Nobiin. Each word was then produced in the carrier phrase "aj X igitis", meaning "I say X". Participants repeated this phrase three times, and one token of each lexical item was selected for analysis. A total of 72 vowels are analyzed. Recordings were made using a Zoom H4n recorder and a lavalier microphone.

In the second group, two Guébie speakers were recorded in Gnagbodougnoa, Côte d'Ivoire. Both speakers are male and over the age of 30. Due to constraints on resources in the field work setting, recording sessions took place in quiet locations outside of homes. For the production task, target words were chosen to elicit every combination of vowel

and tone pairs. The word list controlled for the voicing on the preceding and following consonants to the extent possible.

For the task, speakers were given a phrase in French and asked to translate the phrase into Guébie. All of these phrases had the third person singular pronoun [ɔ] in the subject position. Carrier phrases were not used in elicitations because of cultural considerations of collecting data in Gnagbodougnoa. All phrases were repeated three times, and one lexical item was selected for analysis. Because recordings were not made in a quiet lab-like setting, tokens were only chosen if they had minimal background noise. A total of 120 tokens are thus included in the present analysis. Again, recordings were made using a Zoom H4n recorder and a lavalier microphone.

Acoustic measurements were made in Praat (Boersma, 2017). Mean F0, Max F0, and Min F0 were measured in Hz. Vowel duration of each target vowel was measured in milliseconds. In order to control for speech rate of each utterance, vowel duration was measured as a ratio with the pronoun in the subject position. For Nobiin, the duration of the pronoun [aj] was measured in milliseconds for each phrase, and the duration of the target vowel was divided by the duration of the pronoun. For Guébie, the duration of the pronoun [ɔ] was measured in milliseconds for each phrase, and the duration of the target vowel was divided by the duration of the pronoun. The results report duration as a ratio value.

In order to address what acoustic values correlate to tone contrasts, logistic mixed-effects models were run separately for Nobiin and Guébie, with tone identity as the dependent variable. Secondly, to address the correlation between pitch and vowel duration, a correlation analysis between F0 and vowel duration ratio was run for each speaker and each language. Results are presented in section 3.

3 Results

3.1 Nobiin acoustic results

First, mean F0 of each tone height was compared for H and L tones separately for each speaker, in order to show that there is in fact a difference in pitch between H and L tones. Figures 1 and 2 show the average F0 for all vowels for Speaker 1 and Speaker 2 respectively.

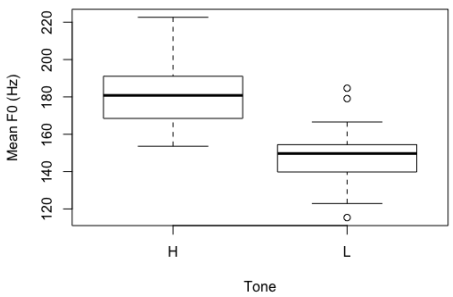

Figure 1: Mean F0 (Hz) for H and L tone vowels produced by Nobiin Speaker 1

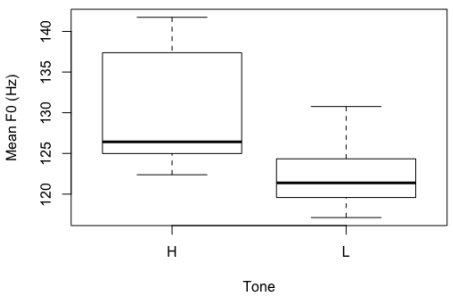

Figure 2: Mean F0 (Hz) for H and L tone vowels produced by Nobiin Speaker 2

As can be seen, both speakers produce H tone vowels with a higher F0 than L tone vowels. A t-test confirms that the difference in F0 between H and L tones is significant for both speakers (Speaker 1: p=1.144e-6; Speaker 2: p=0.0035). H tones are produced with higher F0 for the two Nobiin speakers, while L tones are produced with a lower F0.

Next, two logistic mixed-effect regression models were run with tone type as the dependent variable; one model was run for short vowels, and one model was run for long vowels. Separate models were run for phonemically short and long vowels to avoid confounds with including vowel duration as a predictor for tone identity. For both models, mean F0, vowel duration ratio, max F0 and min F0 were included as fixed effects. Random effects included speaker, vowel quality, and preceding consonant voicing. Tables 1 and 2 show the predictors that were significant from the models in predicting tone identity.

Fixed-effect	p-value
Mean F0	2e-16 **
Max F0	2e-16 **
Duration Ratio	2e-16 **

Table 1: Acoustic factors that influence tone height identity; output of logistic-regression model for Nobiin speakers' productions of phonemically **short** vowels

Fixed-effect	p-value
Mean F0	0.068
Max F0	0.062
Duration Ratio	0.026*

Table 2: Acoustic factors that influence tone height identity; output of logistic-regression model for Nobiin speakers' productions of phonemically **long** vowels

The output of the regression models show different patterns for short and long vowels in Nobiin. Table 1 shows that pitch measures and vowel duration measures are significant factors in predicting tone identity as H or L. However, for phonemically long vowels, 2 shows that pitch measures are not strong predictors of tone identity, but vowel duration is. The acoustic correlates to tone identity in Nobiin appear to differ depending on the phonemic status of vowel length for the vowels measured.

Finally, Pearson's correlation was measured between F0 and vowel duration in order to address whether tone and vowel length have a positive or negative correlation in Nobiin. Again, phonemically short and long vowels were measured separately. The two speakers were also measured separately, due to individual differences seen in the data. Figures 3 and 4 show the correlation between F0 and vowel duration for Speaker 1's phonemically short and long vowels (respectively), and Figures 5, and 6 show the correlation between vowel duration and mean F0 for Speaker 2's phonemically short and long vowels (respectively).

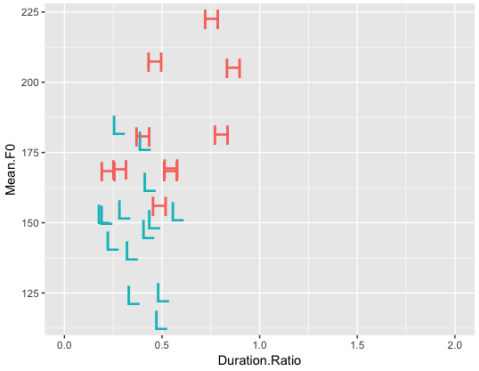

Figure 3: Nobiin Speaker 1: correlation between mean F0 and vowel duration for phonemically short vowel productions

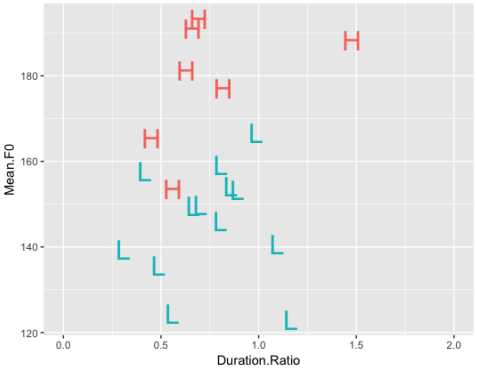

Figure 4: Nobiin Speaker 1: correlation between mean F0 and vowel duration for phonemically long vowel productions

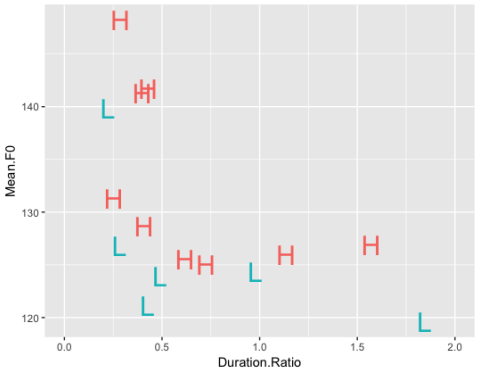

Figure 5: Nobiin Speaker 2: correlation between mean F0 and vowel duration for phonemically short vowel productions

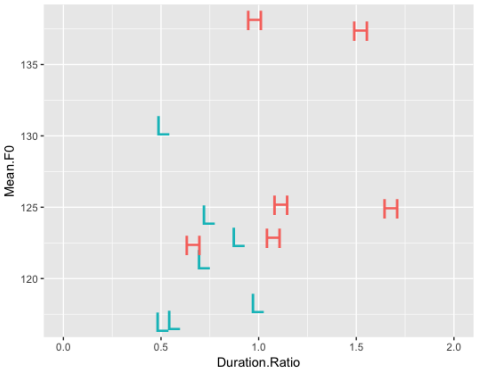

Figure 6: Nobiin Speaker 2: correlation between mean F0 and vowel duration for phonemically long vowel productions

For Nobiin Speaker 1, there is a moderate correlation between mean F0 and vowel duration for phonemically short vowels (Pearson's R=.473). This shows that pitch and vowel duration are moderately positively correlated for phonemically short vowels. For Speaker 1's phonemically long vowel productions, mean F0 and vowel duration are only weakly correlated (Pearson's R= .143). This shows a positive correlation between pitch and vowel duration, but the correlation is weak.

Nobiin Speaker 2 shows different results from Speaker 1. Speaker 2 has different correlation patterns between pitch and vowel duration depending on whether the vowel is phonemically short or long. For Speaker 2's phonemically short vowels, F0 and vowel duration are moderately *negatively* correlated (Pearson's R= -.52). Speaker 2's phonemically long vowels show the opposite trend, with a positive correlation between F0 and vowel duration (Pearson's R= .42).

3.2 Guébie acoustic results

Turning to the Guébie results, we first look at the differences in F0 for the four tone heights. Figures 7 and 8 show the average F0 values in Hz for the four contrastive level tones. As can be seen Guébie Speaker 1 and Speaker 2 have different patterns.

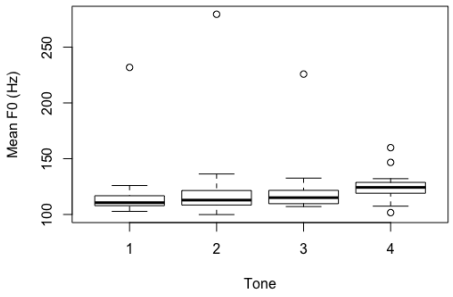

Figure 7: Mean F0 (Hz) for vowels with tones 1, 2, 3, and 4 produced by Guébie Speaker 1

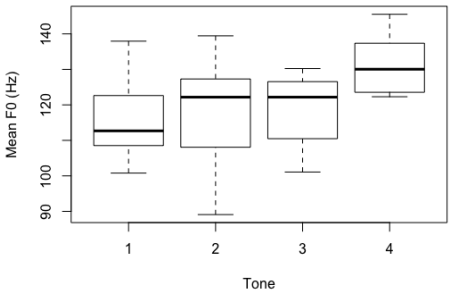

Figure 8: Mean F0 (Hz) for vowels with tones 1, 2, 3, and 4 produced by Guébie Speaker 2

Speaker 1 does not produce much difference in F0 for the four level tones. A one-way Anova shows no main effect of tone identity on average F0 (p=0.98). Speaker 2 does produce a difference between the four contrastive tones, and a one-way Anova shows that there is a main effect of tone identity on average F0 of vowels (p=0.0028). A post-hoc Tukey HSD test reveals that Speaker 2 produces tone 4 with a different mean F0 from tones 1, 2, and 3.

Next, a Logistic mixed-effects model was run in order to reveal which acoustic factors contributed to tone height identity. Tone identity was included as the dependent variable, and mean F0, vowel duration ratio, min F0, and max F0 were included as fixed effects. Speaker, vowel quality, and preceding consonant voicing were included as random effects. The output of the model is summarized in Table 3.

Fixed-effect	p-value
Mean F0	2e-16
Max F0	2e-16
Min F0	2e-16
Duration Ratio	2e-16

Table 3: Acoustic factors that influence tone height identity; output of logistic-regression model for Guébie speakers

Interestingly, the results of the mixed-effects model show that all pitch measurements tested (mean F0, max F0, and min F0) are significant factors in predicting tone height identity. This result may not be immediately apparent from the comparison of mean F0 values across the tone heights shown in Figures 7 and 8. However, the regression model includes random effects for the voicing of the preceding consonant, which can impact the pitch of a following vowel. This will be discussed further in Section 4. Vowel duration is also a significant factor in predicting tone identity for Guébie speaker productions.

Finally, the correlation between mean F0 and vowel duration was measured in order to describe the relationship between these two acoustic measurements. The correlation of vowel duration and pitch are shown in Figure 9 for Guébie Speaker 1, and the correlation of vowel duration and pitch are shown in Figure 10 for Guébie Speaker 2.

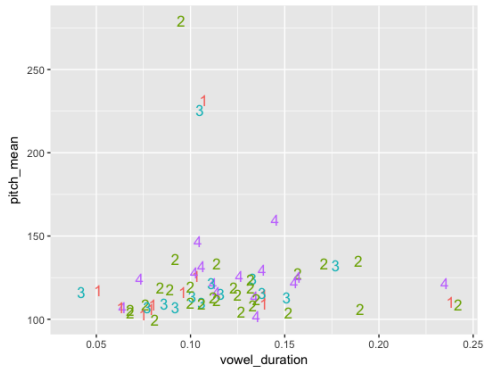

Figure 9: Guébie Speaker 1: correlation between mean F0 and vowel duration vowel productions

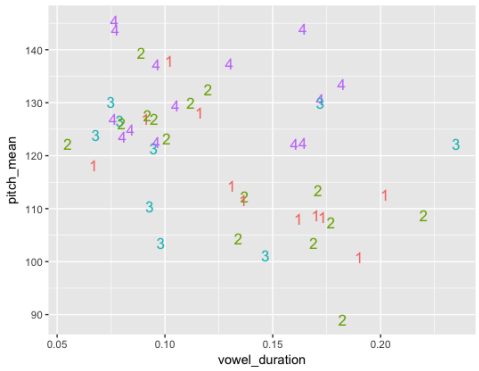

Figure 10: Guébie Speaker 2: correlation between mean F0 and vowel duration vowel productions

The results for Guébie Speaker 1 show a very weak negative correlation between vowel duration and mean F0 (Pearson's R=-0.09). Although there is a slight trend showing a negative correlation between F0 and vowel duration, the correlation is too weak to make any generalizations. The results for Guébie Speaker 2 show a slightly stronger negative correlation between F0 and vowel duration (Pearson's R=-0.29), but again, the correlation is weak.

4 Discussion

The above results show that acoustic correlates to tone differ by language. Furthermore, the results show that within one language (in this case Nobiin) different acoustic correlates to tone depend on phonological vowel length. The acoustic results from 2 Nobiin speakers shows that overall, H tones have higher pitch than L tones. However, the output of the regression model shows that phonemically short and long vowels have different acoustic factors that predict tone identity in Nobiin. For phonemically short vowels, F0 as well as vowel duration are significant predictors of tone identity. For phonemically long vowels, only vowel duration is a significant predictor of tone identity. The fact that none of the pitch measurements were significant predictors of tone identity for long vowels in Nobiin may be caused by physiological factors. It may be difficult for speakers so sustain high and low pitch for a sustained period of time, so long vowels make use of the length distinctions to discriminate between H and L tones rather than large pitch differences.

Turning to the correlation between F0 and vowel duration, there are differences across the two Nobiin speakers, and differences between phonemically short and long vowels. For phonemically short vowels, vowel duration and pitch are (moderately) positively correlated for Nobiin Speaker 1, but negatively correlated for Nobiin Speaker 2. The variation between the two speakers may be caused by dialectal differences. Data from additional Nobiin speakers would help to shed light on individual and dialectal differences if this data becomes available. For phonemically long vowels, vowel duration and pitch appear to be only weakly correlated, although this trend appears to be in the positive direction.

The Guébie production results show that mean F0 is relatively similar across all 4 pitch heights for the two Guébie speakers. Despite this finding, the output of the logistic regression show that pitch measurements are significant factors in predicting tone

height. As suggested in the previous section, this apparent discrepancy may be caused by the influence of the voicing of the preceding consonant. Voiced consonants can act as depressor consonants in many languages, including Mijikenda (Cassimjee & Kisseberth, 1992), Nguni (Downing, 2017), and Ga (Kpodo & Akpanglo-Nartey, 2018) among many others. It is thus possible that the presence of voiced stops preceding the vowels measured neutralizes the difference in F0 between the four contrastive tone heights. When Voicing of the previous consonant was included as a random effect in the mixed-effects model, mean F0, maximum F0, and minimum F0 are significant factors in predicting tone height. Thus, the apparent lack of difference in F0 between the 4 Guébie tone heights is likely a result of the surrounding consonants. Future research will address this question more in depth. However, there is currently limited data that balances vowel quality, preceding consonant voicing, and preceding place of articulation across all 4 vowel heights, making it difficult to draw generalizations about the effect of depressor consonants. Future production tasks are planned to collect a more comprehensive data set to test this hypothesis. Next, the results of the production task also show that vowel duration is a significant predictor of tone identity. Higher tones tend to have shorter vowel durations in Guébie. Although the correlation is weak, there is a negative correlation between F0 and vowel duration in Guébie.

Taken together, this study finds that Nobiin and Guébie both have multiple acoustic correlates to contrastive level tones. In Guébie and in Nobiin, both pitch and vowel duration are predictors of tone identity. For Nobiin, vowel length is thus an acoustic correlate of both phonological vowel length and pitch. It has been suggested that when vowel duration is a contrastive phonological feature of a language, duration may not be an active phonetic cue to prominence (Remijsen, 2014). In Washo, Welsh, and Zapotec, vowel duration is not used as an acoustic correlate to stress, contrary to typological evidence that vowel length is typically the primary acoustic correlate to stress. These languages have phonemic vowel length, and vowel length is not used as an acoustic correlate to stress (Remijsen, 2014). Remijsen argues that optimal phonetic cues to prominence vary depending on the phonological contrasts of a language. If a language has phonemic vowel length, vowel duration may not be an optimal phonetic correlate of prominence, explaining why stress is not cued by vowel duration in languages that have phonemic vowel length. However, the findings of the present study do not support the extension of this hypothesis to tone. Vowel duration is an acoustic correlate to tone height in Nobiin, despite having contrastive vowel length. This finding may suggest that the phonetic cues to prominence do not depend on the phonological inventory of a language. The same phonetic cues can be used for several contrasts.

As for the correlation between phonetic correlates to tone, this study does not find evidence for a universal negative correlation between pitch and duration, as has been suggested in previous studies (Gandour, 1977; Dreher & Lee, 1968). In Nobiin, vowel length and mean F0 tend to be positively correlated. Again, however, we see that this correlation does depend on the length of the vowel. Long vowels are only weakly correlated with F0. Recall F0 was not a significant factor in predicting tone height for long vowels in Nobiin. This weak correlation may be related to the fact that speakers make less use of F0 distinctions for tone contrasts on long vowels, thus neutralizing F0 distinctions. Turning to the results from Guébie, there does appear to be a negative correlation between pitch and vowel duration, albeit a weak correlation. The results from Nobiin and Guébie show that the correlation between pitch and vowel duration is a language specific phenomenon, rather than a universal phonetic fact.

5 Limitations

One limitation to the present study is the small sample of speakers representing Nobiin and Guébie. Both of these languages are endangered, and gathering phonetic data from a large number of speakers is not feasible. For Nobiin, speakers have been displaced, making it difficult to work with a large group of native speakers. For Guébie, very few speakers live outside of Côte d'Ivoire, making it necessary to travel to collect recordings. In the villages where Guébie is spoken, there is social pressure to work with male speakers, rather than female speakers, and only certain male speakers are willing to participate in individual recording sessions. Despite the limitations on the small sample size of the speakers from each language, this research represents the first time acoustic correlates to tone in Nobiin or Guébie has been documented, adding to a diversity of language data represented in the phonetic literature.

6 Conclusion

This study investigates the acoustic properties of lexical tone in two understudied African languages, Nobiin and Guébie. Nobiin has two contrastive level tones realized as H and L on the surface, and phonological vowel length. Guébie has four contrastive level tones and no phonological vowel length. The results of the production task show that in Nobiin, the acoustic correlates to tone depend on the phonological length of vowels. For short vowels, both F0 and vowel duration are acoustic correlates to tone, but for long vowels, only vowel length correlates to tone. For Guébie, both F0 and vowel duration correlate to tone. These results have implications for the phonetics-phonology interface, and show that vowel length can be the primary acoustic correlate to multiple phonological contrasts. As for the correlation between these acoustic features, the direction of the correlation is language specific. Nobiin results show a positive correlation between F0 and vowel duration, and Guébie results show a negative correlation. These results support more recent findings that argue that the assumed universal negative correlation between pitch and duration is, in fact, language specific (contra Gandour (1977)), and highlights the importance of including a wider range understudied languages in phonetic research.

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