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# An Acoustic Analysis of Burmese Tone

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# An Acoustic Analysis of Burmese Tone

by

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**REPORT**

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I dedicate this Master's report to my parents, for their constant support, encouragement, faith and love.

Just know, wherever you go,
you can always come home.
- Jason Mraz,
"93 Million Miles"

# Acknowledgments

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## An Acoustic Analysis of Burmese Tone

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This paper examines the acoustic characteristics that differentiate the four tones of Burmese: high, low, creaky and stopped. The majority of previous work on Burmese tone is impressionistic (Bradley, 1982; Wheatley, 1987) but recently has become experimental (Watkins, 2001, 2005; Gruber, 2011). There are conflicting analyses of how the tones are distinguished. In particular, there is disagreement about the f0 contour of the high and low tones, the consistency of creakiness in the creaky and stopped tones, the role of f0 in distinguishing the creaky and stopped tones, and the vowel quality of the stopped tone.

Recordings were made of four native speakers of Burmese, aged 24-30, who read sentences containing a carrier word with one of the four tones and one of two vowels, /a/ and /i/. Seven variables were measured: f0 contour (onset, offset, peak f0, peak delay), duration, voice quality, and vowel quality.

It was found that the high and low tones are differentiated from the creaky and stopped tones by onset f0, peak f0, relative peak delay, duration, and voice quality. The high and low tones are distinguished from one another by offset f0, peak f0, relative peak delay, and voice quality. The creaky and stopped tones appear to be differentiated from one another mainly by vowel quality.

This paper adds necessary acoustic analysis to the literature on Burmese tone, with the finding that a variety of characteristics is used to distinguish each tone. The findings of this experiment also add to the current understanding of the interactions between tone and phonation, as well as phonation and vowel quality.

# Table of Contents

# List of Tables

# List of Figures

# Chapter 1

# Introduction

This experiment was designed to examine the acoustic properties that differentiate the tones of Burmese, the most widely spoken member of the Tibeto-Burman language family, being spoken by about 32 million people in Burma (Watkins, 1997). Tibeto-Burman is one branch of the Sino-Tibetan family, which also includes Chinese. Burmese is in the Eastern branch of Tibeto-Burman. Earliest descriptions and grammar references for this language include Ko (1924); Cornyn and Roop (1944, 1968); Okell (1969); Roop (1972). The purpose of this investigation is to examine a number of properties that appear to be used to differentiate the tones (f0, voice quality, vowel quality, duration) in order to provide further, detailed quantitative analysis of the characteristics of each tone.

Previous research (Bradley, 1982; Green, 2005; Wheatley, 1987; Watkins, 2001) agrees that there are four tone categories: high, low, creaky, and stopped (also referred to as the 'checked' or 'killed' tone, it refers to the tone that ends in a glottal stop), as well as a toneless category. A minimal set example is: High[1]: "lá" *mule*, Low: "là" *come*, Creaky: "la̰" *moon*, Stopped: "laˀ" *bribe*. The majority of previous work on Burmese tone is impressionistic (Bradley, 1982; Wheatley, 1987) but recently has become experimental (Watkins, 2001, 2005; Gruber, 2011). Watkins (2001) is a qualitative analysis involving one speaker, while Watkins (2005) and Gruber (2011) are both quantitative and involve recordings of multiple speakers. A preliminary instrumental analysis by the author (Kelly, 2011) examined peak f0 and spectral tilt of one speaker's recordings of words containing each of the tones with the vowel /a/. As this involved only one speaker, few tokens, and two measurements, a broader investigation is needed. The current study adds detailed quantitative analysis

[1]High tone: á/í, Low tone: à/ì, Creaky tone: a̰/ḭ, Stopped tone: aˀ/iˀ

of multiple measures to the current descriptions. Connell (2000) notes that some tone languages have a correlation among pitch, duration, and intensity, suggesting that f0 alone is not necessarily the only distinguishing factor for tones. The tones of Burmese will be described in turn, based on descriptions in the literature.

The toneless syllable only occurs with the vowel /ə/, it is an open syllable with a simple onset, and it cannot be word-final (Wheatley, 1987). It is unstressed and tonally non-contrastive (Watkins, 2001).

The high tone is described as having a higher peak fundamental frequency (f0) than the low tone (Bradley, 1982; Wheatley, 1987; Jenks, 2007). Watkins (2005) shows the high tone having its f0 peak at the end of the vowel, and the low tone with its peak f0 at the onset of the vowel. Some analyses describe the high tone as having a falling contour, (Bradley, 1982; Jenks, 2007) but Kelly (2011) found the high tone to have a rising contour, with its f0 peak at the vowel offset. Since Kelly (2011) is an instrumental rather than an impressionistic analysis, the evidence for the high tone having a rising contour appears to be better supported. Figure 1.1 is a pitch track from one speaker from the current experiment, showing the vowel (shaded section) of the high tone to have a rising contour, the typical contour for this tone.

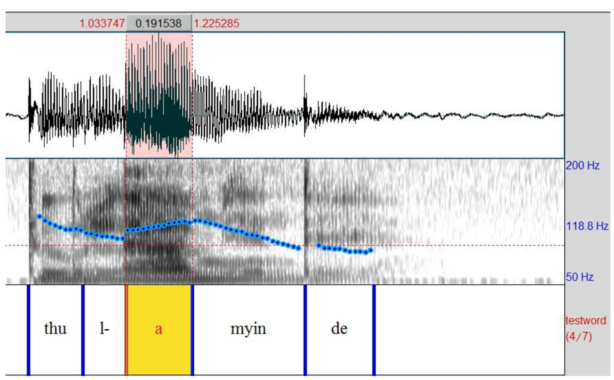


Figure 1.1: High, “lá” *mule*

The low and high tones start off at a similar f0, from which the high rises and the low falls, so they differ in the shape of their contours. There is disagreement on whether the low tone is falling (Jenks, 2007) or rising (Wheatley, 1987). Figure 1.2 is a typical pitch track from the current experiment, where the shaded vowel of the low tone is shown to have a falling f0. Again, since this is an instrumental analysis, the description of the low tone as falling is better supported than the claim that it has a rising contour.

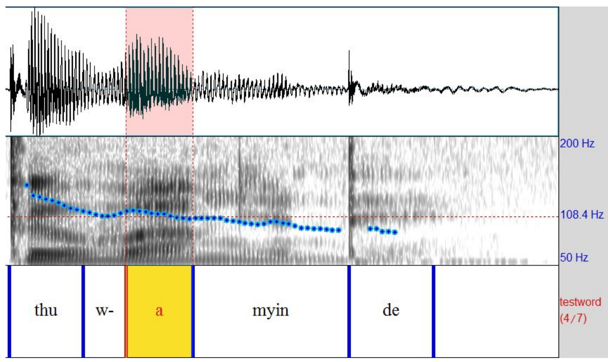


Figure 1.2: Low, “wà” *cotton*

Some analyses also claim that the high and low tones are longer than the creaky and stopped tones (Hutchinson and McClenon, 1977; Tun, 1982). The current experiment will examine this.

The creaky tone differs from the the high and low tones by having a higher f0 at its onset (Bradley, 1982; Watkins, 2005). Watkins (2005) shows it starting off relatively level and its f0 falling from about the midpoint. The creaky tone also differs from the high and low tones in its phonation. Figure 1.3 shows Watkins' (2005) measure of the closed quotient in phonation (measured by EGG), showing that both the creaky and stopped tones have a higher closed quotient percentage, associated with creaky voice.

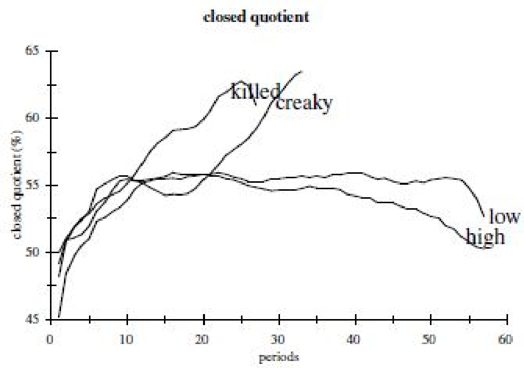


Figure 1.3: Watkins (2005)

Watkins (2005) also shows that the stopped tone has a similar f0 contour to the creaky tone, and Figure 1.3 shows it to have creaky phonation. Kelly (2011) found no significant difference in peak f0 or voice quality that could reliably differentiate the low, creaky and stopped tones from one another. Also, Bradley (1982) notes that the creaky tone has creaky phonation, but describes the stopped tone as having modal phonation. Gruber (2011) recorded ten speakers of Burmese and measured vocal fold vibration using EGG, and found that the creaky phonation was often lost in connected speech, so this cannot be the only distinguishing characteristic of the creaky and stopped tones. Although these studies disagree on the voice quality of the creaky and stopped tones, the differences may be explained by differences in methodology, such as whether the tokens were isolated words or in connected speech. The interaction of tone with phonation has been found in a number of language families (Otomanguean (Silverman, 1997; DiCanio, 2012), Chinese (Pan, 2005), Hmong Mien (Andruski, 2006)). Creaky phonation has been described as inducing a high pitch (Frazier, 2010) or a low pitch (DiCanio, 2012) in the preceding vowel. Garellek and Keating (2011) note that in Jalapa Mazatec, a language that combines pitch and phonation contrasts, the pitch contrasts are partially lost in the sections of the vowel where the phonation contrasts are strongest. The creaky and stopped tones of Burmese appear to have a high onset, so one important question is whether f0 contour is also a distinguishing factor for these tones.

A factor that may differentiate the creaky and stopped tones from one another is vowel quality. Bradley (1982) mentions that the stopped tone has a different vowel quality from the other three tones, but an instrumental analysis by Hutchinson and McClenon (1977) does not show different F1 and F2 values for this tone. Figures 1.4 and 1.5 show example vowels from Speaker 4 from the current experiment, showing the pitch tracks for the creaky and stopped tones (again, the shaded sections are the vowels containing the tones) with the vowel /a/.

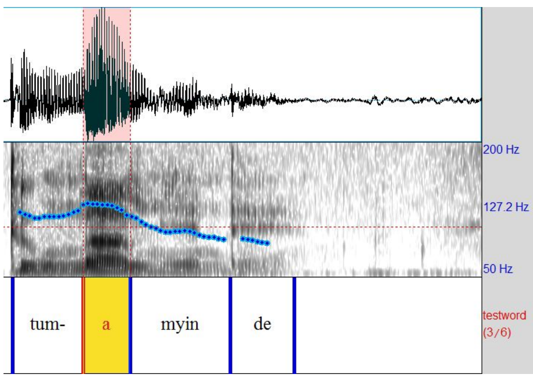

Figure 1.4: Creaky, “a-ma̰” *older sister*

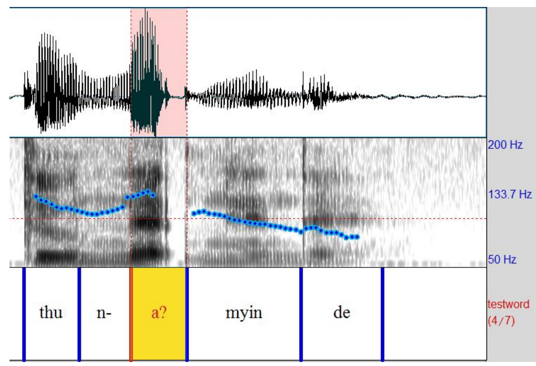

Figure 1.5: Stopped, na$^{ʔ}$ *spirit*

Examining the above data impressionistically, it can be seen that the vowel of the stopped tone has different formants from the other three vowels, insofar as F1 and F2 are further apart from each other in the stopped tone. Vowel quality will thus be examined in the current experiment. Previous research into a variety of languages has also shown a relation between voice quality and vowel quality. Gordon and Ladefoged (2001) explain that creakiness is often associated with a raising of F1 due to raising of the larynx which causes the vocal tract to shorten. This would cause the vowel to be lowered. Based on impressionistic analyses from Kelly (2011), it seems that where the other three tones have the vowel /a/, the stopped tone has a lax, higher vowel, similar to /ɛ/. This would mean that for the stopped tone with /a/, F1 is lower and F2 is higher than for the other tones. Kelly (2011) did not examine any other vowel, so the current experiment examines /i/ to see if the vowel quality difference is generalizable across vowels.

The (blue) pitch tracks in Figures 1.1, 1.2, 1.4 and 1.5 show how the f0 contour is different for each tone: rising for the high tone, falling for the low tone, level and then falling for the creaky and stopped tones. Figure 1.4 shows no creaky phonation; this speaker (Speaker 4) generally did not produce any creak. The glottal stop can be seen in the stopped tone (Figure 1.5). In contrast, the shaded portions of figures 1.6 and 1.7 show that Speaker 1 produced creakiness for both the creaky and stopped tones, although even for this speaker, creakiness was often lost in connected speech.

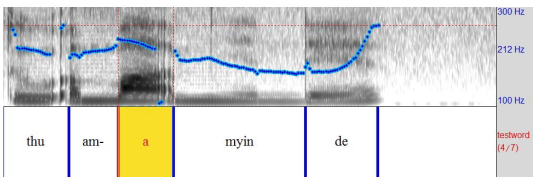


Figure 1.6: Creaky, "a-ma̰" *older sister*

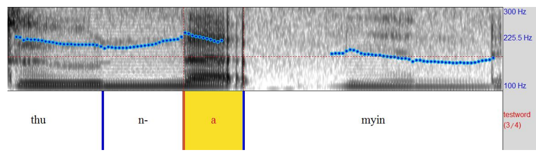


Figure 1.7: Stopped, na$^{ʔ}$ *spirit*

Combining the findings of previous research and the preliminary study, the questions that remain unanswered are those that involve the role of duration, the exact vowel quality difference of the stopped tone, the contour of the high and low tones, whether peak f0 is a distinguishing factor for the low, creaky and stopped tones, and whether f0 contour and creaky phonation are both important distinguishing factors for the creaky and stopped tones.

The literature on Burmese tone is fraught with disagreement, and as such it will benefit from further quantitative analysis. It is likely that more than one property distinguishes these tones from one another in terms of perception, and perhaps particular properties are more important for each of the tones. Perception studies have found that the most important cues for distinguishing tonal categories vary among languages: Massaro et al. (1985) found that pitch height and pitch contour were equally important in distinguishing Mandarin tones, while Svantesson and House (2006) found that in Northern Kammu (Mon-Khmer), small differences in absolute pitch height affected listeners perception of tone categories. The purpose of this study is to examine each of the acoustic factors that can affect the tones of Burmese and to determine if they are all reliably produced in each tone. The properties examined are: f0 contour (onset, offset, peak f0, peak delay), duration, voice quality, and vowel quality. The previous experimental analyses have generally used isolation forms and have not examined all the characteristics examined in the current experiment. This investigation is a quantitative analysis involving four speakers, both female and male, and examines multiple measures of the tones in a carrier sentence, rather than in isolation. The use of a carrier sentence is necessary due to the confounding effects of examining a word in isolation, which means it would be phrase-initial, phrase-final, and focused (Bruce, 1977; Beckman and Pierrehumbert, 1986). This experiment is based on quantitative data which will provide information on how the tones are realized and how they should be characterized in the literature. In this way, it is hoped that a more concise analysis of the tone differences will be reached. Examining the various characteristics of the tones of Burmese will also add to the literature on tone systems and on the interaction of tone with phonation and vowel quality.

# Chapter 2

# Method

This experiment examines f0, f0 timing, duration, phonation, and vowel quality for each of the four tones. The measures for these are the following: peak f0 (Hz), f0 at vowel onset and offset (Hz), peak delay (ms), duration (ms), spectral tilt (H1-A3), F1 (Hz) and F2 (Hz). These were measured for each tone at two speaking rates and with two different vowels, /a/ and /i/.

The expected outcomes for all measures are based on previous findings and on the preliminary investigation (Kelly, 2011).

## 2.1 Participants

There were four speakers:

| **Speaker** | **Age** | **Sex** | **From** | **Time in US** | **Native Languages** |
|---|---|---|---|---|---|
| **1** | 26 | F | Yangon | 5yrs | Burmese, Karen |
| **2** | 27 | F | Shan State | 4yrs | Burmese |
| **3** | 30 | F | Kayah State | 2yrs | Burmese, Karen |
| **4** | 29 | M | Yangon | 3yrs | Burmese |

Table 2.1: Speaker Data

The Burmese language is described as being "remarkably uniform over its large language area" (Barron et al., 2007, p.17). As such, it is expected that the results will be generalizable across these speakers. The bilingual speakers are native speakers of Burmese and a Karen language, which is also tonal.

## 2.2 Materials

The test words included one of the four tones, on the vowel /a/ or /i/. Examples are the following: High: "wá" *bamboo*, "ní" *way*; Low: "wà" *cotton*, "njì" *younger brother*; Creaky: "la̰" *moon*, "mḭ" *mother*; Stopped: "na$^{ʔ}$" *spirit*, "mji$^{ʔ}$" *river*. As such, the factors that were varied were tone class, vowel quality and speaking rate. Vowel quality was varied in order to control for intrinsic duration (Whalen and Levitt, 1995) and to examine how the vowel quality differs for the stopped tone. The tones were examined at a normal and a fast speaking rate in order to obtain a broader examination of the f0 contour. Speaking rate can also be useful in determining which phonetic properties are important in maintaining contrasts. At a fast speaking rate, speakers will still maintain the important phonetic cues used to distinguish phonemes.

The background factors that were controlled were neighboring consonants, neighboring tones, and phrase position. These will be explained in turn.

Neighboring consonants were controlled by using target words containing only voiced sonorant consonants. Obstruent consonants have no f0 due to their aperiodicity, so this would interrupt the pitch track. Using only voiced sonorants ensures that the effect of the neighboring consonant's phonation class is controlled. Test words were nouns obtained from Cornyn and Roop (1944, 1968) and Okell (1969). The test syllable was of the structure CV or CVC, where the C was always a voiced sonorant.

Neighboring tones were controlled by using neighboring syllables with either a low tone or no tone. Neighboring tones can affect f0 timing due to coarticulatory effects (Potisuk et al., 1997; Xu, 1994). It was expected that a neighboring toneless or low toned syllable would have similar effects because the low tone appears to be the most neutral in Burmese. Evidence of this comes from Watkins (2005), which examined f0 movement in two-tone sequences and found that when a low toned syllable was first, there was no significant change on f0 of the following syllable in comparison to this syllable in isolation. (This was not the case with the other three tones.) The toneless syllable is described as having no f0 target, so should likewise exert no effects on the tone of the target syllable. These two contexts (low and toneless) were randomly interspersed.

Phrase position was controlled for by using the same carrier phrase for each target word. This had to be controlled in order to eliminate the effects of boundary tones and final lowering (Liberman and Pierrehumbert, 1984; Beckman and Pierrehumbert, 1986). Having the test word in second position controlled for effects on f0 timing of phrase position (Myers, 2003) and word boundaries (Prieto et al., 1995). The carrier sentence (see Table 2.2 below) translates as "He sees (test word)." The appendix contains the entire list of test words.

Sample sentences are below, in IPA (with the test syllable in bold):

| Tone | Vowel | Burmese | English |
|---|---|---|---|
| **High** | **/a/** | tʰù **wá** mjɪ̀n dè | 'He sees bamboo.' |
| **Low** | **/a/** | tʰù **wà** mjɪ̀n dè | 'He sees cotton.' |
| **Creaky** | **/a/** | tʰù **la̰** mjɪ̀n dè | 'He sees the moon.' |
| **Stopped** | **/a/** | tʰù **naʔ** mjɪ̀n dè | 'He sees a spirit.' |
| **High** | **/i/** | tʰù **ní** mjɪ̀n dè | 'He sees a way.' |
| **Low** | **/i/** | tʰù **njì** mjɪ̀n dè | 'He sees his younger brother.' |
| **Creaky** | **/i/** | tʰù a **mḭ** mjɪ̀n dè | 'He sees a mother.' |
| **Stopped** | **/i/** | tʰù **mjiʔ** mjɪ̀n dè | 'He sees a river.' |

Table 2.2: Example sentences

## 2.3 Procedure

Speakers were recorded in a sound-treated room on a MOTU recorder through a Shure SM10A head-mounted microphone at 44.1kHz. The recorder was connected to a computer and recorded through the program Audacity. Sentences were presented in a randomized order in the Burmese orthography. The sentences and their order were the same for the normal and fast speaking rates. Speakers were asked to read the sentences from a list presented in hard copy form "at a natural speed" and when they had completed all sentences, they were asked to read them again "as fast as you can". There were 16 tokens of each of the four tones for the two vowels, which over 4 speakers equaled 128 tokens for each of the two speaking rates (4 tones x 2 vowels x 2 speech rates = 16 conditions x 16 tokens = 256 tokens per speaker). Recordings were analyzed using Praat (Boersma and Weenink, 2011). Any effect of list intonation should not affect the lexical tones of the target words since these were in sentence-medial position.

## 2.4 Measurements

For all of the measurements, the vowel was measured and not the syllable because in Kelly (2011) it was found that the high tone had its f0 peak at the end of the vowel and that the creaky and stopped tones also have a high f0 right at the onset of the vowel. Vowel onset, which always followed a voiced sonorant, was measured as the point at which the spectrogram began to darken and there was an increase in amplitude of the waveform. Vowel offset was sharply defined as the beginning of the following nasal murmur. Even in CVC words, the coda consonant was always a nasal.

### 2.4.1 F0 Contour

*Peak f0* is a measure of the maximum f0 of the vowel. The peak f0 of the high tone should be significantly higher than that of the other three tones, replicating previous findings.

*Onset and Offset*: F0 in Hertz at vowel onset and offset was measured to see if Watkins' (2005) findings can be replicated; that is, that the creaky and stopped tones start off at a higher onset than the low and high tones. There should be a significant difference in onset f0 between the high and low tones on one hand, and the creaky and stopped tones on the other. Since the high tone seems to rise and the low tone appears to fall from the onset, it appears that there should be a significant difference in f0 at offset of these tones.

*Peak delay* was measured as the interval from vowel onset to f0 peak (Xu, 1998). The measure used in this experiment is relative peak delay; that is, a measurement of peak delay divided by the duration of the segment. Based on Kelly (2011), the high tone should have its f0 peak at the vowel offset, so should have a longer relative peak delay than the other tones. The low tone is thought to have its f0 peak at the vowel onset and a falling contour, so should have a very short relative peak delay. However, some analyses describe the low tone as rising (Wheatley, 1987), so this will be examined. The creaky and stopped tones are predicted to have a relative peak delay in between those of the high and low tones because in Kelly (2011) and Watkins (2005) the creaky and stopped tones appear to have their f0 peak between the onset and midpoint of the vowel.

### 2.4.2 Duration

*Duration* was measured as the length of the vowel. This was measured to test previous claims that the high and low tones are longer than the creaky and stopped tones (Hutchinson and McClenon, 1977; Tun, 1982; Watkins, 2005). (It should be noted here that the vowel duration includes the creaky-voiced portion in the creaky and stopped tones.)

### 2.4.3 Voice Quality

*Voice quality* was measured towards the vowel offset for each tone, because the most striking phonation differences were found at the end of the vowel. Phonation type was measured five-sixths into the vowel by a Praat script. It was not measured at the offset in order to avoid the measurement being affected by the following nasal. The measurement of spectral tilt was H1-A3[1], the amplitude of the first harmonic minus the amplitude of the third formant peak, which is correlated with source spectral tilt (Hanson, 1997; Esposito, 2012). This was to test whether the creaky and stopped tones consistently contain creaky phonation. It was also hypothesized that the high tone would have breathy phonation, and the low tone, modal phonation, based on the findings of Kelly (2011). This would result in a higher value for H1-A3

[1]Thanks to James Gruber (p.c., April 2012) for suggesting H1-A3 as a more accurate measure than H1-H2 for voice quality in Burmese. This measure appears to be more accurate because, as Gruber suggested, the higher frequency energy of the third formant seems to be less affected than lower frequencies by the varying amplitude and f0 of the tones.

for the high tone than the low tone. In the current experiment, the creaky and stopped tones should have lower values for H1-A3 than the high and low tones. Esposito (2010) notes that while some studies do not report negative H1-A3 values for creaky phonation, her measure of phonation in White Hmong resulted in negative values for the creaky tone. In the current experiment, the stopped tone is expected to have a low H1-A3 because it ends in a glottal stop so voicing breaks down at the offset. This hypothesis is also supported by Watkins' (2005) examination of Burmese tones in isolation. The creaky and stopped tones were shown to have a much higher closed quotient than the high and low tones, indicative of creaky phonation.

#### 2.4.4 Vowel Quality

*Vowel quality* was measured as F1 and F2 (in Hertz) at the midpoint of the vowel. These are measures of height (F1) and frontness (F2) of the vowel. The midpoint was chosen because the formants were noted to be most static at this point. This was measured to test the hypothesis that the stopped tone has a different vowel quality from the vowels of the other three tones, as was noted in Bradley (1982) and Kelly (2011). This hypothesis will be tested on two vowels, /a/ and /i/, to determine whether the stopped tone induces a laxing of both vowels. Half of the target words contained the vowel /a/ and half /i/.

In sum, the results that are predicted to be replicated are those relating to peak f0, onset, voice quality, and duration. The results being tested are how the tone classes differ in peak delay, offset, and vowel quality.

# Chapter 3

# Results

The following sections provide graphs of group means for each tone for each of the seven measures (onset, offset, peak f0, peak delay, duration, voice quality, vowel quality), and the results of statistical tests, which consisted of a mixed model multiple linear regression analysis. This was conducted using the lme4 package in R (R Development Core Team, 2008). The independent variables were tone, vowel and speaking rate, which were all binary. For example, "High" classifies the tones into high versus the other three tones, so the four-way tone contrast is encoded as three binary contrasts. The dependent variables were the seven measures described above. Speaker was included as a random factor. The reference level for tones was the creaky tone and for vowels was /a/. The direction of the difference is shown by the sign of the coefficient. The effect of speaking rate is examined only for the temporal measures - peak delay and duration. In total, 15 soundfiles were disregarded due to noise (caused by movement of or hitting the microphone during the target word) or the speaker saying a different word or pausing during the target word. These tokens were distributed among the speakers and tones. For the graphs where the two speech rates are not presented separately, the graph represents both speech rates condensed.

## 3.1 F0 Contour

### 3.1.1 Onset F0

The following data show the group means (Figure 3.1) and regression results (Table 3.1) for mean f0 at onset. The graph is organized by speaker (1-4), and each bar is the group mean for each of the tones. The hypothesis was that the creaky and stopped tones would have a higher onset than the high and low tones. The graph shows that there is a trend across speakers for the creaky and stopped tones to have a higher onset.

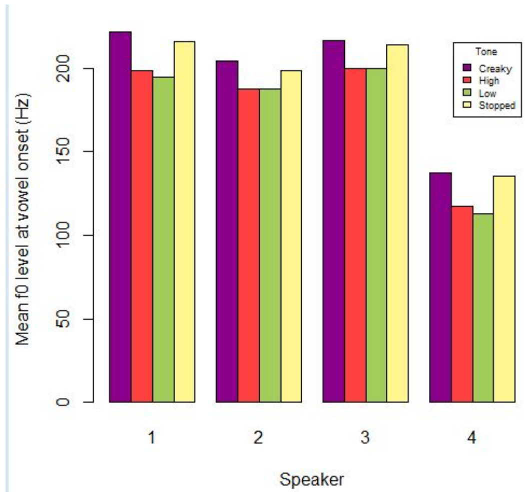


Figure 3.1: Mean F0 Onset

As mentioned above, the mixed model multiple linear regression analysis encodes the factors as binary contrasts. This means that in Table 3.1 below, "High" divides the tones into the high tone versus all the other tones, and "Low" divides the tones into the low tone versus all the other tones, and so on. The sign of the coefficient shows the direction of the difference, so the negative sign for the "High" coefficient means that the high tone has a lower average onset f0 than the average onset for all of the other tones. These results show a main effect of tone and vowel, and an interaction of tone with vowel:

| | Coef. | t-value | p-value |
|---|---|---|---|
| **High** | -11.3 | -4.6 | <0.001 * |
| **Low** | -11.4 | -4.7 | <0.001 * |
| **Stopped** | 3.1 | 1.2 | 0.226 |
| **/i/** | 18.2 | 7.4 | <0.001 * |
| **High:/i/** | -15.7 | -4.6 | <0.001 * |
| **Low:/i/** | -19.8 | -5.7 | <0.001 * |
| **Stopped:/i/** | -15 | -4.2 | <0.001 * |

Table 3.1: Results for F0 Onset

Table 3.1 shows that the high tone had a significantly lower onset f0 than the average of the other tones, as did the low tone. But since there is an interaction of tone with vowel, it is necessary to determine whether the tone effect held across vowels. In order to do this, the subset of /a/ vowels was examined and then the subset of /i/ vowels. The same regression test as before was run on each vowel subset to examine whether tone had the same significant effect for both vowels. It was found that the effect of tone held across both vowels; that is, for both /a/ and /i/, both the high and low tones had a significantly lower average onset f0 than the other tones.

In order to determine which tones were significantly different from one another, post-hoc linear regression tests were run on groups of the tones. Since the hypothesis was that the creaky and stopped tones would have a higher onset than the high and low tones, the combined group of creaky and stopped tones was compared to the combined group of high and low tones. It was found that the creaky and stopped tones had a significantly higher onset f0 than the high and low tones (at a significance level of .05), supporting the hypothesis.

### 3.1.2 Offset F0

For offset, the hypothesis was that the high tone would have a higher offset than the low tone. The graph (Figure 3.2) shows that the four speakers have a higher offset for the high tone than the low tone:

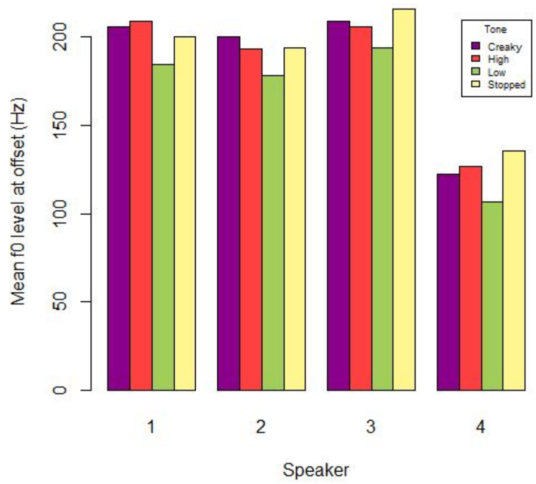


Figure 3.2: Mean F0 Offset

The linear regression results show that there is a main effect of tone and vowel, and a significant interaction of tone with vowel:

| | **Coef.** | **t-value** | **p-value** |
|---|---|---|---|
| **High** | 5.5 | 1.6 | 0.114 |
| **Low** | -10.4 | -3 | <0.05 * |
| **Stopped** | 4 | 1.1 | 0.285 |
| **/i/** | 16.1 | 4.6 | <0.001 * |
| **High:/i/** | -12.8 | -2.6 | <0.01 * |
| **Low:/i/** | -16.6 | -3.4 | <0.01 * |
| **Stopped:/i/** | -5.1 | -1 | 0.32 |

Table 3.2: Results for F0 Offset

The results presented in Table 3.2 show that the low tone has a significantly lower average offset f0 than the average of all the other tones, but there is an interaction of low tone and vowel. Again, tests were run on subsets of the data containing first just the /a/ vowel and then just the /i/ vowel. These results found that the effect of tone held across vowels; that is, the low tone had a significantly lower average offset f0 than the average of all the other tones for both vowels.

A post-hoc comparison between the high tone and the low tone show that the high tone had a significantly higher offset f0 than the low tone (at a significance level of .05), supporting the hypothesis.

### 3.1.3 Peak F0

Figure 3.3 shows the group means and Table 3.3 shows the regression results for peak f0. It was predicted that the high tone would have a higher peak f0 than the other tones. However, the graph shows that in fact the creaky and stopped tones have the highest peak f0 (except for the stopped tone of Speaker 1), and the low tone has the lowest peak f0 for all speakers.

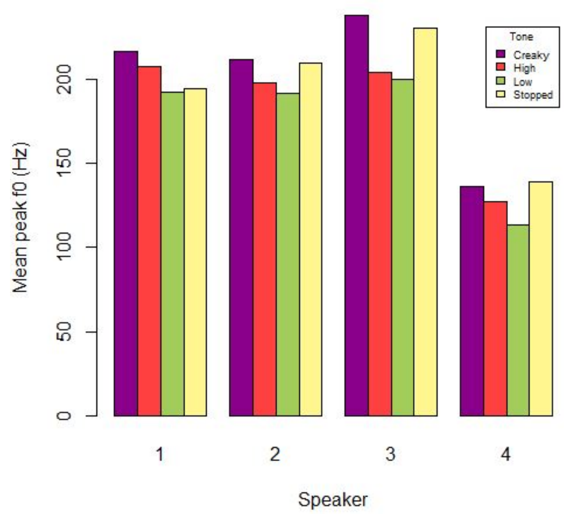


Figure 3.3: Peak F0

The regression results show that the effect of tone and vowel was significant, and that there was an interaction of tone with vowel:

| | **Coef.** | **t-value** | **p-value** |
|---|---|---|---|
| **High** | -6.1 | -1.9 | 0.051 |
| **Low** | -15.1 | -4.8 | $<$0.001 * |
| **Stopped** | -1.3 | -0.4 | 0.68 |
| **/i/** | 24.6 | 7.9 | $<$0.001 * |
| **High:/i/** | -20.1 | -4.6 | $<$0.001 * |
| **Low:/i/** | -23 | -5.2 | $<$0.001 * |
| **Stopped:/i/** | -12.7 | -2.7 | $<$0.01 * |

Table 3.3: Results for Peak F0

The results in Table 3.3 show that the low tone has a significantly lower average peak f0 than the average for all the other tones, but there is an interaction of tone with vowel. Further linear regression tests on subsets of the data by vowel found that the effect of tone held across vowels. This means that the low tone had a significantly lower average peak f0 than the other tones, for both vowels.

In order to determine whether there was a significant difference between the creaky and stopped versus the high and low, and also between the high and low tones, two post-hoc linear regression tests were run. Because two tests were run, it was necessary to compensate for running multiple comparisons. This was done using Bonferroni's adjustment, where in this case, the normal significance level of .05 was divided by 2 so the significance level of each test was set at .025. These results showed that the creaky and stopped tones combined had a higher average peak f0 than the high and low tones combined. It was also found that the high tone had a significantly higher peak f0 than the low tone. This shows that peak f0 is a distinguishing factor for both the high tone and the low tone. The direction of results was not expected - that is, that high tone in fact had a lower f0 peak than the creaky and stopped tones, but the results show that peak f0 is in fact a distinguishing factor for both the high and low tones. Peak f0 being a distinguishing factor for the low tone was not predicted.

### 3.1.4 F0 Timing (Relative Peak Delay)

The following data show the group means (Figures 3.4 - 3.5) and regression results (Table 3.4) for relative peak delay. The hypothesis was that the high tone would have the longest peak delay and the low tone would have the shortest peak delay. The graphs show that this seems to be the case, except for Speaker 4's creaky tone, which is slightly shorter than his low tone.

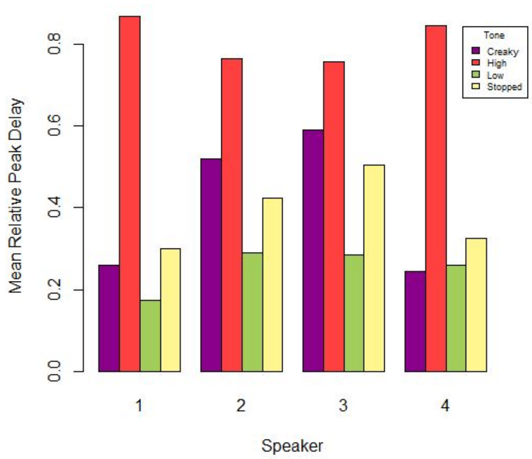


Figure 3.4: Relative Pk Delay, Norm

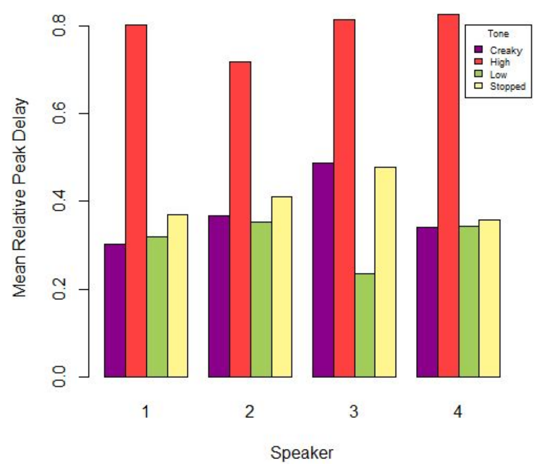


Figure 3.5: Relative Pk Delay, Fast

Figures 3.6 and 3.7 plot duration against peak delay for the two speaking rates. The letters[1] represent the tones and the colors are the different speakers.

[1]Tones: C=Creaky; H=High; L=Low; S=Stopped

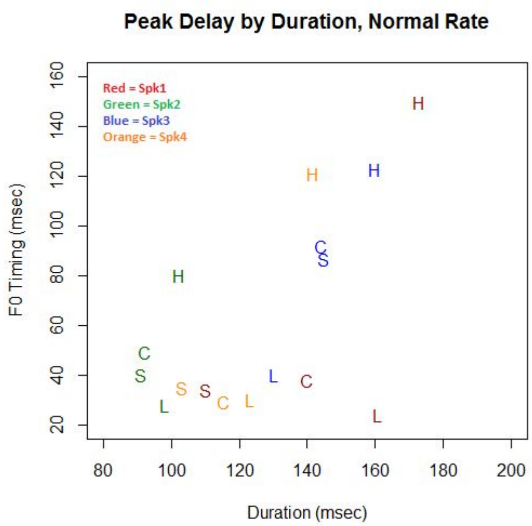


Figure 3.6: Pk Delay by Duration, Norm

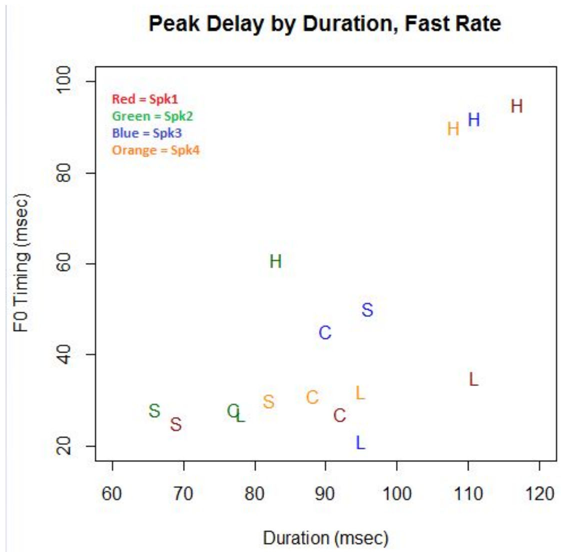


Figure 3.7: Pk Delay by Duration, Fast

The regression results reveal that there was a main effect of tone but not vowel or rate, and that the interaction between tone and vowel was significant only for the low tone:

| | Coef. | t-value | p-value |
|---|---|---|---|
| **High** | 0.4 | 11.3 | <0.001 * |
| **Low** | -0.1 | -3.9 | <0.001 * |
| **Stopped** | -0.01 | -0.36 | 0.722 |
| **Norm rate** | 0.007 | 0.2 | 0.836 |
| **/i/** | -0.06 | -1.6 | 0.115 |
| **High:/i/** | 0.01 | 0.32 | 0.745 |
| **Low:/i/** | 0.16 | 3.1 | <0.01 * |
| **Stopped:/i/** | 0.08 | 1.6 | 0.1 |

Table 3.4: Results for Rel. Peak Delay

Table 3.4 shows that the high tone had a significantly longer average relative peak delay than the average for the other tones, and that the low tone had a significantly shorter relative peak delay than the other tones. Since there was an interaction of vowel with the low tone, further tests were run and found that the effect of tone held across vowels. Rate did not have a significant effect, as would be expected when relative peak delay is examined.

To determine which tones were significantly different from which, post-hoc linear regressions were run. These compared the high tone to the low tone, the high tone to the creaky and stopped tones combined, and the low tone to the creaky and stopped tones combined. Since this involved three tests, Bonferroni's adjustment set the significance level at .05/3=.017. These tests showed that the high tone had a significantly longer peak delay than the low tone and than the creaky and stopped tones, and that the low tone had a significantly shorter peak delay than the creaky and stopped tones.

As such, these results support the hypothesis in that the high tone has a longer peak delay than the other tones, and the low tone has a shorter peak delay than the other tones.

## 3.2 Duration

Figures 3.8 & 3.9 show the group means and Table 3.5 shows the linear regression results for vowel duration. The hypothesis was that the vowels of the high and low tones would be longer than the vowels of the creaky and stopped tones. The graphs show that at both rates, this was the case for three speakers. Speaker 3 shows a longer stopped and creaky tone (than low tone) at the normal rate and a slightly longer stopped tone at the fast rate.

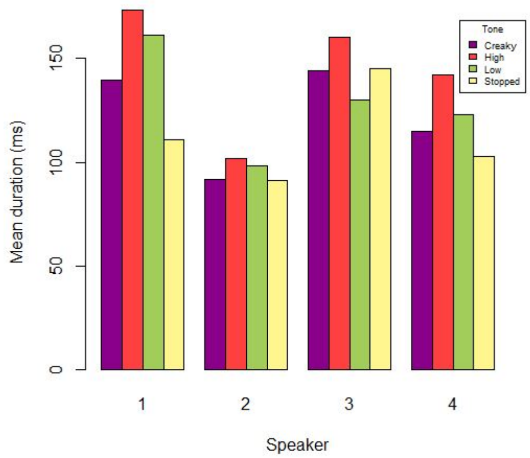


Figure 3.8: Mean Duration, Norm

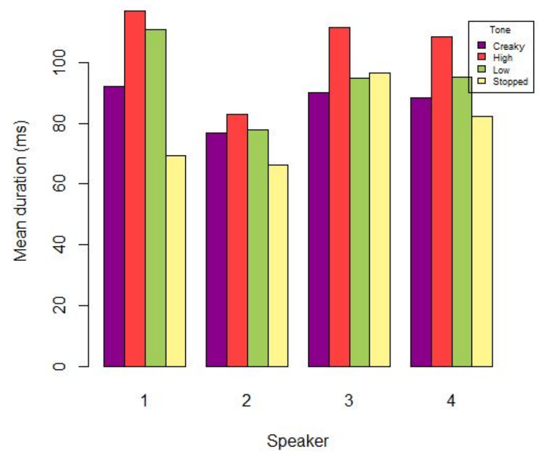


Figure 3.9: Mean Duration, Fast

The regression results reveal that the the overall effects of tone, rate and vowel were significant, and there was no interaction of tone with vowel:

| | **Coef.** | **t-value** | **p-value** |
|---|---|---|---|
| **High** | 21.2 | 4.4 | <0.001 * |
| **Low** | 4.9 | 1.1 | 0.29 |
| **Stopped** | -12.7 | -2.6 | <0.01 * |
| **Norm rate** | 35.4 | 7.5 | <0.001 * |
| **/i/** | -17 | -3.6 | <0.001 * |
| **High:/i/** | -6.2 | -0.9 | 0.35 |
| **Low:/i/** | 5.4 | 0.8 | 0.41 |
| **Stopped:/i/** | 9.2 | 1.4 | 0.17 |

Table 3.5: Results for Duration

Table 3.5 shows that the high tone has a significantly longer average duration than the average for all the other tones, and the stopped tone has a significantly shorter average duration than all the other tones. There is no interaction of vowel with these tones. Since the hypothesis was that the high and low tones would be longer than the creaky and stopped tones, these two groups were compared in a post-hoc linear regression analysis. This test found that the high and low tones were indeed longer than the creaky and stopped tones, as predicted.

## 3.3 Voice Quality

Figure 3.10 shows the group means and Table 3.6 shows the linear regression results for voice quality. It was predicted that the high tone would have a higher value for spectral tilt than the low tone, and that both the high and low tones would have a higher value than the creaky and stopped tones. The graphs show that for three speakers, the high and low tones have a higher spectral tilt value than the creaky and stopped tones, and for three speakers the high tone also has a higher value than the low tone, but for Speaker 2 the low tone has the lowest value of all the tones.

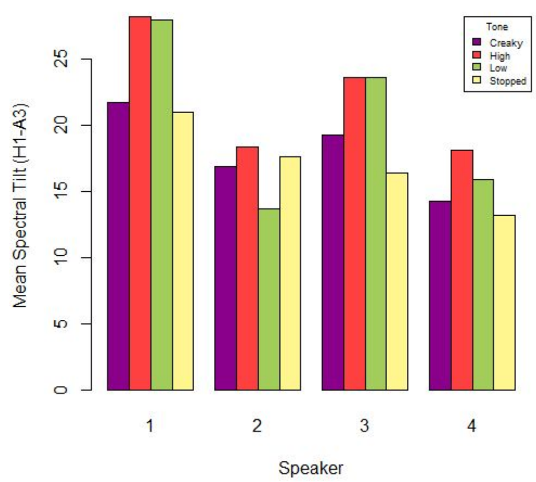


Figure 3.10: Mean Spectral Tilt

The regression results show a significant effect of tone and vowel, and no interaction of tone with vowel:

| | Coef. | t-value | p-value |
|---|---|---|---|
| **High** | 5.5 | 4.4 | <0.001* |
| **Low** | 3.6 | 2.8 | <0.01 * |
| **Stopped** | 0.2 | 0.1 | 0.89 |
| **/i/** | 3.6 | 2.8 | <0.01 * |
| **High:/i/** | -3.2 | -1.7 | 0.083 |
| **Low:/i/** | -2.7 | -1.5 | 0.147 |
| **Stopped:/i/** | -2.6 | -1.4 | 0.151 |

Table 3.6: Results for Spectral Tilt

Table 3.6 shows that the both the high and low tones have a significantly higher average value for this measure than the other tones.

To examine which tones were significantly different, post-hoc comparisons were run comparing the high tone to the low tone, and also comparing the high and low tones combined to the creaky and stopped tones combined. Since this involved two tests, Bonferroni's adjustment set the significance level at .05/2=.025. The results of these tests showed that the high tone had a significantly higher value for spectral tilt than the low tone, and that the high and low tones combined had a significantly higher spectral tilt than the creaky and stopped tones combined, supporting the hypothesis.

## 3.4 Vowel Quality

This section examines the formant values for F1 and F2 at the midpoint of the vowels /a/ and /i/ for each speaker. The following charts show the positions in the vowel space of each tone for the four speakers, for both vowels (Figures 3.11 - 3.12). Tables 3.7-3.8 show the linear regression results for F1 and F2. The hypothesis was that the stopped tone would have a different vowel quality from the other three tones, for both vowels. Examining the graphs, it is clear that for all speakers, for the vowel /a/ (Figure 3.11), the stopped tone occupies a different region of the vowel space from the other three tones. For the vowel /i/ (Figure 3.12), the results are not as clear cut, but it can be seen that both the creaky and stopped tones cluster at a different point in the vowel space from the high and low tones.

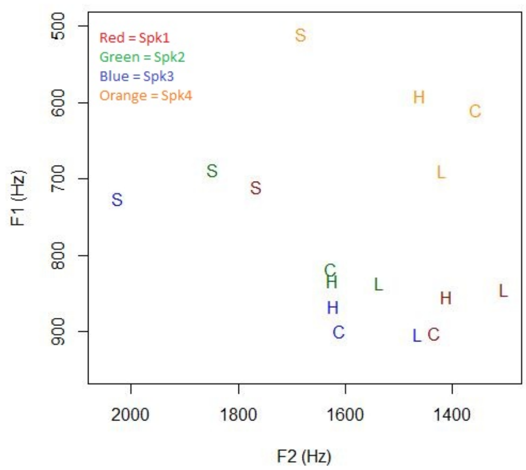


Figure 3.11: Mean F2*F1 /a/

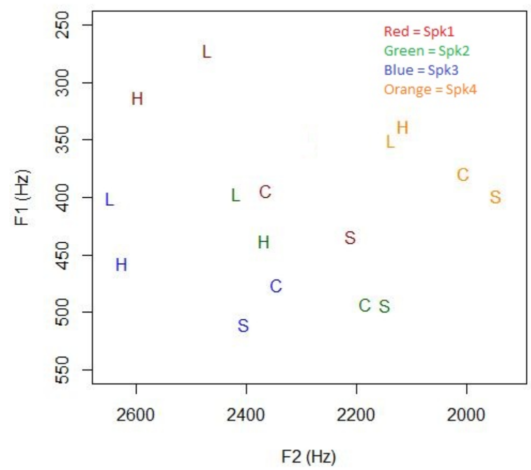


Figure 3.12: Mean F2*F1 /i/

Examining F1 first, the linear regression results show a main effect of tone and vowel, and an interaction of tone with vowel for the stopped tone:

| | **Coef.** | **t-value** | **p-value** |
|---|---|---|---|
| **High** | -17.8 | -0.9 | 0.36 |
| **Low** | 2 | 0.1 | 0.9 |
| **Stopped** | -148.8 | -7.2 | <0.001 * |
| **/i/** | -357 | -18.3 | <0.001* |
| **High:/i/** | -15.1 | -0.5 | 0.584 |
| **Low:/i/** | 2.3 | 0.1 | 0.934 |
| **Stopped:/i/** | 159.3 | 5.6 | <0.001 * |

Table 3.7: Results for F1

Table 3.7 shows that the stopped tone had a significantly lower average value for F1 (meaning a higher vowel) than the average F1 of all the other tones, but there is an interaction of the stopped tone with vowel. Further regressions on the subsets of vowels separately showed that the effect of tone was only significant for /a/, so the effect of tone did not hold across vowels. In order to examine how exactly the stopped tone differed from the other tones, a number of post-hoc tests were run. These compared the stopped tone to each of the other three tones, for each vowel. Since that consisted of six tests in total, Bonferroni's adjustment set the significance level at .05/6=.008. At this level of significance, the stopped tone was found to have a different F1 from each of the other three tones for /a/, but for the vowel /i/, the stopped tone was only different from the high tone.

These results support the hypothesis that the stopped tone has a different value for F1 from the other tones for the vowel /a/, but it is surprising that this is not the case for the vowel /i/.

The regression results for F2 show a significant main effect of tone and vowel, and an interaction of tone with vowel:

| | **Coef.** | **t-value** | **p-value** |
|---|---|---|---|
| **High** | 21.9 | 0.8 | 0.44 |
| **Low** | -62.5 | -2.2 | <0.05 * |
| **Stopped** | 312.3 | 10.4 | <0.001 * |
| **/i/** | 641.3 | 22.6 | <0.001 * |
| **High:/i/** | 149.7 | 3.7 | <0.001 * |
| **Low:/i/** | 300 | 7.5 | <0.001 * |
| **Stopped:/i/** | -316.7 | -7.6 | <0.001 * |

Table 3.8: Results for F2

Table 3.8 shows that the stopped tone had a significantly higher average value for F2 (meaning a fronter vowel) than the average F2 of the other tones, and the low tone had a significantly lower average F2 (backer vowel) than the average F2 of the other tones. There was an interaction of these tones with vowel, so further regression tests were run on the vowels separately. These tests found that the effect of tone did not hold across vowels. Pairwise post-hoc tests compared both the stopped tone and the low tone to each of the other tones, for both vowels. This consisted of ten tests, so Bonferroni's adjustment set the significance level at .05/10=.005. The results of these tests showed that the stopped tone had a significantly different F2 from each of the other three tones for /a/, and from both the high tone and the low tone for /i/. F2 of the stopped tone was not different from the creaky tone for /i/. F2 of the low tone was significantly different only from that of the creaky tone for /i/.

In sum, for /a/, the stopped tone had a significantly different value for F1 and for F2 from the other three tones, as predicted. For the vowel /i/, the stopped tone was different from the high tone in F1 and different from the high and low tones in F2. The stopped and creaky tones were not significantly different in either F1 or F2 for this vowel, which was not expected. One other unexpected result for this measure was that the low tone had a significantly different F2 from the creaky tone for /i/.

Overall, the effect of rate was significant for onset, duration, and peak, while it was not significant for offset, relative peak delay, voice quality, or vowel quality. Those characteristics for which rate had no significant effect may be more important cues and as such are resistant to time requirements.

# Chapter 4

# Discussion

The goal of this study was to examine what acoustic properties differentiate the four tones of Burmese. Overall, the results showed that f0 contour, duration, voice quality and vowel quality are all important characteristics in distinguishing the tonal categories. The results of each measure will be discussed in turn.

*F0 Contour*:

The results of the current experiment found that onset f0 was higher for the creaky and stopped tones than the high and low tones, as predicted, and also as found by Watkins (2005). This indicates that onset f0 is a distinguishing factor between the creaky and stopped tones versus the high and low tones. The fact that onset f0 is higher in the creaky and stopped tones is further discussed with the voice quality results, below.

Offset f0 was higher for the high tone than the low tone, also as predicted based on Watkins (2005) and Kelly (2011). This supports the descriptions of the high tone as rising. This result shows that offset f0 is a distinguishing factor between the high and low tones.

The high tone was found to have a lower peak f0 than the creaky and stopped tones, which is the opposite of what was expected based on Kelly (2011). However, Watkins (2005) describes the high tone's peak as slightly lower than that of the creaky and stopped tones. The high tone was found to have a higher peak f0 than the low tone, as predicted. These results show that peak f0 distinguishes the high and low tones from the creaky and stopped tones, and from each other.

It was also found that the high tone had a longer relative peak delay than the other three tones, and the low tone had a shorter relative peak delay than the other three tones, which fits in with descriptions that the high tone rises so has its peak at its offset, and the low tone falls, so has its peak at its onset.

These results show that a variety of characteristics involved in the f0 contour are used to distinguish the tones, as would be expected in most tone systems.

*Duration*: The high and low tones were found to be longer than the creaky and stopped tones, as predicted and support by previous findings (Hutchinson and McClenon, 1977; Watkins, 2005; Jenks, 2007; Tun, 1982). In the current experiment, however, one of the speakers had a low tone that was shorter than the creaky and stopped tones. Whether we can then generalize these results is questionable. It may be that this speaker is from a different population and that there are regional differences. Further research would be beneficial in order to examine if there are different geographical or social varieties of Burmese, and if so, how they differ from one another in the implementation of the tones.

*Voice Quality*:

For voice quality, the high tone and low tones were found to have a higher value for spectral tilt than the creaky and stopped tones, as predicted, and the high tone was also found to have a higher value for this than the low tone, as predicted. The one speaker whose low tone had a lower value for this than the creaky and stopped tones may again be representative of a different dialect group, and this requires further investigation.

The high tone was found to have breathy phonation in Kelly (2011), which is why the current finding that the high tone has the highest value for spectral tilt is in line with previous research. The high onset f0 of the creaky and stopped tones may be correlated with their low value for spectral tilt. Frazier (2010) points out that it is common cross-linguistically for a vowel involving creaky voice to begin with a high pitch and have only its final portion with creaky phonation. She notes that diachronically, "a coda glottal stop (which is likely correlated with creaky voice in the vowel) can condition a rising pitch contour in the preceding vowel" (Frazier, 2010, p.13). This appears to be the case in Burmese too, since the creaky and stopped tones begin with a high pitch and if creakiness is present, it begins towards the end of the vowel. However, DiCanio (2012) notes that creaky phonation has been found to also cause pitch lowering, for example in Navajo and Alacatlazala Mixtec. So it appears that creaky phonation can have varying effects on f0, but in any case, the high f0 onset for the creaky and stopped tones in Burmese is likely used to distinguish them from the high and low tones. Acoustically, it is understandable that the f0 of the modal part of the vowel would be used to distinguish the tone, if creakiness is not consistent, as appeared to be the case in the current study. Silverman (1997) notes that tone is heard most clearly when it appears with modal phonation, but when one vowel contains both tone and phonation features, these features may be sequenced with one another, so that the pitch feature can be perceived before voice quality changes. This ties in with Burmese tone because it appears that for the creaky and stopped tones, the creaky phonation occurs towards the end of the vowel, and not all the way through it.

Burmese is not unusual in its language family for having a system in which tone interacts with phonation. DeLancey (1992) explains that tone may not be reconstructible for Proto-Tibeto-Burman, and that most researchers agree that tone arose from coda laryngeal consonants. This has interesting implications when examining the stopped tone, because it seems that a coda consonant led to a pitch and phonation distinction, which is now (at least partly) surfacing as a vowel quality difference.

*Vowel Quality*:

For vowel quality, the stopped tone had a different vowel quality (higher and fronter) from the other three tones for the vowel /a/, as predicted, but it was not found to have a different vowel quality from the creaky tone for /i/, which was unexpected. The low tone was also found to have a different vowel quality from the creaky tone for /i/.

The different vowel quality of the stopped tone can be explained in terms of physiology. Esling (2003) notes that a laryngeal sphincter mechanism that is used to make a tense/lax vowel distinction in Yi (Tibeto-Burman) is used to produce harsh phonation in Bai (Sinitic). The correlation found in the current experiment between the tone that ends in a glottal stop (the stopped tone) and the presence of a laxer vowel than the other tones with the same underlying vowel, may be the result of a different laryngeal configuration (in order to produce glottalization) which has been reinterpreted over time as also having a different vowel quality. Similar correlations between voice quality and vowel quality have been described in other languages, for example, DiPaolo and Faber (1990) found that in certain varieties of American English, lax vowels are creakier than their tense counterparts. They also note that American English speakers from the Utah region have reanalyzed vowel quality as voice quality. Their experiment found that the F1/F2 distinction that differentiated tense and lax vowels was lost before the velar /l/ and replaced by a phonation distinction. Wayland and Jongman (2003) found that in Khmer (Austroasiatic), male speakers appear to have reinterpreted what was originally a breathy versus clear distinction as a tense versus lax distinction. As such, voice quality and vowel quality are not independent processes and appear to be able to influence one another in either direction, so an interaction between them in Burmese is not too surprising. It is possible that in Burmese, the coda glottal stop caused laryngealization which has affected the tenseness of vowel of the stopped tone.

The unexpected finding that the stopped tone did not have a different vowel quality from the creaky tone for /i/ could be explained by the fact that the majority (80%) of target words for the creaky tone with the vowel /i/ had a coda nasal, while the target words for the other tones with the vowel /i/ were generally open syllables. This difference was simply due to the fact that words containing creaky tones with /i/ in an open syllable were rare in the sources consulted. Bradley (1982, p.121) notes that "the vowel system in 'killed' syllables (and in nasalised syllables...) is radically different from that of open syllables." The stopped tone evolved from a coda final stop, and the only other codas allowed in Burmese are nasals, and it appears that all coda consonants affect vowel quality in the same way. In fact, Tun (1982) mentions that for the vowel /i/ with the creaky tone when followed by a coda nasal, the vowel moves downward and backward. To determine whether the vowel quality for /i/ differed between the open and closed (coda nasal) syllables in the current experiment, a linear regression was run on the creaky tone tokens containing the vowel /i/. A significant effect of syllable type was found for both F1 and F2, with the closed syllable showing a significantly lower and backer vowel than the open syllable. This means that the higher number of closed syllable tokens for the creaky tone likely skewed the results because the closed syllable induces a different vowel quality for /i/. It would be useful to examine /i/ with a creaky tone in open syllables, if enough tokens could be found, to see if its vowel quality still patterns with the stopped tone. It would also be insightful to examine the other vowels in the system to determine whether their quality consistently changes for the stopped tone.

The different F2 of the low tone showed that this tone has a more front vowel than the creaky tone for /i/, which is supported by Figure 3.12. Tun (1982) notes that the low tone has a different vowel quality, but says that /i/ is actually backer for this tone. He also states that the low tone has a different vowel quality for /a/, but this was not found in the current results. As such, it has been reported that the low tone has a different vowel quality, but the results are conflicting. Perhaps there are regional differences in how this tone affects vowel quality, or perhaps f0 contour is more important in distinguishing this tone so its vowel quality is more flexible. Further research could clear this up by recording more subjects from a variety of regions.

# Chapter 5

# Conclusion

This experiment examined seven variables relating to f0 contour, duration, voice quality, and vowel quality, in the four tones of Burmese. Jenks (2007) proposed that the tones could be divided into two categories: high and low versus creaky and stopped. The current experiment found that the high and low tones are differentiated from the creaky and stopped tones by onset f0, peak f0, relative peak delay, duration, and voice quality. This indicates that the creaky and stopped tones are distinguished from the other tones not only by phonation but also by f0 contour. This experiment also found that the high and low tones are distinguished from one another by offset f0, peak f0, relative peak delay, and voice quality. The creaky and stopped tones appear to be differentiated from one another mainly by vowel quality. These findings indicate that speakers of Burmese tune into a variety of factors to differentiate each of the tones. Research examining speakers' perception of these tones will provide further information on which cues and combinations are more important in distinguishing the tones.

# Appendix

| **Tone** | **Vowel** | **Word** | **English** |
|---|---|---|---|
| High | /a/ | wá | ‘bamboo’ |
| | | ngá | ‘fish’ |
| | | lá | ‘mule’ |
| | | kalá | ‘an Indian’ |
| | | nwá | ‘cow’ |
| | | ná | ‘ear’ |
| | | thwá | ‘tooth’ |
| | | lin majá | ‘married couple’ |
| | | nán | ‘palace’ |
| | | lán | ‘road’ |
| Low | /a/ | jà | ‘field’ |
| | | jwà | ‘village’ |
| | | nàjì | ‘clock’ |
| | | wà | ‘cotton’ |
| | | anà | ‘disease’ |
| | | pawà | ‘scarf’ |
| | | lù mamà | ‘patient’ |
| | | nànme | ‘name’ |
| Creaky | /a/ | la̰ | ‘moon’ |
| | | a ma̰ | ‘older sister’ |
| | | nja̰ | ‘night’ |
| | | mja̰ | ‘emerald’ |
| | | hkana̰ | ‘moment’ |
| | | awa̰ | ‘fat’ |
| | | htàna̰ | ‘department’ |
| | | tùma̰ | ‘niece’ |
| | | bamàma̰ | ‘Burmese girl’ |

| **Tone** | **Vowel** | **Word** | **English** |
|---|---|---|---|
| Stopped | /a/ | na$^{ʔ}$ | ‘spirit’ |
| | | ahma$^{ʔ}$ | ‘mark’ |
| | | la$^{ʔ}$ | ‘bribe’ |
| | | aja$^{ʔ}$ | ‘place’ |
| | | hpana$^{ʔ}$ | ‘sandal’ |
| | | zaja$^{ʔ}$ | ‘rest house’ |
| | | sala$^{ʔ}$ | ‘Slav’ |
| | | hnja$^{ʔ}$ | ‘tongs’ |
| | | madara$^{ʔ}$ | ‘Madras’ |
| | | thana$^{ʔ}$ | ‘gun’ |
| High | /i/ | mjí | ‘grandchild’ |
| | | mí | ‘fire’ |
| | | ní | ‘way’ |
| | | thamí | ‘daughter’ |
| | | wají | ‘uncle’ |
| | | míjathá | ‘train’ |
| | | jín | ‘ginger’ |
| | | mín | ‘king’ |
| | | mjín | ‘horse’ |
| | | lín | ‘light’ |
| | | htamiín | ‘rice’ |
| | | palín | ‘bottle’ |
| Low | /i/ | njì | ‘younger brother’ |
| | | lìn | ‘husband’ |
| | | nàjì | ‘clock’ |
| Creaky | /i/ | a pwḭn | ‘flower’ |
| | | a mḭ | ‘mother’ |
| | | hkwḭn | ‘permit’ |
| | | amjḭn | ‘height’ |
| | | mjḭn | ‘Myint’ (name) |
| Stopped | /i/ | myi$^{ʔ}$ | ‘river’ |
| | | a mji$^{ʔ}$ | ‘root’ |
| | | kùnmjùni$^{ʔ}$ | ‘Communist’ |
| | | sani$^{ʔ}$ | ‘policy’ |
| | | paji$^{ʔ}$ | ‘cricket’ |
| | | qali$^{ʔ}$ | ‘absence’ |

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