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Variation in Fricative Production in Malagasy Dialects

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Abstract
The development of phonological tone has been linked in many languages to consonant voice quality contrasts that impart pitch differences to preceding or following vowels. In particular, modal voicing on a syllable-initial consonant has been shown to correlate with low pitch on a following vowel in both tone and non-tone languages (Hombert et al. 1979). In the Austronesian language Malagasy, a strong relationship between consonant voicing and vowel pitch has been observed in the literature; previous studies state, however, that Malagasy does not have phonological tone. In contrast with these previous descriptions, the results presented in this paper from a production study of homorganic fricative pairs in several different dialects of Malagasy suggest that in certain dialects in the center of the country, in and around the capital city, pitch has replaced modal voicing as the primary phonetic cue to fricative voicing category. Based on word list data from 11 Malagasy speakers, this study finds that the homorganic fricatives of speakers of the Central dialects are best classified based on the pitch of the following vowel, while those of speakers of non-Central dialects are best classified based on the duration of modal voicing on the fricative. Secondary phonetic cues typically associated with a voicing distinction (i.e., duration, frication intensity) appear to be undergoing neutralization among the Central speakers.

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1 Introduction

The development of phonological tone has been linked in many languages to consonant voice quality contrasts that impart pitch differences to preceding or following vowels. In particular, modal voicing on a syllable-initial consonant has been shown to correlate with low pitch on a following vowel in both tone and non-tone languages (Hombert et al. 1979). In the Austronesian language Malagasy, a strong relationship between consonant voicing and vowel pitch has been observed in the literature; previous studies state, however, that Malagasy does not have phonological tone. In contrast with these previous descriptions, the results presented in this paper from a production study of homorganic fricative pairs in several different dialects of Malagasy suggest that in certain dialects, pitch has replaced modal voicing as the primary phonetic cue to fricative voicing category.

2 Background

2.1 Malagasy Language and Dialects

The term MALAGASY refers to a macrolanguage, which is considered to include about 18 individual dialects coinciding with geographically-bounded ethnic groups in Madagascar. The dialect spoken in Antananarivo, the capital city, is called Merina. Other dialects spoken in geographic proximity to the capital have been grouped under the name Plateau Malagasy (Lewis et al. 2013), in reference to the elevated plateau which distinguishes this central region of the island geographically from the coastal areas. In addition to Merina, this grouping includes the Betsileo dialect, among others. In this paper, the term CENTRAL DIALECT GROUP will be used to refer only to speakers of Merina and Betsileo, since the area where these groups are located is in the center of the country; this term does not encompass all of the dialects designated by the term Plateau Malagasy, as data on all these dialects was not available for the current study. Other dialects from which data was collected for this study include Antakarana, Sakalava, and Tsimihety, all spoken in the north of Madagascar and therefore referred to herein as the NORTHERN DIALECT GROUP. The dialect regions and the areas studied in this work are indicated on the map in Figure 1.

2.2 Fricative Contrasts in Malagasy

The phonological inventory of Malagasy includes two homorganic fricative pairs: /f/ and /v/ are labio-dentals, articulated in the canonical place just behind the top of the lower lip (Dahl 1952:175), and /s/ and /z/ are described as displaying interdialectal variation in terms of place and manner of articulation, ranging from denti-alveolar to postalveolar and varying between apical and laminal productions. Dahl (1952:176–7) notes in particular that the Betsileo and sometimes the Merina dialects use an apical articulation, lending these sounds a "hissing" quality.[1] In his study of the Merina dialect, Rakotofiringa (1982:522–8) writes that /f/ and /v/ are unremarkable in comparison to the same phonemes in French and other languages. Like Dahl, he also notes inter- and intra-speaker variability in place of articulation for /s/ and /z/; he states that in general these sounds are produced further back in the mouth than the /s/ and /z/ of French but that several decades prior to the time of his work, people in the capital used a more anterior /s/ because the retracted /s/ was associated with peasants and indigents. In contrast, Rakotofiringa claims that younger generations around 1980 at the time of his work felt the anterior pronunciation to be a pretentious affectation associated with foreign influence.

[1]Translated from French *"chuintante"*.

Both of these previous accounts describe the fricative pairs as primarily distinguished by the presence or absence of modal voicing. Dahl states that /f/ and /s/ are always voiceless and generally have greater frication intensity than /v/ and /z/, as expected for a voiceless fricative in comparison with its voiced counterpart. Although he notes that /v/ and /z/ may sometimes be devoiced in the middle, he provides no empirical quantitative indication of the frequency of this devoiced realization and asserts that realization *with* modal voicing is the norm.

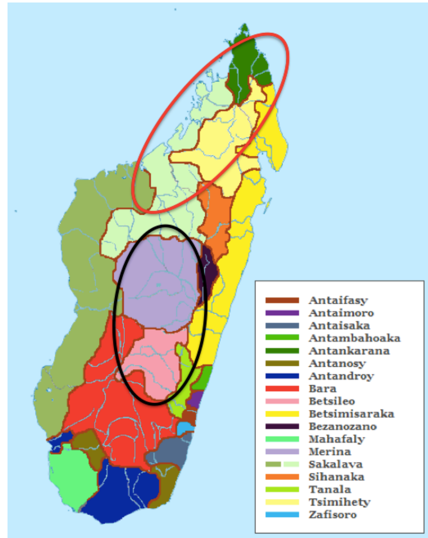

Figure 1: Map of Madagascar showing geographic boundaries of ethnic/dialect groups. Black oval marks the region termed “Central” in this study; red oval marks the region termed “Northern”. Map from *http://en.wikipedia.org/wiki/File:Ethnic_groups_of_Madagascar_Map.png*.

2.3 Voicing and Tone

Although they consider modal voicing to be the primary factor distinguishing the pairs /f/-/v/ and /s/-/z/, both works discussed above note that vowel pitch is significantly lower following phonemically voiced fricatives than voiceless fricatives. This distinction is also observed on vowels following other pairs of voiced and voiceless consonants. Both assert, however, that pitch does not play a role in Malagasy phonology; they argue that it is one of several elements involved in the marking of lexical stress, which can be contrastive, but state that Malagasy is not a tone language.

Differences in vowel *f0* that correlate with the voicing class of prevocalic consonants are attested in a variety of languages, including English (Lehiste and Peterson 1961, Hombert et al. 1979). Such differences are argued to be physiologically related to larynx position and vocal fold tension associated with the presence or absence of modal voicing (Hombert et al. 1979) and more broadly with phonation quality in general. The phonetic correlation between *f0* and voicing has been widely claimed to be the source of the development of phonologically contrastive tone in a variety of South Asian and African languages (Haudricourt 1954, Matisoff 1970, Hombert et al. 1979). Under these models of tonogenesis, an original voice quality contrast produces an *f0* contrast which acts as a secondary cue to voice quality; the relative weightings assigned to these cues then undergo a shift, such that *f0* becomes the primary contrastive cue and the voice quality distinction becomes secondary. Once the voice quality distinction has lost its critical role in marking phonological contrast, it is often neutralized, leading to the loss of a phonological voice quality contrast in exchange for the introduction of a tone contrast in the language.

2.4 Overview of the Current Study

In a non-tonal language such as English, *f0* values on post-obstruent vowels produced by male speakers differ due to consonant voicing distinctions by an average of about 15–20 Hz at vowel onset and then fairly rapidly converge over the next 100 ms of the vowel (Hombert et al. 1979). The impetus for the present study was the observation of a stronger and more persistent pattern of phonemic voicing and *f0* correlation in the production of post-fricative vowels in stressed syllables by a female speaker of the Merina (Central) Malagasy dialect. This speaker typically displayed a pitch difference of 30 to 50 Hz at vowel onset following voiced versus voiceless fricatives, and the high *f0* following voiceless fricatives was often sustained throughout most of the vowel; this speaker also exhibited very little modal voicing on any fricatives. Moreover, the pitch distinction occurred in this speaker's productions even when the phonemically voiced fricative was produced without modal voicing, indicating that the *f0* patterns were not simply a physiological consequence of modal voicing.

In light of these observations, the present study of fricative production was conducted during fieldwork in Madagascar in 2012. Acoustic measurements of voiced and voiceless fricatives in recordings collected from Central and Northern dialect speakers suggest that there is a dialectal difference in the relative contribution of acoustic cues to fricative voicing, with Central dialects distinguishing fricatives primarily through following vowel pitch and Northern dialects primarily through presence or absence of modal voicing.

3 Data and Methods

3.1 Speakers and Recordings

Word lists containing 95 items, including target items with stressed fricatives as well as distractor items, were recorded from ten speakers during fieldwork in Madagascar. In addition, one Malagasy speaker was recorded producing two tokens each of a subset of 32 of the items in the sound lab at Rice University in Houston, TX. Information about the gender, age and dialect region of these speakers is listed in Table 1. See the map in Figure 1 for the locations of the dialect regions.

Central Speakers	Sex	Age	# Tokens	Northern Speakers	Sex	Age	# Tokens
AMAL	F	26	53	DFR	F	19	55
DTR	M	24	54	JFR	M	30	53
LN	F	28	54	LV	F	25	53
OHR	F	28	64*	MR	M	22	52
TNH	M	25	52	R	M	22	53**
TNR	M	22	53				

Table 1: Speaker information and number of tokens measured. *Houston speaker: 2 tokens of each of 32 lexical items. **Pitch measurements not available for Speaker R due to excessive creaky phonation.

All recordings were made using a Zoom H4n digital recorder at 44.1kHz sampling rate with a Samson SE50 Omnidirectional headworn microphone. Recordings of the Houston speaker were made in a sound-attenuated booth in the Linguistics Department at Rice University, while field recordings were conducted in the quietest environment available in each location. Field consultants produced each word embedded in the carrier phrase *Nanoratra* ___ *teo aho* ‘I wrote ___ there’. Words were presented in the same order for each speaker.

3.2 Measurements

Measurements were made in Praat for all fricative-vowel syllables carrying primary stress. All boundaries were marked at zero-crossings in the waveforms. Table 1 above lists the number of measurable tokens produced by each speaker.

3.2.1 Measurements for Fricatives

Duration Since Malagasy syllables are strictly CV and all phonetic measurements were made on words embedded in a carrier phrase, all target fricatives were surrounded by vowels. Fricative boundaries were identified by examining both the sound wave and the spectrogram for the presence of high-frequency aperiodic noise and for the offset and onset of neighboring vowel formants.

Percent modal voicing Modal voicing during the fricative was detected following a method used by Boersma (2006, reproduced in Rivas 2006:48), which examined the fricative in 10 ms windows and reported the percentage of windows not meeting the standard threshold for modal voicing.

Intensity In order to measure the intensity of high-frequency frication noise excluding contributions due to the glottal source, a high-pass filter with a cutoff of 400 Hz and 100 Hz smoothing was applied. The value measured was the mean intensity over the middle 50% of the fricative.

3.2.2 Measurements for Vowels

Duration Vowel onset coincided with fricative offset and was identified according to the criteria outlined in Section 3.2.1. Vowel offset was identified as the point where the characteristic periodicity of the vowel diminished in the waveform and formants were no longer evident in the spectrogram.

Fundamental frequency Vowels were divided into ten equal intervals and *f0* in Hz was measured at the midpoint of each. Mean *f0* over the first half of each vowel was calculated by averaging the values at the midpoints of the first five intervals. In order to perform inter-speaker comparisons, the Hz values in each interval were converted to the Bark scale and normalized relative to each speaker's mean reference pitch.

4 Results

4.1 Fricative Percent Modal Voicing

Figures 2 and 3 show the median and variance of percent modal voicing during production of voiceless and voiced fricatives for Central and Northern dialect speakers, respectively. Figure 2 shows that there is significant overlap in this variable across voicing categories for Central dialect speakers. Speakers AMAL, LN, OHR and TNH produce very little modal voicing in either fricative condition, with median values below 40% for both conditions; speakers DTR and TNR have median percent modal voicing values above 70% for voiced fricatives but show large amounts of variance in the voiced category, resulting in overlap between the two fricative categories. In contrast, Figure 3 shows virtually no overlap between the voicing categories in terms of percent modal voicing for any of the speakers from the Northern dialect region. With the exception of speaker DFR, whose median percent modal voicing for voiced fricatives is around 50%, the Northern dialect speakers have median values of 100% modal voicing for voiced fricatives.

A linear mixed-effects regression model for proportion of modal voicing on the fricative produces the results shown in Table 2. Random effects are subject and lexical item. This confirms that mean percent modal voicing is significantly greater in voiced fricatives compared to voiceless fricatives for both dialect groups (slope = 0.25, $p < .0001$); but the interaction between voicing class and dialect group indicates that voiced fricatives have significantly more modal voicing compared to voiceless fricatives for Northern dialect speakers than they do for Central dialect speakers (slope = 0.45, $p < 0.0001$).

Proportion Modal Voicing	Estimate	Std. Error	*t*	*p*
Intercept	0.12	0.06	2.11	<**0.05**
Voice category: voiced	0.25	0.03	9.02	<**0.0001**
Dialect group: Northern	−0.02	0.08	−0.27	0.78
Voice category: voiced * Dialect group: Northern	0.45	0.03	15.19	<**0.0001**

Table 2: Results for fixed effects in a linear mixed-effects model of proportion of modal voicing. Random effects are subject and lexical item. Bold indicates significant effects.

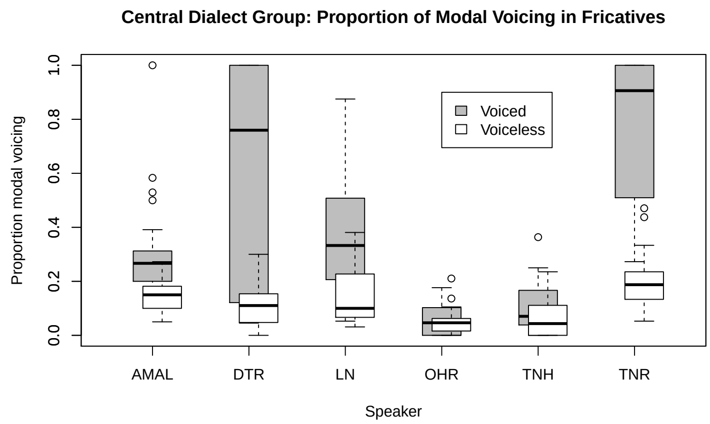

Figure 2: Percent modal voicing for voiced and voiceless tokens by speaker for Central dialect region. Heavy lines indicate median values; boxes indicate bounds of lower and upper quartiles; whiskers indicate minimum and maximum excluding outliers; outliers falling more than 1.5 times the interquartile range at either extreme are represented by circles.

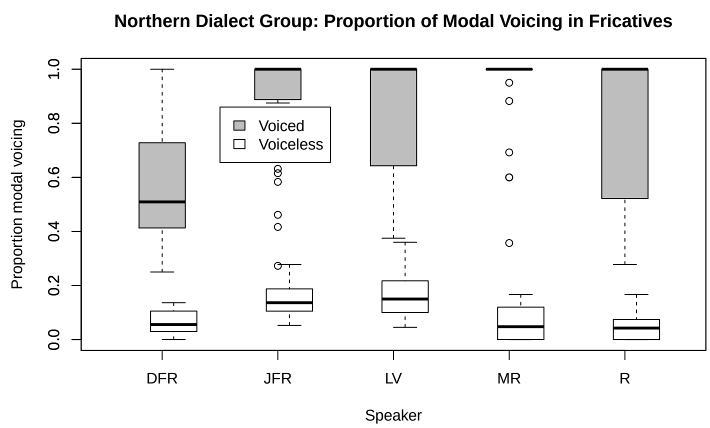

Figure 3: Percent modal voicing for voiced and voiceless tokens by speaker for Northern dialect region.

4.2 Vowel Pitch

All speakers displayed differences in *f0* over the first half of the vowel following voiced versus voiceless fricatives.[2] However, a qualitative difference in the evolution of the pitch contours over the vowel for the two groups suggests that this difference is more robust and regular for Central dialect speakers than for Northern dialect speakers. Figure 4 shows mean vowel pitch contours in normalized Bark scale by dialect region and sex. For Northern speakers, the *f0* distinction is neutralized more quickly than it is for Central dialect speakers; whereas Northern speakers' low contour begins to rise towards the high contour immediately at vowel onset, the Central speakers' low contour dips even lower after vowel onset and remains at or below onset level until the vowel midpoint. This holds for both sexes, although the effect is clearer for women. The area between the curves for voiceless and voiced cases is greater for Central dialect speakers than for Northern dialect speakers. Given that Central dialect speakers exhibit relatively little modal voicing on voiced fricatives, this persistence and enhancement of the *f0* distinction on the vowel suggests that pitch has become decoupled from modal voicing as its own contrastive cue; if vowel pitch were purely a

[2] Vowel *f0* values are not available from the recordings of Northern dialect speaker R due to excessive creak.

coarticulatory phenomenon, we would expect devoicing of voiced fricatives on its own to have the opposite physiological effect of eliminating the *f0* difference on following vowels.

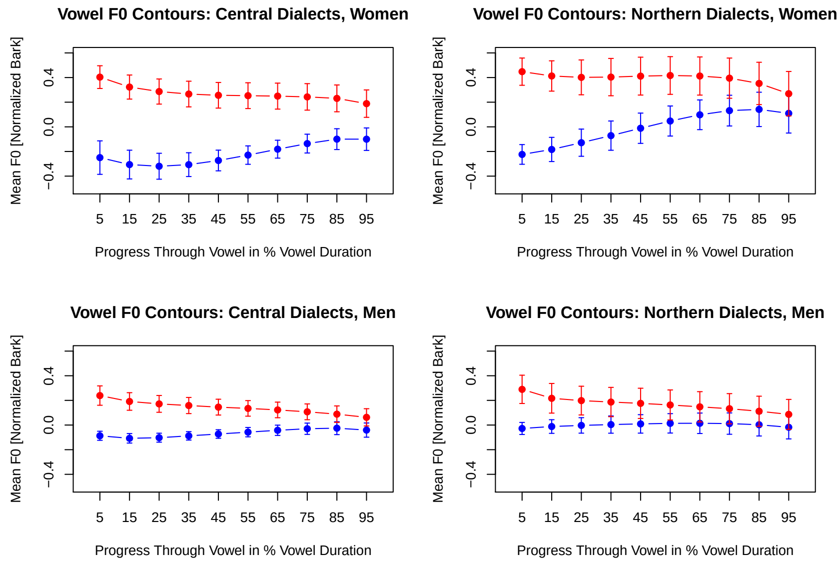

Figure 4: Mean *f0* contours in normalized Bark scale as a function of percent vowel duration following voiced (blue) and voiceless (red) fricatives for women and men from the two dialect groups. Error bars indicate standard error of the mean.

Mean 1st 1/2 Vowel Pitch [Norm. Bark]	Estimate	Std. Error	*t*	*p*
Intercept	0.25	0.02	11.33	$<$**0.0001**
Voice category: voiced	−0.44	0.03	−17.61	$<$**0.0001**
Dialect group: Northern	0.06	0.03	2.31	$<$**0.05**
Voice category: voiced * Dialect group: Northern	0.08	0.03	2.90	$<$**0.01**

Table 3: Results for fixed effects in a linear mixed-effects model of mean pitch over the first half of the vowel. Random effects are subject and lexical item. Bold indicates significant effects.

A linear mixed-effects regression model for mean pitch over the first half of the vowel is presented in Table 3. Random effects are subject and lexical item. The large effect of voicing class (slope = −0.44, $p < 0.0001$) confirms that for all speakers, pitch on the first half of the vowel is significantly lower following voiced rather than voiceless fricatives. The interaction term, however, indicates that Northern dialect speakers have significantly higher *f0* compared to their overall mean *f0* over the first half of the vowel following voiced fricatives than do Central dialect speakers (slope = 0.08, $p < 0.01$). This confirms the significance of the qualitative observation concerning the tendency for the pitch contour to begin rising immediately at vowel onset following voiced fricatives for Northern dialect speakers. The small but significant effect of Northern dialect group alone on mean vowel pitch in the first half of the vowel (slope = 0.06, $p < 0.05$) is also attributable to this fact.

4.3 Interaction of Modal Voicing and Pitch

Figures 5 and 6 show percent modal voicing versus mean pitch over the first half of the vowel for each token for each speaker for the Northern and Central dialect regions, respectively. Regression lines represent the boundary between the voiced and voiceless fricative classes for each speaker; however, the slopes of these lines are biased low due to the upper bound of 100% on the modal voicing variable. In Figure 5, we see that the voicing categories can be separated by a line intersecting the modal voicing axis for all Northern speakers, but that a line intersecting the pitch axis could not separate the voicing classes for at least some of these speakers (JFR and MR); this suggests that the primary distinction between these categories for these speakers is the amount of modal voicing on the fricative. In contrast, the regression lines in Figure 6 all intersect the pitch axis, and it is not possible to separate the two voicing classes with a line intersecting the voicing axis; this indicates that for speakers from the Central dialect group, vowel pitch is more salient in distinguishing the fricative voicing categories. While the slopes of these boundaries indicate that both cues are relevant to the voice category distinction for most of these speakers, the relative weightings of these cues are different in the two groups; for Northern dialect speakers, modal voicing is primary and vowel pitch is secondary, and for Central dialect speakers, vowel pitch is primary and modal voicing secondary.

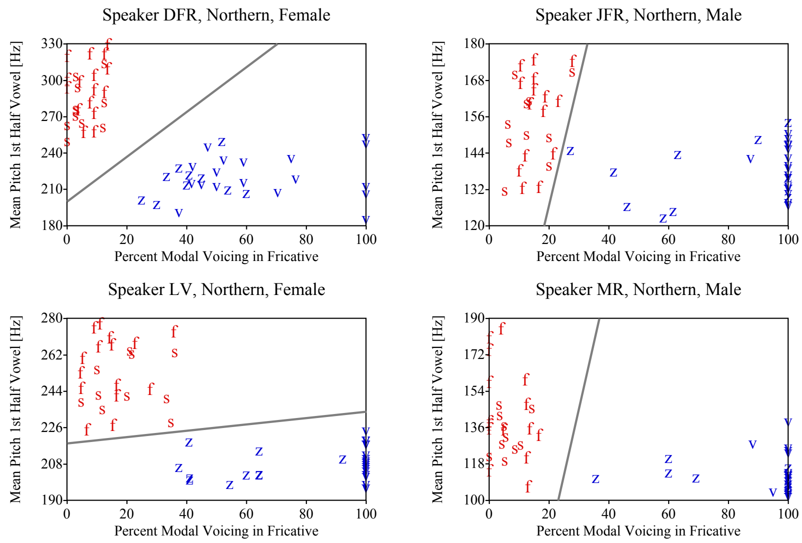

Figure 5: Percent modal voicing versus mean pitch over first half vowel for voiced (blue) and voiceless (red) fricatives by speaker for Northern group. Logistic regression lines (gray) calculated in Praat.

4.4 Ratio of Fricative Duration to Syllable Duration

For both dialect groups, absolute duration for voiceless fricatives was slightly longer than for voiced, as expected cross-linguistically (e.g., Rivas 2006). Fricative duration was also examined as a ratio of the whole syllable. A linear mixed-effects regression model for ratio of fricative duration to full syllable duration is presented in Table 4. Random effects were subject and lexical item. There is a significant effect of voicing category on fricative duration for all speakers considered together, with voiced fricatives shorter with respect to the whole syllable than voiceless fricatives (slope = -0.08, p <0.001). The interaction of voicing class and dialect group falls just short of reaching significance at the 0.05 level; however, it does show a trend in the expected direction if this variable were undergoing neutralization in the Central dialect group, namely that voiced fricatives are shorter compared to voiceless fricatives to a greater degree for the Northern than for the Central dialect group.

Although there is no statistically significant effect of the interaction of dialect group and voicing class on fricative to syllable duration ratios when considering all speakers in the dialect groups together, Welch one-sided t-tests show that the duration difference is significant for each speaker individually in the Northern dialect group (at p <0.05 or less), but that for two of the six Central speakers (AMAL and TNH), the difference is not significant ($p = 0.06$ and $p = 0.23$, respectively). As there was no known social or other factor distinguishing these two speakers from the other Central speakers in the study, this fact suggests that for Central speakers, neutralization of the duration distinction between voiceless and voiced fricatives may be underway. Referring back to Figures 2

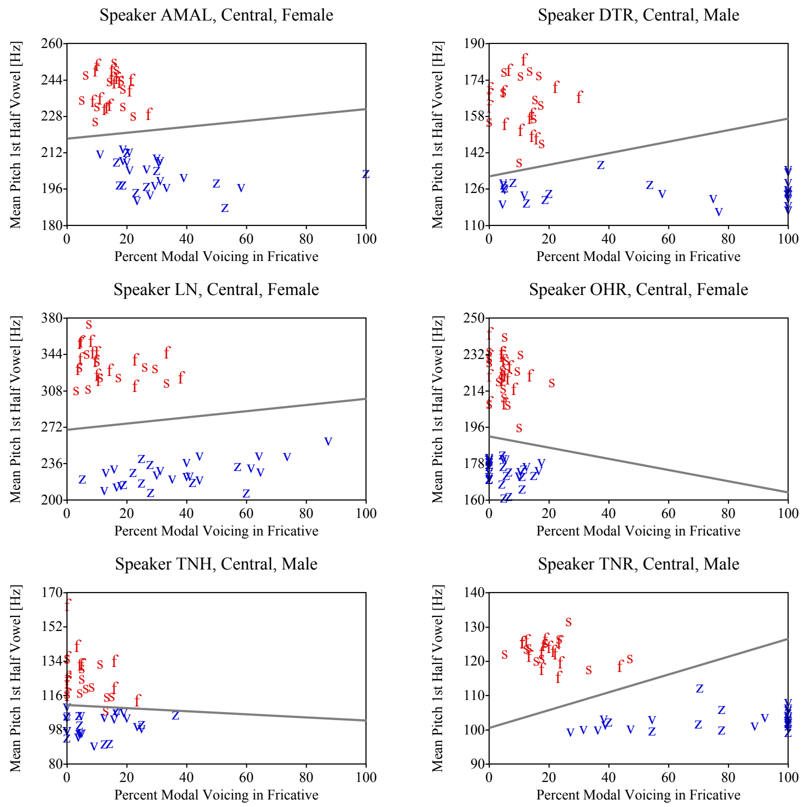

Figure 6: Percent modal voicing versus mean pitch over first half vowel for voiced (blue) and voiceless (red) fricatives by speaker for Central group. Logistic regression lines (gray) calculated in Praat.

and 6, we see that the two speakers for whom the duration distinction is not statistically significant are also among those who display the highest degree of neutralization of the modal voicing cue.

4.5 Fricative Intensity

As expected, there is a general trend of higher frication intensity on voiceless than voiced fricatives. However, whereas the intensity differences are significant for all five of the Northern speakers individually, they are not significant for the same two Central speakers (AMAL and TNH) for whom duration was not significant. This suggests that the intensity cue may also be neutralizing for the Central dialect group along with duration and modal voicing. Since the intensity difference is usually assumed to be a direct phonetic consequence of the modal voicing difference, loss of the intensity cue is expected when the modal voicing cue is neutralized. Indeed, speakers AMAL and TNH are among the Central speakers with the highest degree of modal voicing neutralization. It is interesting to note, however, that the intensity cue is still significant for speaker OHR ($p < 0.02$), despite the fact that she exhibits the most extreme neutralization of modal voicing of all speakers in the sample (cf. Figure 2). This decoupling between modal voicing and intensity indicates that speakers are sensitive to very low level phonetic cues.

5 Discussion

This study found a difference in the weighting of individual phonetic cues to fricative voicing in the Central and Northern dialect groups and considerable variability in the use of modal voicing and other secondary cues within the Central group. While both Central and Northern speakers exhibited the physiologically-expected pitch distinctions following voiced versus voiceless fricatives,

Duration Ratios	Estimate	Std. Error	***t***	***p***
Intercept	0.58	0.02	26.71	<**0.0001**
Voice category: voiced	−0.08	0.02	−3.91	<**0.001**
Dialect group: Northern	0.04	0.02	1.57	0.12
Voice category: voiced * Dialect group: Northern	−0.02	0.01	−1.90	0.06

Table 4: Results for fixed effects in a linear mixed-effects model of fricative to syllable duration ratios. Random effects are subject and lexical item. Bold indicates significant effects.

voicing categories of Northern speakers were best separated in terms of modal voicing, while those of Central speakers were best separated by following-vowel pitch. Some Central speakers' "voiced" fricatives were almost identical to their voiceless fricatives in terms of modal voicing; dominance of the pitch cue coincided with neutralization of the modal voicing cue for these speakers. In general, duration was a secondary cue for both dialect groups, but some Central speakers appeared to be neutralizing this distinction as well as the frication intensity distinction; however, one Central speaker displayed a statistically significant intensity effect despite near-complete neutralization of the modal voicing cue.

Studies of other languages with a voiced-voiceless fricative distinction have also found that intervocalic phonemically voiced fricatives may be partially devoiced. Stevens et al. (1992) found that for English speakers producing nonsense VCV words, only 78% of tokens containing /v/ or /z/ exhibited uninterrupted modal voicing throughout the fricative. In her study of American English /z/ devoicing, Smith (1997) found much lower rates of uninterrupted voicing in tokens analyzed from four speakers reading at a normal speaking rate. Only about 25% of tokens were "fully voiced" (90–100% voiced), while about 40% were "devoiced" (0–25% voiced); the remainder were "partially devoiced" (25–90% voiced).

Studies like these indicate that partial devoicing of voiced fricatives is a cross-linguistically common phenomenon and on its own is not an unusual finding. The data presented here, however, show that for some Malagasy speakers, the degree of devoicing has extended beyond what such cross-linguistic patterns would lead us to expect. Some Central speakers produced exclusively "devoiced" fricatives according to Smith's categorization, while such "devoiced" tokens were almost non-existent in the productions of Northern speakers. In addition, whereas Smith (1997) found that devoicing occurred most often in phonetic contexts that favored it (adjacent to voiceless segments, and in unstressed and final syllables and phrases), devoicing in Malagasy occurs between voiced vowels and in stressed syllables. The difference between Malagasy and English fricative devoicing is further supported by the fact that native English speakers have difficulty distinguishing voiced and voiceless fricatives in Central dialects of Malagasy. Since previous authors did not provide quantification of the devoicing phenomenon in Malagasy, it is difficult to say to what extent this marks a change from the previous state of the language; either way, however, it merits further investigation.

Labov (1994, 2001) showed that sound changes occur gradually and probabilistically at the level of individual phonetic cues, leading to extensive synchronic inter- and intra-speaker variability during periods of ongoing change. The results reported here concerning variability in the use of modal voicing, duration and intensity cues among Central speakers conform to this description and suggest that change may be ongoing within this group.

Recently, Beddor (2009) suggested a coarticulatory path to sound change in which reweighting of phonetic cues results from synchronic covariation in duration of coarticulatory source and effect. She discusses the development of phonologically contrastive nasal vowels from historical ṼN sequences with anticipatory nasalization of the vowel due to coarticulation, observing that in American English ṼN sequences, shorter duration of the nasal segment implies earlier onset of nasalization on the vowel, and vice versa. She argues that in terms of perception, the counterpart to this covariation in production is "perceived equivalence between the coarticulatory source and its effects" (2009:788). In other words, nasalization on the vowel is treated as perceptually equivalent to the presence of a nasal segment, and the synchronic variation in duration of the nasal segment in production can lead listeners to treat the nasalized vowel as the primary cue, eventually resulting in phonological change in the language.

As noted by Beddor, a similar process can be hypothesized as a pathway to tonogenesis. A language with a consonantal voice quality contrast may display both inter- and intra-speaker variation in, for example, VOT or the duration of modal voicing produced on these consonants. Beddor's model would predict that the extent or duration of modal voicing on a voiced consonant should covary with the persistence and/or magnitude of the *f0* contrast on the vowel; thus, a decrease in modal voicing on a voiced onset consonant should be accompanied by an increase in persistence and deviation from the mean of low *f0* on the vowel. As a result of this variability, coarticulatory *f0* distinctions on following vowels may attain perceptual equivalence with consonant voicing contrasts. This paves the way for *f0* to become the primary phonetic cue and the voicing distinction to neutralize, so that the language comes to contain minimal pairs that differ only in tone.

The production data presented herein demonstrate the presence of considerable synchronic variation in the use of modal voicing on /v/ and /z/ in the Central dialects. Further work is required to determine whether there is regular covariation between the modal voicing and pitch cues and whether pitch (the coarticulatory effect) has achieved equivalence with voicing (the coarticulatory source) in the perceptions of Central dialect speakers. Additional work is also required to explore the patterns of variation in production and perception of other consonant types in Malagasy dialects, including stops, affricates, sonorants, and prenasalized stops and affricates. Further analysis of these factors should help to illuminate the prevalence of pitch as a phonetic cue in the Central dialects of Malagasy and the extent of development of a phonological tone contrast. Additional investigation of the social salience of fricative production, as touched on by Rakotofiringa (cf. Section 1), may give insight into the factors driving such change.

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