

# AN ACOUSTIC VOWEL SPACE ANALYSIS OF PIJAL MEDIA LENGUA AND IMBABURA QUICHUA\*

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## 1. Introduction

This paper investigates the acoustic nature of vowel systems in both moderate and extreme contact situations. I gathered the data for this study from two languages with varying degrees of contact spoken in the Ecuadorian province of Imbabura. The first is the Imbabura dialect of Quichua<sup>1</sup> spoken by 81.9% of the provincial population (Buttner 1993:48) where an estimated one fifth (21%) of the total lexicon is borrowed from Spanish (Gómez Rendón 2007:517). The second language is the Pijal dialect of Media Lengua spoken by an estimated 200-300 people in the community of Pijal Bajo where 89% of the total lexicon is borrowed from Spanish (Stewart 2011).

Different varieties of Media Lengua (ML)<sup>2</sup> have emerged throughout the Andean region of Ecuador including several documented cases in the provinces of Cotopaxi (Muysken 1979, 1981, 1988, 1997), Imbabura (Gómez Rendón 2005, 2008; Stewart 2011) and several lesser studied varieties in the provinces of Cañar and Loja (Muysken 1997). ML is often described as an exemplary case of a bilingual mixed language (Backus 2003, McConvell and Meakins 2005) because of its split between roots and suffixes. ML is formed through various processes of lexification (relexification, translexification and adlexification<sup>3</sup>) where nearly all the lexical roots in Quichua, including core vocabulary, are replaced by their Spanish counterparts. Impressionistically, the Spanish-derived lexicon in Pijal Media Lengua (PML) appears to conform to Quichua phonotactics while maintaining Quichua word order and the vast majority of

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<sup>1</sup> The Ecuadorian variety of Quechua is known as *Quichua* or *Kichwa* /'ki.tʃua/ by both mestizo and indigenous populations.

<sup>2</sup> Media Lengua literally translates to 'half-language' from Spanish. See Muysken (1997), Gómez-Rendón (2005) and Stewart (2011) for a more in-depth description of Media Lengua varieties.

<sup>3</sup> For an overview of relexification and translexification in Media Lengua see Muysken (1981). For an overview of adlexification in Media Lengua see Shappeck (2011).

Quichua's agglutinating suffixes. Example (1) illustrates a typical PML sentence. The italicized elements are derived from Spanish:

- (1) *si no aseti-ta okupa-kpika uebo-ka sarten-pi-mi pega-ſpa keda-n*  
 if not oil-ACC use-SUB.DS egg-TOP pan-LOC-VAL stick-SUB.SS remain-3  
 'If you don't use oil, the egg will stick to the pan.' (Consultant 50)

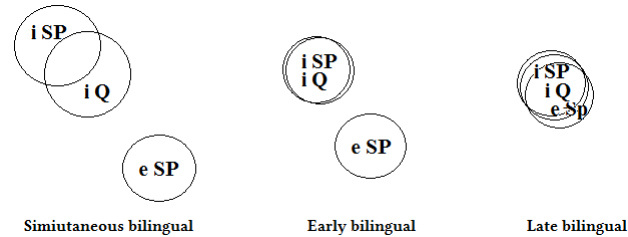
All three languages in this study (Quichua, Media Lengua and Spanish) have relatively small vowel inventories. Traditionally, both ML (Muysken 1997) and Imbabura Quichua (Guion 2003) are considered three vowel systems made up of /i/, /u/ and /a/. Spanish is typically considered a five vowel system consisting of /i/, /u/, /e/, /o/, and /a/. Muysken (1997:365) says Media Lengua often collapses the mid-vowels /e/ and /o/, in the Spanish (SP)-derived lexicon, to /i/ and /u/ respectively. However, under certain circumstances such as proper names, interjections, stressed positions and certain lexical items, the mid vowels may be retained.

In this paper, I attempt to answer the question: what is the phonetic nature of vowel production in these contact situations? Do vowels merge into a single system where L2 borrowings undergo complete phonetic assimilation? Do they function in a dual system where separate vowels are used depending on the origin of the morpheme in question? Do they co-exist as an intermediate variety with overlapping formant frequencies (varying degrees of merger)? To the best of my knowledge, acoustic data from a mixed language has not been analyzed to answer these questions. However, the idea of phonetic duality among bilinguals has been a common topic of linguistic analysis.

The Perceptual Assimilation Model proposed by Best et al. (2003) predicts that bilinguals assimilate L2 sounds based on how similar or contrastive a given sound is perceived. This theory suggests that bilinguals have only one phonological system where L2 sounds are produced on the basis of L1 patterns. Within this system, categories are allowed to (1) merge into a single category, (2) remain independent, or (3) may co-exist with varying degrees of overlap. This model would therefore, predict that in contact situations SP-derived /e/ and /o/ might emerge as new vowels and that /i/, /u/ and /a/ may or may not end up with Quichua and Spanish subsets.

Flege's (2007:370) Speech Learning Model (SLM) suggests that when an L2 learner establishes a new category, crowding of the phonetic space occurs, causing dispersion in order to maintain phonetic contrast. The SLM proposes that categories operate in the same phonological space and readjust according to external conditions.

Guion (2003) found that simultaneous bilinguals of Ecuadorian Spanish and Imbabura Quichua (IQ) maintained three separate front vowels: an /i/ with lower F1 frequencies for Spanish production, an /i/ with higher F1 frequencies for Quichua production, and an /e/ for Spanish production. Early (but not simultaneous) L2 learners tended to merge Spanish /i/ and Quichua /i/ into the same vowel space while late L2 learners merged both /i/s and the Spanish /e/ into the same vowel space.



**Figure 1: Simultaneous bilinguals' (left), early bilinguals' (middle) and late bilinguals' (right) vowel production (right). Based on Guion (2003)**

Another important factor regarding phonetic duality is that of assimilation (merger) and covert contrasts (near-merger). Hickey (2004:125) defines a merger as “the collapse of a phonemic distinction by one sound becoming identical with another wherein later shifts will mean that the merged sounds move together.” Hickey (2004:131) shows that near-mergers appear when a speaker consistently makes small articulatory differences between items of two lexical sets but cannot distinguish these distinctions auditorily. He emphasizes that “the essential crux of the near-merger assumption is that speakers cannot hear the phonetic distinction which linguists tease out in a spectrographical analysis and by examining vowel formants”. As we will see, mergers and near-mergers play a large role in vowel perception in both Pijal Media Lengua and Imbabura Quichua.

In the following sections, I present a comparative analysis of formant one (F1) and formant two (F2) vowel frequencies in both PML and the Imbabura dialect of Quichua from the nearby and historically related communities of Chirihuasi and Cashaloma. This section provides acoustic evidence which shows treating PML and IQ as either a three or five vowel system is a gross oversimplification and that, depending on how you want to define a vowel category, PML speakers may be manipulating as many as eight vowels while IQ speakers may be manipulating up to six. Here, I provide evidence for the existence of a fourth and fifth vowel, /e/ and /o/ respectively, in both PML and IQ. I also present evidence for the possibility of three more vowels in PML—SP-derived subsets of /i/, /u/, and /a/ which co-exist as covert contrasts along side Quichua (Q)-derived /i/, /u/, and /a/ subsets. Similarly, I provide evidence for the possibility of one more vowel subset in IQ, SP-derived /a/ which co-exists as a covert contrast alongside native Q /a/.

## 2. Method

### 2.1 Materials

A list containing 100 Spanish sentences was developed for this study. This list was designed to cover all places of articulation in both pre-vowel and post-vowel positions in PML including both voiced and voiceless phonemes and allophones in the bilabial (/p/, /b/ or [β], /m/), labiodental (/f/),

dental/alveolar/postalveolar (/tʃ/, /t/, /d/, /n/, /r/, /r/, /s/, [z], /ʃ/, /z/, /l/), palatal (/ɲ/, /j/), velar (/k/, /x/, /ɣ/) and glottal /h/ positions. Participants were asked to give their best oral interpretation of the sentence in PML. The same sentence list was also used during IQ elicitions in order to maintain the same elicitation conditions.

The participants' oral interpretations were recorded on a TASCAM DR-1 portable digital recorder using TASCAM's compatible TM-ST1 MS stereo microphone set to 90° stereo width. Elicitations were recorded in 16-bit Waveform Audio File Format (WAV) with a sample rate of 44.4 kHz.

## 2.2 Participants

Ten Quichua /Media Lengua /Spanish trilinguals, six women and four men, and ten Quichua /Spanish bilinguals, six women and four men participated in this study. From the trilingual group, all participants acquired Quichua and Media Lengua simultaneously from birth and began to learn Spanish upon entering primary school, typically at 6-7 years of age. From the bilingual group, four women had a rudimentary level of Spanish, one man was a simultaneous bilingual and one man acquired Spanish at the age of 18, while the rest acquired Spanish upon entering primary school, typically at 6-7 years of age. All Media Lengua participants were from the community of Pijal Bajo, while all Quichua participants were from the nearby communities of Chirihuasi and Cashaloma. Participants from both groups reported normal hearing and lived their entire lives in their respective communities.

## 2.3 Procedure

A native Spanish speaker and I gave all instructions and verbally elicited the 100-sentence list in Spanish for the Media Lengua participants. The native Spanish speaker elicited the 100 sentence list in Spanish for the Quichua participants and a native Quichua speaker from Chirihuasi interpreted if confusion arose. The participants were asked to give their best oral interpretation of each sentence on the 100-sentence list and wait at least five seconds before producing the utterance. We encouraged participants to consult with others if any doubts arose. We also asked participants to speak at a normal conversational speed and to repeat if needed. Consultations with other participants and the five second waiting period made it more likely that speakers were accessing their long-term memory and reducing mimicry (Guion 2003:107).

We recorded of 4706 sentences for this study. I measured F1 and F2 frequencies from 2515 PML and 2191 IQ vowel tokens. These included 926 tokens from Q-derived lexemes/ morphemes in PML and 1589 tokens from SP-derived lexemes in PML. From the IQ data, I measured 990 tokens from native Quichua lexemes/ morphemes and 1201 tokens from SP-derived lexemes. SP-derived vowels were organized based on their original Spanish pronunciation, i.e., the /u/ in *kumina* 'eat', would be considered /o/ and not /u/, since its prelexified production was that of /o/ in Spanish *comer* /komet/ 'eat'.

### 3. Results

The results of this study are presented in three sections. The first tests the hypothesis that Pijal Media Lengua (PML) Spanish (SP)-derived vowels /i/, /u/ and /a/ differ significantly from their PML Quichua (Q)-derived counterparts. Based on the same hypothesis, I then repeat the tests using data from Imbabura Quichua (IQ). For each vowel pair, I built a separate mixed effects model to test F1 and F2 frequencies between Q-derived /i/, /u/ and /a/ and their SP-derived counterparts. The same model building strategy was then repeated for IQ vowels from native Q and SP-derived words.

The second section tests the hypothesis that PML SP-derived vowels /i/ and /u/ differ significantly from PML SP-derived /e/ and /o/ respectively. I anticipated that vowel formant comparisons from the same language of origin would provide evidence for or against the existence of /e/ and /o/ in PML. The same hypothesis is then tested using IQ data. I used the same model building strategy as found in the first section to build mixed effects models for the SP high and mid vowel comparisons.

The third section tests the hypothesis that PML Q-derived vowels /i/ and /u/ differ significantly from PML SP-derived /e/ and /o/ respectively. Finally, I test the same hypothesis using native Q vowels /i/ and /u/ against SP-derived /e/ and /o/ respectively. I used the same model building strategy as found in the first section to build mixed effects models for the Q high vowel and SP mid vowel comparisons.

Mixed effects models were created in R 2.12.2 with the *lmer* function of the *lme4* package included in the *LanguageR* package (Baayen 2008). P-values and 95% confidence intervals (CI<sub>95</sub>) were estimated by Monte-Carlo Markov chain (P<sub>MCMC</sub>) sampling using the *pvals.fnc* of *languageR* (Baayen 2008). All the models included ‘speaker’ and ‘morpheme’ as random effects.

I considered the following as possible predictors when building all mixed effects models: position of the syllable relative to the end of the word, features of the pre-vowel environment (including: nasal, stop, fricative, tap, approximant, labial, alveolar, postalveolar, palatal, velar, high-front & mid-front vowels, high-back & mid-back vowels, low vowel, word-initial and word-final) and post-vowel environment (including: nasal, stop, fricative, tap, approximant, labial, alveolar, postalveolar, palatal, velar, high-front & mid-front vowels, high-back & mid-back vowels and low vowel, word-initial and word-final), the part of speech of the word (including: noun, verb, adjective or adverb), if the vowel formed part of a root or suffix, language derivation (is the morpheme in question from Quichua or Spanish?), and if the vowel was found at a language switch (i.e., *komi-nahun* ‘they eat together’.)

Each of the following subsections includes a density plot of the residuals from its respective F1 mixed effects model. They include every possible variable except the contrast being discussed, (e.g., the graphs are smoothed histograms summarizing how far away each vowel is from the best prediction of where it ‘should’ be according to a model that knows everything about the vowel except its language of origin). It is important to note that the

models that the graphs are based on contain all the possible predictors, not just those that are statistically significant (as in the models which reported the statistical results), therefore there is likely to be a great deal of overfitting to the data.<sup>4</sup>

### 3.1 PML vowel space analysis: SP-derived vowels vs. Q-derived vowels

The following subsections include the results from the *pvals.fnc* and the model summary of each mixed effects model. When a result is significant, we are most interested in the coefficient estimate ( $\beta$ ), which is a conservative estimate of the average frequency distance in Hertz between SP-derived and Q-derived vowels.

#### 3.1.1 PML SP-derived vs. Q-derived high and low vowels

This section presents the results from the F1 frequencies of PML SP-derived and Q-derived high and low vowels (e.g., the /i/ in the word [*kiŋse*] ‘fifteen’, with the /i/ in the word [*abla-hu-ni*] ‘speak-PROG-1S.PRES’).

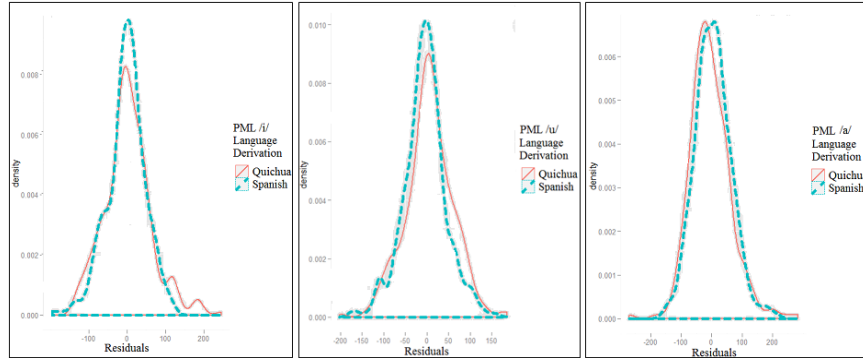
- The F1 for /i/ in SP-derived lexemes was significantly lower than that of Q-derived morphemes [ $t=-2.6$ ,  $p=0.014$ ,  $\beta=-13$ ,  $CI_{95\%}=-23$ : -2].
- The F1 for /u/ in SP-derived lexemes was significantly lower than that of Q-derived morphemes [ $t=-2.5$ ,  $p=0.0004$ ,  $\beta=-15$ ,  $CI_{95\%}=-29$ : -9].
- The F1 for /a/ in SP-derived lexemes was significantly higher than that of Q-derived morphemes [ $t=1.9$ ,  $p=0.04$ ,  $\beta=11$ ,  $CI_{95\%}=0.2$ : 21]

The results of these statistical tests report significant differences in tongue body height (F1) in all three SP-derived vowels when compared with their Q counterparts. The differences in F1 frequency among the SP-derived and Q-derived high vowels indicates a subtle increase in tongue body position for the SP-derived subset. For the low vowel subsets, the differences in F1 frequency indicate a subtle decrease in tongue body position for the SP-derived subset.

The results of the same statistical tests regarding the F2 frequencies reported non-significant differences in tongue body frontedness for all three vowel pairs.

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<sup>4</sup> It is also important to note that some of those predictors are correlated with the contrast being investigated. For example, whether a vowel comes from a root or a suffix is fairly strongly correlated with whether its language of origin was SP or Q, so it is quite possible that a model is removing some of the variation that is really related to language of origin and incorrectly attributing that variation to the root/suffix distinction. For these reasons, each graph illustrates the worst possible case for the hypothesis that the vowel classes are different. If despite those disadvantages we can still see a difference between, for example, Q-derived and SP-derived vowels in a graph, we can be fairly confident that the difference is real and that it probably really is due to the language of origin.



**Figure 2: Residual density plots of F1 frequencies from SP-derived (dashed) and Q-derived (solid) high and low vowels in Pijal Media Lengua - /i/ (left) /u/ (middle) and /a/ (right).**

### 3.1.2 IQ: SP-derived vs. Native Q high and low vowels

The statistical tests reported in this section were designed to answer the question: is there a significant difference between SP-derived vowels and native Q vowels in Imbabura Quichua? It is also worth noting that SP-derived words in IQ are similar to those in PML in that they typically underwent the same processes of lexification (i.e., they are not taken from L1 Quichua speakers speaking Spanish or part of code-switching phrases).

- There was a non-significant difference between the F1 frequencies of /i/ in SP-derived and native Q morphemes in IQ [ $t=-0.4$ ,  $p=0.61$ ,  $\beta=-2$ ,  $CI_{95\%}=-9: 6$ ].
- There was a non-significant difference between the F1 frequencies of /u/ in SP-derived and native Q morphemes in IQ [ $t=0.8$ ,  $p=0.28$ ,  $\beta=4$ ,  $CI_{95\%}=-4: 14$ ].
- The F1 frequency for /a/ in SP-derived morphemes was significantly higher than that of Q-derived morphemes [ $t=1.7$ ,  $p=0.045$ ,  $\beta=11$ ,  $CI_{95\%}=0.1: 23$ ]. I am not fully convinced of this result for two reasons: (1), the t-value is suspiciously small (within  $\pm 2$  is usually non-significant with large datasets) and (2) the  $P_{MCMC}$  value is just below 0.05. P-value results tend to differ slightly across runs using Monte-Carlo Markov chain sampling. In order to avoid cherry picking the data, I also restricted each model to only one run of *pvals.fnc*. I did not make any corrections for multiple comparisons by using methods such as Bonferroni's correction, Scheffé's test or Tukey's Honesty Significant Difference. Therefore, I consider this result not to be strong evidence for a difference between SP-derived and native Q /a/s in IQ. If this effect is real, it is the biggest F1 difference one will find in IQ.

The results of these statistical tests reported non-significant differences in tongue body height (F1) with the exception of /a/. Non-significant results in tongue body frontedness (F2) were also found between SP-derived vowels and their native Q counterparts with the exception /u/ where the SP-derived vowel

appears to be 40.8 Hz lower than its Q-derived counterpart [ $t=-1.6$ ,  $p=0.03$ ,  $\beta=-41$ ,  $CI_{95\%}=-91 : -3$ ]. These non-significant findings regarding the F1 frequencies contrast with the small but significant differences for the same tests in PML.

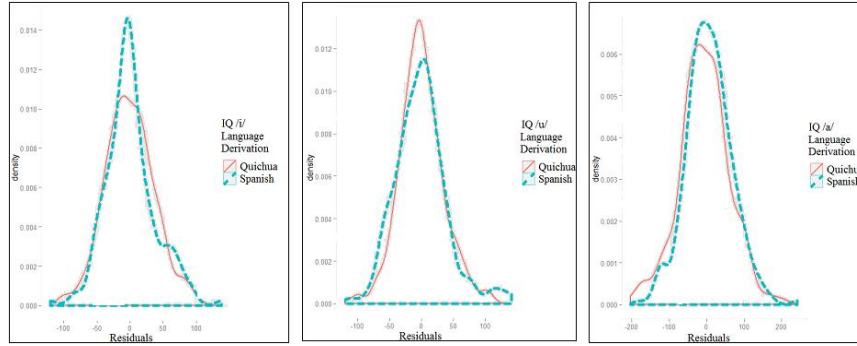


Figure 3: Residual density plots of F1 frequencies from SP-derived (dashed) and native Q (solid) high and low vowels in Imbabura Quichua - /i/ (left) /u/ (mid) and /a/ (right).

### 3.2 PML analyses: SP-derived high and mid vowels

The statistical tests reported in this section were designed to answer the question: is there a statistically significant difference between SP-derived high vowels and SP-derived mid vowels in PML?

This question is of interest for a number of reasons: (1) No one has yet to take acoustic measurements from Media Lengua (ML), and therefore we cannot know to what extent Spanish phonological contrasts (i.e., the degree to which PML has incorporated a separate set of mid vowels into its phonology) have crossed over into ML. (2) To my knowledge, a mixed language has not been tested using acoustic measurements and statistics to determine the existence of a dual vowel system. While data from sections 3.1.1 and 3.12 show SP-derived vowels and Q-derived vowels have not completely merged, the addition of SP-derived mid vowels would provide even more evidence for two co-existing systems. (3) The adoption of the SP mid vowels and diphthongs could be a practical strategy for dealing with homophony and ambiguities that might otherwise arise through Q vowel assimilation.

#### 3.2.1 PML: SP-derived high-vowels vs. mid-vowels

This section compares the F1 and F2 frequencies of PML SP-derived /i/s and /u/s like those found in the words [*pintur-kuna-ka*] ‘painter-PL-TOP’ and [*fruta-ta-ta*] ‘fruit-ACC-WH.Q’ respectively with PML SP-derived /e/s and /o/s similar to those found in the words [*eskribi-ʃun-mi*] ‘write-SUBJ.DS-VAL’ and [*pueblɔ-man-mi*] ‘to the town-DIR-VAL’.

- The F1 frequency in SP-derived /i/ was significantly lower than that of SP-derived /e/ in PML morphemes [ $t=-9.8$ ,  $p<0.0001$ ,  $\beta=-44$ ,  $CI_{95\%}=-53 : -35$ ].



- The F2 frequency in SP-derived /i/ was significantly higher than that of SP-derived /e/ in PML morphemes [ $t=7.3$ ,  $p<0.0001$ ,  $\beta=112$ ,  $CI_{95\%}= 85: 137$ ].
- The F1 frequency in SP-derived /u/ was significantly lower than that of SP-derived /o/ in PML morphemes [ $t=-8.3$ ,  $p<0.0001$ ,  $\beta=-38$ ,  $CI_{95\%}= -46: -28$ ].
- There was a non-significant difference between the F2 frequencies for SP-derived /u/ and SP-derived /o/ in PML morphemes [ $t=0$ ,  $p=0.73$ ,  $\beta=-0.0001$ ,  $CI_{95\%}= -34: 23$ ].

The results of these statistical tests reported significant differences in tongue body height between PML SP-derived high vowels and mid vowels. Unlike, the subtle F1 frequency differences found between SP-derived and Q-derived vowels in section 3.1.1, the F1 frequency differences between the PML high vowels and mid vowels are quite apparent. Unlike in section 3.1.1, the F2 frequencies between PML /i/ and /e/ were also significantly different, but no significant F2 frequency difference was reported between PML /u/ and /o/.

These effects are not being caused by a handful of clear mid-tokens that are dragging the average up and down – rather the entire distribution for /e/ and /o/ has been shifted over relative to /i/ and /u/.

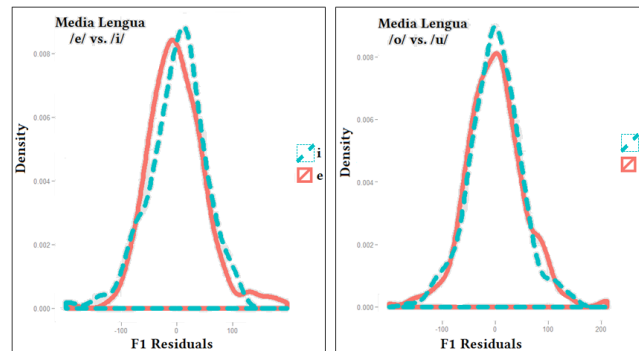


Figure 4: Residual density plots of F1 frequencies from Spanish-derived high (dashed) and mid vowels (solid) in Pijal Media Lengua - /i/ vs. /e/ (left) and /u/ vs. /o/ (right).

### 3.3 IQ vowel space analyses: SP-derived high and mid vowels

The statistical tests reported in this section were designed to answer the question: is there a statistically significant difference between SP-derived high vowels and SP-derived mid vowels in IQ? This question is similar to the one found in section 3.2 and important for Quichua for essentially the same reasons.

#### 3.3.1 IQ: SP-derived high-vowels vs. SP-derived mid-vowels

This section compares the F1 and F2 frequencies of Imbabura Quichua SP-derived /i/s and /u/s like those found in the words [amigu-mi] ‘friend-VAL’ and

[*luna-ka*] ‘moon-TOP’ with Imbabura Quichua SP-derived /e/s and /o/s similar to those found in the word [*kuadernu-ta*] ‘notebook-ACC’.

- The F1 frequency in SP-derived /i/ was significantly lower than that of SP-derived /e/ in IQ morphemes [ $t=-4.9$ ,  $p<0.0001$ ,  $\beta=-27$ ,  $CI_{95\%}=-38:-18$ ].
- The F2 frequency in SP-derived /i/ was significantly higher than that of SP /e/ in IQ morphemes [ $t=6.5$ ,  $p<0.0001$ ,  $\beta=126$ ,  $CI_{95\%}=93:163$ ].
- The F1 frequency in SP-derived /u/ was significantly lower than that of SP-derived /o/ in IQ morphemes [ $t=4.4$ ,  $p<0.0001$ ,  $\beta=-25$ ,  $CI_{95\%}=-36:-14$ ].
- The F2 frequency for SP-derived /u/ was significantly lower than that of SP-derived /o/ in IQ morphemes [ $t=-2.7$ ,  $p=0.0056$ ,  $\beta=-61$ ,  $CI_{95\%}=-97:-17$ ].

The results of these statistical tests reported significant differences in tongue body height (F1) between SP-derived high vowels and mid vowels in IQ. The F2 frequencies between SP-derived high vowels and mid vowels were significantly different as well.

These effects are not being caused by a handful of clear mid tokens that are dragging the average up and down – rather the entire distribution for /e/ has shifted over relative to /i/. In contrast, a small handful of SP-derived /o/ tokens appear to show up as clear /o/ with no appreciable shift in the rest of the distribution. This case of hypercorrection by the Q speakers could be causing a significant difference where there may otherwise be a non-significant result. The F1 frequency differences in IQ indicate a noticeable raise in tongue body height but only about half the size of those found in PML (i.e., the SP mid vowels are higher (Hz) in PML than in IQ).

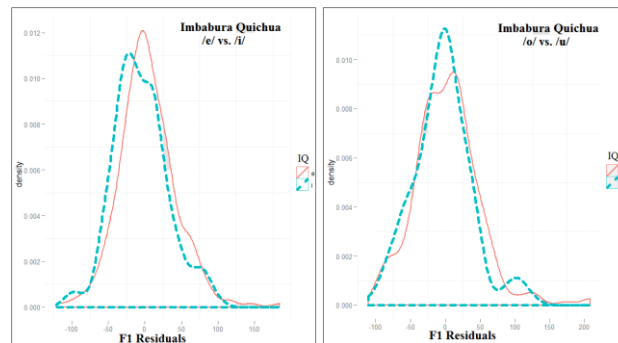


Figure 5: Residual density plots of F1 frequencies from SP-derived high (dashed) and mid (solid) vowels in Imbabura Quichua- /i/ vs. /e/ (left) and /u/ vs. /o/ (right).

### 3.4 PML analyses: Q-derived high vowels and Sp-derived mid vowels

I have shown that SP-derived /i/ and /u/ are significantly higher and fronter than Quechua-derived /i/ and /u/ in PML. I have also shown that SP-derived /i/ is

significantly higher and fronter than SP-derived /e/, while SP-derived /u/ is significantly higher than SP-derived /o/. But it remains unclear whether PML speakers have merged Q-derived /i/ and /u/ with SP-derived /e/ and /o/ respectively, the way that Guion (2003) found many early Quichua/Spanish bilinguals did, or whether they also maintain the distinction between those two vowels, the way Guion found many simultaneous Q/SP bilinguals did.

### 3.4.1 PML: Q-derived high vowels vs. SP-derived mid vowels

This section compares the F1 and F2 frequencies of Pijal Media Lengua Q-derived /i/s and /u/s like those found in the words [*komi-ngiʃi*] ‘eat-2P’ and [*kasa-kuna*] ‘house-PL’, with Pijal Media Lengua SP-derived /e/s and /o/s similar to those found in the words [*kaʒo-mi*] ‘car-VAL’.

- The F1 frequency in Q-derived /i/ was significantly lower than that of SP-derived /e/ in PML morphemes [ $t=-6.9$ ,  $p<0.0001$ ,  $\beta=-39$ ,  $CI_{95\%}=-50: -28$ ].
- The F2 frequency in Q-derived /i/ was significantly higher than that of SP-derived /e/ in PML morphemes [ $t=7.9$ ,  $p<0.0001$ ,  $\beta=139$ ,  $CI_{95\%}=104: 162$ ].
- The F1 frequency in Q-derived /u/ was significantly lower than that of SP-derived /o/ in PML morphemes [ $t=-4.6$ ,  $p<0.0001$ ,  $\beta=-23$ ,  $CI_{95\%}=-34: -13$ ].
- There was a non-significant difference between the F2 frequencies for Q-derived /u/ and SP-derived /o/ in IQ morphemes [ $t=-1.5$ ,  $p=0.21$ ,  $\beta=-30$ ,  $CI_{95\%}=-57: 13$ ]. Recall there was also a non-significant difference in F2 between SP-derived /i/ and SP-derived /e/.

The results of these statistical tests reported significant differences in tongue body height (F1) between Quichua (Q)-derived high vowels and Spanish (SP)-derived mid vowels in Pijal Media Lengua (PML). As would be expected, the F1 frequency differences between Q-derived high vowels and Spanish-derived mid vowels are not as large as those found between SP-derived high vowels and SP-derived mid vowels in section 3.2.1. These results suggest that PML may be manipulating as many as eight vowels.

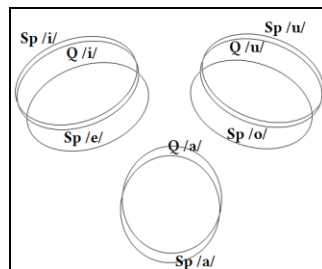


Figure 6: PML vowel inventory (approximation— not to scale).

### 3.5 IQ analyses: native Q high vowels and SP-derived mid vowels

The statistical tests reported in this section were designed to answer essentially the same question proposed in section 3.4 but regarding Imbabura Quichua (IQ): is there a statistically significant difference between native Q high vowels and SP-derived mid vowels in IQ?

#### 3.5.1 IQ: Native Q-derived high vowels vs. SP-derived mid vowels

This section compares the F1 and F2 frequencies of native Quichua /i/s and /u/s like those found in the words [ʃimi-ta] ‘language-ACC’ and [rura-nʃi] ‘do-1P’ with SP-derived /e/s and /o/s similar to those found in the word [kuadernu-ta] ‘notebook-ACC’.

- The F1 frequency in native Q /i/ was significantly lower than that of SP-derived /e/ in IQ morphemes [ $t=-6.3$ ,  $p<0.0001$ ,  $\beta=-29$  CI<sub>95%</sub>= -36: -20].
- The F2 frequency in native Q /i/ was significantly higher than that of SP-derived /e/ in IQ morphemes [ $t=6.5$ ,  $p<0.0001$ ,  $\beta=132$ , CI<sub>95%</sub>= 85: 155].
- The F1 frequency in native Q /u/ was significantly lower than that of SP-derived /o/ in IQ morphemes [ $t=-6$ ,  $p<0.0001$ ,  $\beta=-24$ , CI<sub>95%</sub>= -33: -16].
- The F2 frequency in native Q /u/ was significantly lower than that of SP-derived /o/ in PML morphemes [ $t=-3.5$ ,  $p=0.0008$ ,  $\beta=-75$ , CI<sub>95%</sub>= -103: -30].

The results of these statistical tests reported significant differences in tongue body height (F1) between native Quichua high vowels and SP-derived mid vowels in IQ. Similar to the SP-derived high vowel and mid vowel tests in section 3.3.1, all F2 frequencies were significantly different between the native Q high vowels and SP-derived mid vowels. These results suggest IQ may manipulate up to 6 vowels.

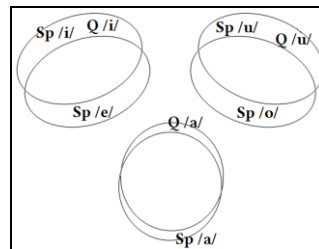


Figure 7: Imbabura Quichua vowel system (approximation— not to scale)

## 4. Discussion and Conclusions

This study had the goal of presenting a comparative analysis of F1 and F2 frequencies from both PML and IQ. I provided acoustic evidence for as many as

eight vowels in PML and up to six vowels in IQ. This evidence shows the possibility of a fourth and fifth vowel, /e/ and /o/ respectively, in both PML and IQ in what are both traditionally considered three vowel systems (Muysken 1997:336, Guion 2003:104). In addition, this evidence supports the possibility of SP-derived /i/, /u/, and /a/ subsets which co-exist as near mergers along with Q-derived /i/, /u/, and /a/. Similarly, I also provided evidence for one more possible vowel subset in IQ, SP-derived /a/ which co-exists as a near merger along with Q-derived /a/.

Very little acoustic or psycholinguistic work has been conducted regarding mixed languages. However, these languages hold a wealth of information which could be used to better understand the psychological and neurological factors that allow humans to take two typologically unrelated, fully functional languages split them apart and create a new, fully functional language based on different linguistic components and with little blending from each source language. The vowel systems of PML and IQ are prime examples of the complexity of vowel systems that would not have been found without such tools.

The results of this acoustic analysis show that PML uses two overlapping vowel systems based on the vowels' language of origin. SP-derived high vowels (/i/ and /u/) have lower F1 frequencies while the SP-derived low vowel (/a/) has a higher F1 frequency when compared with those of Quichua. The theory of Adaptive Dispersion predicts this type of increased vowel space, showing that five vowel systems like Spanish tend to expand the range of acoustic space to a greater degree than three vowel systems, like Quichua (Livijn 2000). The problem with the Adaptive Dispersion model is that while the vowels are being dispersed in the correct direction, they are not by any means creating separate categories, i.e., they seem to co-exist stably while overlapping each other in an almost identical vowel space. The PML data also contradicts Flege's (2007) Speech Learning Model (SLM) since the SLM suggests that two competing systems with stable overlap should be undesirable. The PML data, however, fits (hypothetically) with Best's Perceptual Assimilation Model which predicts that bilinguals assimilate L2 sounds based on how similar or contractive a given sound is perceived by subject's native phonotactics. Within this system categories are allowed to (1) merge into a single category, (2) stay independent, or (3) may co-exist with varying degrees of overlap. The only issue facing this model is the fact that we are not dealing with L2 sounds and that these co-existing systems appear to have been passed down from generation to generation under conditions of near merger.

Regarding the high and low vowel pairs in PML, the significant differences are not large (13 Hz lower for SP /i/; 15 Hz lower for SP /u/; 11 Hz higher for SP /a/). These frequency differences are, however, on the border of what can be perceived. These effects are not being caused by a handful of clear tokens that are dragging up and down the average – rather the entire distribution of SP-derived vowels has almost completely overlapped the distributions of the Q-derived vowels.

There was no significant difference in acoustic vowel space based on the language of origin for IQ high vowels and low vowels (with the questionable

exception of the F1 frequency in SP-derived /a/, as discussed in section 3.1.2). If Quichua merges Spanish borrowings according to Quichua phonetics, why was this process only partial in PML? The answer may lie in the distinctive evolutionary paths of IQ and PML. In IQ, the main influence of Spanish phonetics on each lexeme would, hypothetically, have been at its point of borrowing, from a small number of bilinguals before immediately conforming to Quichua phonetics when monolinguals adopted the lexemes. The idea of conforming to Quichua phonetics also implies that SP-derived vowels underwent complete merger and consecutive generations would have no point of reference to separate the SP-derived and Q-derived vowels into distinct categories. For PML, the influence of Spanish phonetics would have come from a large number of bilinguals and lasted for generations.

Unlike the PML SP-derived and Q-derived high and low vowels, the significant differences between Pijal Media Lengua SP-derived high and mid vowels are more apparent: the F1 frequency for /i/ is 44 Hz lower than that of /e/; the F2 frequency for /i/ is 112 Hz higher than that of /e/; the F1 frequency for /u/ is 38 Hz lower than that of /o/. There was no significant difference found for F2 values between /u/ and /o/.

Regarding Imbabura Quichua, the significant differences in F1 frequency between SP-derived high and mid vowels are roughly half the size when compared with PML: the F1 frequency for /i/ is 27 Hz lower than that of /e/; the F2 frequency for /i/ is 126 Hz higher than that of /e/; and the F1 frequency for /u/ is 25 Hz lower than that of /o/ and the F2 frequency for /u/ is 62 Hz lower than that of /o/.

These results show that PML speakers produce high vowel and mid vowel contrasts at roughly twice the distance as those of IQ speakers. This means speakers of PML are performing the impressive task of maintaining distinct high vowel and mid vowel categories at greater acoustic differences than monolinguals, but also at roughly half the distance as simultaneous bilinguals (See Guion 2003, Stewart 2011). As with the high vowel and low vowel results, this data shows that the current generation of PML speakers has managed to maintain a highly overlapping system of categories using only L1 input. This is evident in the fact that the current generation of PML speakers are considered early bilinguals (EB). However, their frequency differences are not overshoots like those found in Guion's early bilingual group, but instead are comparable –to a lesser degree– to those of simultaneous bilinguals *without* being simultaneous bilinguals (see Guion 2003, Stewart 2011).

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