Phonetic and Phonological Structures of Iberian Portuguese

An Acoustic Analysis

1. Abstract

Iberian Portuguese is a dialect of Portuguese spoken in Portugal in Western Europe with an estimated speaker population of 10 million. Iberian Portuguese belongs to the Galician-Portuguese language family which includes the descendants of medieval Galician-Portuguese: Portuguese (including all of its dialects), Galician, Eonavian, and Fala (“Portuguese Language”, 2021). This paper describes the basic phonological and phonetic characteristics of this language based on recorded data from one native speaker from Lisbon, Portugal, who speaks the Estremenho sub-dialect of European Portuguese. Aspiration is notably absent in Iberian Portuguese, and the language contains a variety of additional unique characteristics such as post-vocalic nasals as markers of vowel nasalization, the use of the guttural /r/, homonym creation through the diphthongization process of allophones (pg. 45), and the raising of pre-stressed vowels (pg. 41). These phonological characteristics will be analyzed using a combination of acoustic data and an analysis of preexisting literature on Iberian Portuguese.
2. Introduction

There are two main motivations behind my choice to research Iberian Portuguese. As a native Spanish speaker, I am eager to understand the similarities in phonetics between Spanish and a similar language. Portuguese is similar enough to Spanish to the point where I believe I can draw connections between the two languages for my own personal curiosity in a methodical way without sacrificing the original goal of this assignment. More importantly, despite Portuguese being the sixth most widely spoken language on earth, there is still little linguistic research that has been conducted about Iberian Portuguese. With nearly 200 million speakers, Brazilian Portuguese is the main focus of Portuguese linguistic research, leaving European Portuguese with little to no information available for public consumption. Seeing as it would be very simple for me to find information on the phonological processes of Brazilian Portuguese, I believe that focusing on European Portuguese benefits the greater linguistic community by analyzing a topic that has been little studied.

European Portuguese is a Portuguese language spoken in Portugal on the westernmost region of the Iberian Peninsula of Europe with an estimated population of 10 million speakers. There are ten dialects of Iberian Portuguese; they are as follows: Transmontano, Minhoto, Beirão, Alentejano, Alto-Alentejano, Estremenho, Micaelense, Madeirense, Algarvio, and Portuense. The speaker I interviewed speaks in the Estremenho dialect (“Portuguese Language”, 2021).

This paper is based on a series of interviews I conducted with Francesca Lameiro, a nineteen-year-old college student from Lisbon, Portugal in February and March of 2021. Francesca will be referred to as “speaker,” “consultant,” “F.L.,” and “Francesca” throughout this paper. Drawing upon resources provided by the UCLA Phonetics Archive and with minimal
assistance from Francesca, I was able to compile a word list featuring all phonetic elements of the language. I used outside sources such as Milton M. Azevedo’s *Portuguese: A Linguistic Introduction* to further refine my word lists and focus on areas of particular interest. The final word lists will be listed in the appendix.

Once my word list of 581 words had been compiled, I made a recording of my one consultant, Francesca, saying the words. In addition to the recording I made with Francesca reading only the words presented on the list, I created an additional recording where they read 278 of the words in a frame sentence in order to get a better sense of what the sounds are like within a sentence. In this paper, words will be transcribed broadly using IPA symbols and will correspond to the consultant’s pronunciation of Iberian Portuguese.

Francesca identifies as nonbinary and moved to the United States when they were fifteen years old. Before this move, they had lived in Lisbon their entire life. During their time in the United States, they have lived in Wellesley, Massachusetts and Atchison, Kansas. Francesca has been speaking Portuguese, Catalan, and Spanish since they were born and began learning English in third grade when they were eight years old. They explained to me that while their native language is technically Portuguese, their mother is Catalan, so Francesca also grew up hearing Catalan for most of their childhood.

### 3. Methodology

With in-person interviewing made impossible due to the COVID-19 pandemic, I was unable to meet with Francesca face-to-face for both the phonetic and phonological interviews I conducted with them. In lieu of an in-person interview, we spoke over Zoom where I was able to
record both the audio and the video of them speaking. The Zoom audio recordings were transferred to PRAAT for the acoustic analysis.

4. Vowels

4.1 Overview

Iberian Portuguese has nine vowel phonemes stemming from five written vowels, i, e, a, u, o. The language also features six diphthongs which are not considered separate phonemes. Iberian Portuguese is a stress-timed language, and vowels are characterized by a stressed and unstressed system which further divides vowel pronunciation into four distinct categories—open pronunciation, closed pronunciation, reduced pronunciation, and nasal pronunciation (Azevedo, 2009, p.30). Iberian Portuguese has a rich vowel phonology, containing diphthongs and both oral and nasal vowels. Table I contains words illustrating each of the five vowels in an open stressed position.

Table I: Words illustrating five vowels in stressed positions

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>sal</td>
<td>“salt”</td>
</tr>
<tr>
<td>e</td>
<td>tejo</td>
<td>“Tagus” (a river)</td>
</tr>
<tr>
<td>i</td>
<td>picar</td>
<td>“prick”</td>
</tr>
<tr>
<td>o</td>
<td>bota</td>
<td>“boot”</td>
</tr>
<tr>
<td>u</td>
<td>fumo</td>
<td>“smoke”</td>
</tr>
</tbody>
</table>
4.2 Formants

Figure I shows plots of the vowel formants for my speaker. The formant measurements were taken from vowels from a word list designed to include words featuring all nine possible oral vowel pronunciations. Nasal vowels have been excluded from the bark scale because their formant values are equivalent to their corresponding oral vowels; for example, formant values for /ɨ/ correspond to those of /a/. The formant values were determined using PRAAT acoustic analysis. The axes are labelled in Hz and show F1 and F2, excluding F3.

Figure I.

The values for the three formants of each vowel are shows in Table II.
Table II.

<table>
<thead>
<tr>
<th>VOWELS</th>
<th>F1</th>
<th>F2</th>
<th>F3</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>325.3</td>
<td>2768</td>
<td>3642</td>
</tr>
<tr>
<td>e</td>
<td>433.8</td>
<td>2398</td>
<td>3035</td>
</tr>
<tr>
<td>ɛ</td>
<td>621.5</td>
<td>2339</td>
<td>3079</td>
</tr>
<tr>
<td>a</td>
<td>799.1</td>
<td>1303</td>
<td>3420</td>
</tr>
<tr>
<td>u</td>
<td>280.9</td>
<td>991.6</td>
<td>n/a</td>
</tr>
<tr>
<td>o</td>
<td>443.8</td>
<td>1006</td>
<td>2620</td>
</tr>
<tr>
<td>ɔ</td>
<td>532.6</td>
<td>976.8</td>
<td>3050</td>
</tr>
<tr>
<td>i</td>
<td>251.3</td>
<td>2606</td>
<td>3198</td>
</tr>
<tr>
<td>u</td>
<td>621.5</td>
<td>1791</td>
<td>3153</td>
</tr>
</tbody>
</table>

4.3 Vowel Distinctions

As mentioned previously, Iberian Portuguese vowels are split between plain vowels and nasal vowels and vowel pronunciation is stress dependent (Azevedo, 2009, p. 38). Knowing this, I calculated the mean vowel duration for all five oral vowels with open and closed pronunciations as well as nasal vowels. I found that when in not syllable initial positions, nasal vowels tend to be short than oral vowels. Table III featuring the mean duration in milliseconds (ms) of all syllables based on my speaker’s pronunciation is below.
Table III.

<table>
<thead>
<tr>
<th>Vowel</th>
<th>Duration</th>
<th>Example</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>/a/</td>
<td>302.9</td>
<td>[va]</td>
<td>305.1</td>
</tr>
<tr>
<td>/ɛ/</td>
<td>224.6</td>
<td>[bebe]</td>
<td>208.0</td>
</tr>
<tr>
<td>/e/</td>
<td>205.6</td>
<td>[mezə]</td>
<td>155.3</td>
</tr>
<tr>
<td>/i/</td>
<td>308.8</td>
<td>[mi]</td>
<td>332.9</td>
</tr>
<tr>
<td>/ɨ/</td>
<td>202.4</td>
<td>[pikar]</td>
<td>131.8</td>
</tr>
<tr>
<td>/o/</td>
<td>205.3</td>
<td>[kor]</td>
<td>226.4</td>
</tr>
<tr>
<td>/ɔ/</td>
<td>178.1</td>
<td>[kɔɾdɐ]</td>
<td>133.1</td>
</tr>
<tr>
<td>/u/</td>
<td>190.4</td>
<td>[tubu]</td>
<td>156.6</td>
</tr>
<tr>
<td>/ũ/</td>
<td>86.0</td>
<td>[kẽtar]</td>
<td>97.6</td>
</tr>
<tr>
<td>/ẽ/</td>
<td>122.0</td>
<td>[tẽpu]</td>
<td>119.0</td>
</tr>
<tr>
<td>/ɨ/</td>
<td>193.0</td>
<td>[pɨtar]</td>
<td>119.0</td>
</tr>
<tr>
<td>/õ/</td>
<td>131.3</td>
<td>[kõtar]</td>
<td>119.0</td>
</tr>
<tr>
<td>/ũ/</td>
<td>139.0</td>
<td>[mũdu]</td>
<td>146.0</td>
</tr>
</tbody>
</table>

In order to visually represent the differences between nasal and oral vowels, Figure II and Figure III features a spectrogram of the Iberian Portuguese words [kɐdɐ] and [kẽtar]; the former contains an oral /ʊ/ while the later contains its nasal counterpart /ũ/. 
Figure II.

[këtər] spelled “cantar” in Iberian Portuguese

Figure III.

[kẽdɐ] spelled “cada” in Iberian Portuguese
As can be seen from the spectrograms, oral vowels and their nasal counterparts, despite having similar formant values, differ greatly in vowel length. Nasal vowels are significantly shorter than oral vowels. In this example, the nasal vowel /ũ/ is 47.3 ms shorter than the oral vowel /ɐ/. This is true for all oral vowels and their nasal counterparts. Nasal vowels will always be shorter than oral vowels in the same or similar environments.

A note on nasal vowels: It is important to distinguish between nasal vowels and nasalized vowels. Nasal vowels /ɐ̃/, /ẽ/, /ĩ/, /õ/, and /ũ/ occur phonemically while nasalized vowels occur as a result of coarticulation in which vowels preceding a nasal consonant become nasalized in some cases.

4.4 Diphthongs

Similarly, to the simple vowels, diphthongs in Iberian Portuguese are split between oral and nasal diphthongs. Diphthongs are not considered separate phonemes, rather the functions of two vowel phonemes combine into one, forming a diphthong. Nasal diphthongs nearly always appear at the end of the word while oral diphthongs occur at any point of the word with the same relative frequency. Iberian Portuguese diphthongs can also be classified as either falling or raising diphthongs (Azevedo, 2009, p. 30).

Interestingly, Iberian Portuguese also features a vowel feature known as a hiatus. A hiatus refers to adjacent vowels that are pronounced in separate syllables. Pronunciation of these vowels separately would be similar to an English glottal stop. An example of a word featuring a hiatus would be [kɾiẽnsẽ].

4.5 “E Caduc”

Iberian Portuguese features a near-close near-back unrounded vowel in some unstressed syllables. The IPA does not feature a symbol for this sound so the [ɨ] featured in the vowel chart
is what is traditionally used to represent this sound. The e caduc is an elided vowel. Consider the spectrograms below which distinguish the difference between /i/ and /ɨ/.

*Figure IV. /ɨ/*
5. Consonants

5.1 Overview

Overview: The consonant inventory of Iberian Portuguese is shown in Table IV. I will begin by presenting a general overview of each classification of consonants and their function within Iberian Portuguese before examining the voiced onset time (VOT) for each consonant. I will then provide a more detailed description of the Iberian Portuguese guttural /ʁ/. 
Iberian Portuguese is composed of 19 consonant phonemes and can be further divided into five distinct categories: stops, nasals, fricatives, laterals, and flaps (Azevedo, 2009, p. 42). Glides, by virtue of functioning as consonants phonologically and vowels phonetically, have been included in the consonant chart for simplicity but are excluded from the 19 phonemes I will be describing. These phonemes occur in five places of articulation: bilabial, labio-dental, alveolar, post-alveolar, palatal, velar, and uvular. The bilabial consonant phonemes are /p/, /b/, and /m/. The labio-dental phonemes are /f/ and /v/. The alveolar phonemes are /t/, /d/, /n/, /s/, /z/, /l/, and /ɾ/. The post-alveolar phonemes are /ʃ/ and /ʒ/. The palatal phonemes are /ɲ/ and /ʎ/. The velar phonemes are /k/ and /g/, and the uvular phonemes are /ʁ/.

Iberian Portuguese makes a distinction between voiced and voiceless phonemes, and aspirated and unaspirated sounds. Voiceless phonemes are as follows—/p/, /t/, /k/, /f/, /s/, and /ʃ/. Voiced phonemes are as follows—/b/, /d/, /g/, /v/, /z/, /ʒ/, /m/, /n/, /l/, /ɾ/, /j/, /w/, /l/, /ʃ/, /ʒ/, /w/, and /ʁ/. Though there is a distinction between voiced and voiceless stops, voiced stops and in particular voiced velar stops, have a tendency to become devoiced. In the following section, spectrograms will illustrate which types of stops are usually devoiced (Pape, 2014, p. 14). Also,
of interest, Iberian Portuguese speakers do not usually aspirate syllable-initial stops as in English, but an in-depth analysis of the environments in which aspiration occurs is outside of the scope of this undergraduate paper.

5.2 Duration Measurements

*VOT*: Voiced Onset Time (VOT) allows us to determine whether a stop is voiced or devoiced. Stops in Iberian Portuguese occur at three places of articulation, bilabial, dental, and velar, and are further subdivided between oral and nasal stops. At each of these places syllable-initial places, there is an unaspirated stop as can be seen based on the VOT measurements below and lack of discernable bursts on the spectrograms. Using VOT measurements, it is also possible to distinguish cases in which typically voiced phonemes such as /b/ become devoiced. While I will provide an example of devoicing in this section, I will explain the phonological process behind devoicing in the phonological section of this paper.

*Table V*. VOT of syllable-initial stops for both voiced and voiceless sounds. VOT is given in milliseconds (ms).

<table>
<thead>
<tr>
<th>Word</th>
<th>Consonant Phoneme</th>
<th>VOT</th>
</tr>
</thead>
<tbody>
<tr>
<td>bolo</td>
<td>/b/</td>
<td>123.6</td>
</tr>
<tr>
<td>pintar</td>
<td>/p/</td>
<td>8.0</td>
</tr>
<tr>
<td>tejo</td>
<td>/t/</td>
<td>36.3</td>
</tr>
<tr>
<td>do</td>
<td>/d/</td>
<td>113.8</td>
</tr>
<tr>
<td>captar</td>
<td>/k/</td>
<td>46.4</td>
</tr>
<tr>
<td>glande</td>
<td>/g/</td>
<td>97.6</td>
</tr>
</tbody>
</table>
Notice the difference in VOT between voiced and unvoiced stops. Voiced stops in Iberian Portuguese nearly always have a VOT over 50 ms while voiceless stops nearly always have a VOT below 50 ms. This 50 ms threshold is a simple way to determine whether a stop is voiced or devoiced. However, devoicing is a fairly common phenomenon in Iberian Portuguese. Figure VI below illustrates a word in which the syllable-initial voiced stop /b/ becomes devoiced.

*Figure VI.*

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Figure VI is a spectrogram of the Iberian Portuguese word [bɔtɐ]. Lack of clear burst is evident indicating that /b/ is unaspirated in this word. The VOT for [bɔtɐ] is 23.4 ms. This time is under the 50 ms threshold needed to classify a stop as voiceless. Because /b/ is classified as a voiced sound in most environments; this is evidence that /b/ is a sound that can and does become
devoiced in Iberian Portuguese. This devoicing phenomenon occurs under certain conditions which I will elaborate on in the phonological section. For the time being, it is important to keep in mind that voiced stops do become voiceless in some environments.

5.3 The Guttural /ʁ/

The guttural /ʁ/ is a rhotic phoneme not featured in English. This sound, rather than being produced with the front of the vocal tract, is pronounced using the back of the vocal tract as a voiced uvular fricative. In Iberian Portuguese, the guttural /ʁ/ has almost completely replaced the alveolar and uvular trills, particularly in cities, and makes up one of two rhotic phonemes. Figure VII presents a spectrogram of the word [ʁumɐ̃] where the /ʁ/ is highlighted in red. We can compare Figure VII with Figure VIII which features the word [kɾiɐ̃nsɐ̃] which begins with the phoneme /ɾ/ instead. By comparing the spectrograms, it is easier to see the differences between both rhotic consonants.
Figure VII.

Figure VIII.
6. Phonology

6.1 Overview

The phonology of Iberian Portuguese contains aspects unique to this dialect of Portuguese. In this section, I will be focusing on three phonological aspects—syllable-initial stop devoicing, rhotics, vowel raising (Mateus and Andrade, 2009, p. 121), and consonant clusters. Using spectrogram evidence, I will explain how and in which environments these phonological processes occur.

6.2 Devoicing

Iberian Portuguese speakers have a strong tendency to devoice voiced syllable-initial stops under certain conditions. According to my own data as well as literature on this topic, voiced stops and in particular voiced velar stops, have a tendency to become devoiced when preceded by low vowels pronounced with a more posterior place of articulation. In addition to this, the voiced dental stop /d/ often becomes devoiced in a syllable-initial position when followed by high vowels (Pape and Jesus, 2014, p. 1568). Unfortunately, I was not able to gather sufficient data from my recordings nor available literature to come to a conclusion about when exactly devoicing occurs as I did not exceptions to the guidelines above, and thus, I was not able to write a rule for this phonological process.

6.3 Rhotics

Iberian Portuguese features two rhotic sounds, the uvular or “guttural” /ʁ/ as was previously discussed, as well as the alveolar flap /ɾ/. These phonemes are not interchangeable, and their occurrence is predictable. My data shows that when a rhotic is needed in a word, /ɾ/ occurs in word-final positions, syllable-final positions, and as the second consonant in a
consonant cluster. In word-initial or syllable-initial preceded by a syllable-final consonant positions, the rhotic is realized as /ʁ/. Equally important, /ʁ/ is the only rhotic that can follow a syllable with a nasal vowel (Mateus and Andrade, 2009, p. 52).

Figures IX and X below are spectrograms of two Iberian Portuguese words containing a rhotic (highlighted in red) which follows the predictability rules outlined above. Figure IX features the word [ʁjaɫ] and Figure X is a representation of the word [pjɔɾ]. As can be seen, the rhotic in Figure IX is word initial, from this word-initial position and the lack of voicing bars present at the beginning of the sound, we can conclude that the rhotic in [ʁjaɫ] is /ʁ/. In Figure X, the rhotic is word-final and features voicing bars visible in the bottom portion of the spectrogram, from this it is understood that the rhotic in [pjɔɾ] is /ɾ/.

*Figure IX.*
In order to understand how these rhotic rules function, it is important to understand what the underlying form is for words featuring rhotics in Iberian Portuguese. According to previous research from (Mateus and Andrade, 2009, p. 53), words such as [kɐu] and similar words have alveolar flaps in the coda of the first syllable of the underlying form of the word which is erased, as well as a flap in the onset of the second syllable of the word. Because we know of this existence of this underlying coda, we can assume that the underlying rhotic is /ɾ/. Thus, the order of the rules is as follows: /ɾ/ occurs in all environments except (1) word-initially and (2) after a nasal vowel. We can represent these rules using the formula below:

\[ [+ \text{cons}, - \text{cont}, + \text{son}, + \text{voiced}, +\text{alveolar}] \rightarrow [- \text{son}, + \text{uvular}] / \{#_, \text{+syll, +N]_}\} \]

Using Optimality Theory (OT), we can write this rule in a constraint-based form. Consider the example in Table VI using the word [ʁjaɫ]. We know the alveolar flap is unmarked
because it is the underlying phoneme in words with rhotics, so at least one constraint must reflect changes in the flap. We can start our analysis by choosing a markedness constraint and a faithfulness constraint to test against our words. For this rule, I chose IDENT, no changes permitted in the manner or place of articulation, and *FLAP, no flaps allowed. IDENT is the faithfulness constraint and *FLAP is the markedness constraint.

\textit{Table VI.}

<table>
<thead>
<tr>
<th>/ɾjɑl/</th>
<th>*FLAP</th>
<th>IDENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. ɾjɑl</td>
<td>![</td>
<td>*</td>
</tr>
<tr>
<td>2. ʁjɑl</td>
<td>![</td>
<td>*</td>
</tr>
</tbody>
</table>

Based on the table above, we can see that we begin with the underlying form [ɾjɑl]. As we test [ɾjɑl] against *FLAP and IDENT, two things become obvious. First, [ɾjɑl] does not violate IDENT. This is because the alveolar flap /ɾ/ remains the same in Version 1: [ɾjɑl]. Because the phoneme remains the same, there is no change in manner or place of articulation and thus, IDENT is not violated. However, [ɾjɑl] does violate *FLAP because this constraint indicates that flaps are not permitted in words. As evidence by the alveolar flap in [ɾjɑl], this word does contain a flap and as such, it does violate *FLAP.

As we look at Version 2 of the word— [ʁjɑl] —we can see how it compares to Version 1. We see that in [ʁjɑl], the alveolar flap has been replaced with the uvular /ʁ/. Knowing this, we can say that IDENT has been violated because both the manner and place of articulation have been changed as a result of this phonemic switch. [ʁjɑl] does not violate *FLAP because it features no alveolar flap. Because [ʁjɑl] is the faithful word and [ɾjɑl] lost, we can conclude that *FLAP is the more highly ranked constraint and takes precedence over IDENT. So, the beginning of our OT rule can be written as:

\textit{*FLAP} \gg \textit{IDENT}
We know that /ɾ/ does not occur in only two environments, both word-initially and after a nasal vowel. *FLAP >> IDENT fulfills the first part of our constraints and indicates that /ʁ/ occurs word-initially. We can continue to build off of this initial constraint to create more constraints that fulfill the rest of the rules. Consider the example in Table VII below:

Table VII.

<table>
<thead>
<tr>
<th>/vet/</th>
<th>IDENT WORD FINALLY</th>
<th>*FLAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. veʁ</td>
<td>!</td>
<td></td>
</tr>
<tr>
<td>2. ver</td>
<td></td>
<td>!</td>
</tr>
</tbody>
</table>

/veʁ/ is the underlying form of a word. Knowing that in Iberian Portuguese, words with rhotics can use either /ɾ/ or /ʁ/, we can determine that the true form of the word is either /veʁ/ or /vet/. To determine which form of the word is the faithful one, we compare *FLAP and a new faithfulness constraint— IDENT WORD FINALLY. Looking at /veʁ/ first, it can be seen immediately that the word does not violate *FLAP because /ʁ/ takes the place of /ɾ/ word-finally. However, because /ʁ/ has been substituted for /ɾ/ as we can see by comparing /veʁ/ to the underlying form /vet/, we know that /veʁ/ does violate IDENT WORD FINALLY.

Looking at /vet/, we can determine that this form does violate *FLAP because it does feature /ɾ/ word-finally. However, the ending of /vet/ remains identical to that of the underlying form; there is no change whatsoever. For this reason, we can determine that /vet/ does not violate IDENT WORD FINALLY. Because /vet/ is the faithful form of the word, we know that IDENT WORD FINALLY must be ranked higher than *FLAP because the losing form of the word, /veʁ/, does not violate *FLAP but does violate WORD FINALLY. Thus, we can now say:

IDENT WORD FINALLY >> *FLAP >> IDENT

Now, these set of rules tell us that /ʁ/ can occur word-initially and that /ɾ/ can occur word-finally. We know that /ʁ/ is the allophone of /ɾ/ because it is the underlying phoneme, so
our concern is no longer to rank constraints that tell us when /ɾ/ occurs but rather, find constraints that tell us when /ʁ/ outside of word-initially. Table VIII below includes a new markedness constraint, *FLAP POST NASALLY, and a new faithfulness constraint, IDENT POST NASALLY, which will be compared to each other and against *FLAP. By ranking these constraints, we should be able to determine every environment in which /ʁ/ occurs.

Table VIII.

<table>
<thead>
<tr>
<th>/ ẽedu/</th>
<th>*FLAP POST NASALLY</th>
<th>IDENT POST NASALLY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. ẽedu</td>
<td>*!</td>
<td></td>
</tr>
<tr>
<td>2. ẽxedu</td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>

Consider the underlying form /ẽedu/ which features /ɾ/ after a nasal vowel. Version 1 of the word is also /ẽedu/. Immediately, we can see that /ẽedu/ does not violate IDENT POST NASALLY because it does not undergo any change in rhotic from the underlying form. That being said, /ẽedu/ violates *FLAP POST NASALLY because it features a flap after a nasal vowel which according to this markedness constraint, is not permissible in Iberian Portuguese.

Version 2 of the word, /ẽxedu/, violates IDENT POST NASALLY. This is the case because IDENT POST NASALLY stipulates that there cannot be any change in manner or place of articulation after a nasal vowel. In /ẽxedu/, /ɾ/ becomes /ʁ/ after /ẽ/ indicating that this constraint has been violated. Lastly, /ẽxedu/ does not violate *FLAP POST NASALLY because there is no flap after the nasal consonant consonant /ẽ/. Because /ẽxedu/ is the faithful form of the word and /ẽedu/ loses, we know that *FLAP POST NASALLY must be the highest ranked constraint out of the two in Table XXX followed by IDENT POST NASALLY. Thus, our final OT constraint ranking can be written as follows:

*FLAP POST NASALLY >> IDENT POST NASALLY, IDENT WORD FINALLY >> *FLAP >> IDENT
The rules above cover what was outlined at the beginning of Section 6.3. In words, they indicate that /ɾ/ occurs in all environments in which a rhotic is needed except word-initially and after a nasal vowel. IDENT POST NASALLY and IDENT WORD FINALLY are equally ranked faithfulness constraints. Words in Iberian Portuguese never contain a rhotic post-nasally and word-finally, so these constraints never need to compete against each other. Ultimately, by creating constraints that indicate in which environments /ʁ/ always occurs in, we are able to determine in which environments /ɾ/ occurs in.

6.4 Raising

As mentioned in the phonetics section, vowels can be either stressed or unstressed. Multi-syllabic words can be either post-stressed or pre-stressed meaning that they occur either before or after the primary stressed syllable. When unstressed vowels are pre-stressed, they go through a process called raising (Azevedo, 2005, p. 41). In a stressed position, the Iberian Portuguese phonological system is characterized by seven vowels, /i, e, ɛ, a, ɔ, o, u/. These seven vowels are reduced to four vowels in an unstressed position, /i, ɨ, ɐ, u/. All unstressed pre-stressed vowels are raised before alveolar, palato-alveolar, and palatal consonants (Azevedo, 2009, p. 40) to the highest point they can reach. For example, /e/ and /o/ when unstressed are specified as being [+high] because they can be raised very high, but unstressed /a/ can only be marked as [-low] because it has been raised to the point of no longer being a low vowel but can never truly be a high vowel despite being raised to its highest point (Mateus and Andrade, 2009, p. 96).

Generally, the rule is as follows, [-back] [+round] oral vowels are higher when unstressed. In essence, all [-high] vowels become [-low] vowels (334). Nasal vowels, by virtue of always being non-low do not trigger the raising rule.
We can formalize our raising rule as follows:

\[ [+ \text{syll}, - \text{high}] \rightarrow [+ \text{high}]/ \_ \_ [- \text{nasal}] \]

The following spectrograms allow us to compare the vowel positions between the stressed /a/ and the unstressed raised /ɐ/. These words were recorded by my speaker, F.L.

*Figure XI. [ka]*
For clarity, I have indicated on the spectrograms where the first, second, and third formants lie for each word. In Figure XI, where the vowel /a/ is stressed, formants 1 and 2 appear to be very close together while formant 3 is positioned significantly higher than 1 and 2. In Figure XII, where the vowel /ɐ/ is in a pre-stressed unstressed position, formants 1 and 2 have become more distanced and formant 2 in particular has gotten closer to formant 3 than previously seen in Figure XI. It is important to note that both words began with the phoneme /k/, so formants for both words are starting from the same relative position. Thus, we can see based on the distanced formant values in Figure XII that the first syllable in [kɐdɐ] has been raised due to its unstressed and pre-stressed position.
6.5 Consonant Clusters

Iberian Portuguese does not permit any random combination of consonants to function as a consonant cluster in a word. Consonant clusters are permitted in the same syllable both word-initially and word-medially when the consonant is followed by a single liquid in the form of the alveolar tap /ɾ/ or lateral /l/. This rule functions in accordance with the Sonority Principle. Sonority levels are as follows, vowels > liquids > stops. The stop + liquid + vowel combination ensures that sonority steadily increases until reaching its peak at the vowel sound before decreasing at the next syllable. That being said, not all consonants are eligible to begin a consonant cluster. All stops may begin a consonant cluster but only fricatives /v/ and /f/, non-coronal fricatives, may begin a consonant cluster (Mateus and Andrade, 2009, p. 114). Any other combination of sounds outside of stops + liquids and fricatives + liquids rarely exist in Portuguese. This being said, some exceptions do occur which will be discussed later.

Unfortunately, the Sonority Principle does not explain why two consonants, or two fricatives of the same sonority could not both precede a liquid in tandem. If the Sonority Principle were the only constraint behind consonant cluster creation, then there should be no reason why consonant clusters such as /fml/ cannot exist since nasals have a sonority level lower than liquids’ but higher than that of fricatives. Thus, the Dissimilarity Condition comes into play here (Mateus and Andrade, 2009, p. 114).

The Dissimilarity Condition stipulates that consonants with the same degree of sonority cannot be placed adjacently in a consonant cluster. Based on the Sonority Principle and the Dissimilarity Condition, we can conclude that stops and liquids have the preferred distance in sonority in Iberian Portuguese; non-coronal fricatives are also acceptable in cluster onset positions because of their sonority similarity to stops. This would explain why, by and large,
other combinations of consonants are not acceptable in Iberian Portuguese. According to (Mateus and Andrade, 2009), any other non-regular consonant clusters that violate the Sonority Principle can be explained by a vowel deletion between the two consonants that make up the cluster. For example, consider the following:

The word for “small” in Iberian Portuguese is orthographically spelled “pequeno” but the first syllable, despite featuring a vowel in its orthographic form, is sometimes pronounced with a consonant cluster as [pkenu]. Many other words also function in this manner, sometimes deleting a vowel forming a non-regular consonant cluster. This is presumed the case for words which are orthographically written without the in-between vowel. For example, [pnew] spelled “pneu” orthographically features a deleted underlying vowel which explains why this consonant cluster, and others like it, do not subscribe to the same rules outlined by the Sonority Principle and the Dissimilarity Condition.

We can write a vowel deletion rule as follows:

\[ [+\text{syll}, -\text{stress}] \rightarrow 0/[-\text{syll}, +\text{stop}] \_ [-\text{syll}, +\text{stop}] \]

There may be other rules that prevent this from happening in certain environments, but that is beyond the scope of this paper.

To get a better sense of what regular consonant waveforms look like, the spectrograms below show words which contain a consonant cluster. Figure XIII is the word “estreia” which contains a regular mid-syllabic “tr” cluster. Figure XIV is the word “plano” which contains a regular word-initial “pl” cluster. Most importantly to note is that the spectrograms illustrate words in which the consonant cluster belongs to the same syllable, and the second consonant of the cluster is a liquid.
Figure XIII.

Figure XIV.
7. Conclusion

By comparing Iberian Portuguese to American English as I created my word lists and consulted external research, I was able to focus in this paper on the aspects of Iberian Portuguese that are most dissimilar to American English. I considered the guttural /ʁ/ in particular to be an important phonetic and phonological element to focus on. In addition to its nonexistence in American English, in many other dialects of Portuguese around the world, the alveolar trill has not yet been replaced by the guttural /ʁ/. Being able to document firsthand the ways in which Iberian Portuguese has slowly began to evolve separately from other close dialects was difficult but rewarding, and I believe it is important to continue to document the evolution of Iberian Portuguese as less common phonemes begin to disappear and become replaced by other phonemes in the language. To summarize the rhoticity rules in Iberian Portuguese, we can say /ʁ/ (the alveolar flap) occurs in all environments except (1) word-initially and (2) after a nasal vowel.

Analyzing syllable-initial devoicing of stops proved to be an unexpected challenge. As I mentioned in the phonological section, I was ultimately unable to devise a rule. This was due to difficulties I encountered both in the analysis of my available data as well as the lack of information I could find about devoicing both on the Internet and in books. I could not find any consistent pattern in my data for when syllable-initial stops become devoiced. While I have no doubt that this phonological process does follow a rule, I could not confidently create one based on the materials I had available. As of now, this remains a question I have, but I am open to exploring this topic again in the future.

In terms of consonant clusters, the sheer volume of possible exceptions to the rule in Iberian Portuguese created difficulties for me. Because I still do not have much experience with
rule creation or phonological analysis, I quickly realized that it would be impossible for me to create a vowel deletion rule that accounted for any number of exceptions possible in the language. Much of the information I used to analyze consonant clusters was drawn from external sources rather than my own data which made it much harder to analyze since I neither had access to the raw data sets nor was entirely familiar with the terminology or processes that were being referred to. As such, I opted to write a vowel deletion for which I had sufficient data rather than write a comprehensive vowel deletion rule that included any time a vowel is deleted in Iberian Portuguese. Like with the devoicing rule, I would like to explore Iberian Portuguese consonant clusters further and understand the rules that govern them more in-depth. Unfortunately, I felt that that would be too much to tackle for this paper. If anything, consonant clusters could probably be a paper of their own.

Vowel raising was the most interesting phonological rule that I analyzed. As a stress-timed language, I knew from the start of this project that I needed to analyze at least one aspect of the stress system. Vowel raising attracted my attention the most because I was able to notice the influence of this rule right away by looking at my word lists in IPA and listening to my speaker. Like the rhoticity rule, the raising rule is extremely straightforward. There are few if any exceptions to it in the entire Iberian Portuguese language which made analyzing and understanding this rule much simpler. In the most basic terms, pre-stressed vowels are always raised. Understanding this simple concept made it significantly easier for me to understand other stress-related phonological processes in this language, none of which I analyzed in this paper due to time constraints.

For my first time ever doing a project like this, I think I did very well and am proud of my work. However, if I had to do this again, there are definitely things I would choose to do
differently. I think most of my troubles stemmed from the fact that my word lists were generally very disorganized. With the exception of my vowel-focused word list which divided groups of words by their target vowel, the other groups of words I included had no clear division. They were just words I had found online that I thought would fit and as such, I just threw them into the word list without fully understanding why they were relevant to my research. As can be seen by my lack of devoicing rule, not organizing my data meant that I did not have enough words featuring certain phonological processes to be able to come up with rules for these processes. Had I put more thought and deliberate energy towards crafting my word lists, I may have been able to notice a stronger devoicing pattern. For reference, I will include my word list in the appendix.

I also had difficulty finding outside resources to guide me through the phonological processes. Most of the existing literature on Portuguese focuses solely on Brazilian Portuguese. I was able to find plenty of resources about Brazilian Portuguese phonology but there was very little available elsewhere. At Clapp Library, there was only one book about Portuguese linguistics available and it did not even focus on European Portuguese. The lack of available information online and in books made it difficult for me to come to any certain conclusions. I did the best that I could with the data I had and the very limited outside information and was able to come to conclusions I would say are solid and correct, but I have no doubt in my mind that had I had more access to resources about Iberian Portuguese, that I would have come up with significantly more robust conclusions for each phonological process.

Along the same vein, the books and papers I was able to access often referenced rules and processes that I was not familiar with nor was able to learn more about since additional information about those processes within Iberian Portuguese was not available. I interpreted the
things I did not understand as best as I could and built off of them to create my own set of rules. This explains why I did not go more into depth about ideas such as the Dissimilarity Condition when analyzing consonant clusters, or alveolar flaps in the coda of the first syllable of the underlying form of words when talking about rhoticity rules. I myself have a very rudimentary understanding of these ideas and I do not feel I understood them well enough to explain them in more than the minimal detail I went into.

Because I was not able to come to any conclusion for devoicing and created a raising rule with gaps in it, I think I would be interested in returning to these two processes in the future, perhaps as a thesis project, and seeing if I could do more research to explain these processes and write more cohesive rules. Given the abundance of literature about Brazilian Portuguese, this paper would be a good starting point to begin conducting a comparative analysis between Brazilian Portuguese and Iberian Portuguese. In fact, I initially also had a second speaker, a Brazilian woman who recorded the same word lists as my Portuguese speaker. With that data still stored, I do have enough material to begin this analysis at any point.

Ultimately, this proved to be an extremely challenging but highly rewarding project. I am grateful that I had the opportunity to spend the semester diving into a topic which interests me and believe that I gained research and analysis skills that will be applicable in any future project I work on. I have never worked on a similar project so I can confidently say that this project pushed me to my intellectual limits but in turn showed me how to work through uncharted waters and rely on my own data and stored knowledge. I am a more confident researcher, writer, and student because of this phonetic and phonological analysis, and I look forward to returning to this project in the future.
Appendix

The sentences in which words from the word list were inserted and said by my speaker were:

- “Diga ____ de novo” for words beginning with a consonant.
- “Você diz ____ de novo” for words beginning with a vowel.

The lists are as follows:

WORD LIST 1:

1. Beiço
2. Âmbar
3. Sob
4. Cabeça
5. Sobre
6. Cedo
7. Idade
8. Dedo
9. Lenda
10. Digo
11. Ande
12. Balde
13. Fado
14. Café
15. Gato
16. Signo
17. Bingo
18. Guerra
19. Fogo
20. Figueira
21. Cor
22. Dica
23. Quente
24. Kiwi
25. Lua
26. Alô
27. Mal
28. Lhe
29. Velho
30. Mês
31. Somo
32. Não
33. Sono
34. Nhoque
35. Sonho
36. Pó
37. Sopa
38. Apto
39. Rio
40. Carro
41. Enrascado
42. Pör
43. Porto
44. Por favor
45. Frio
46. Caro
47. Por acaso
48. Saco
49. Isso
50. Braço
51. Máximo
52. Escola
53. as portas
54. Dez
55. Texto
56. Chave
57. Achar
58. Xarope
59. Baixo
60. Sushi
61. Tchau
62. Atchim
63. Tip
64. Ritmo
65. Ponte
66. Tempo
67. Átomo
68. Vela
69. Livro
70. Já
71. Gente
72. Rasgo
73. Os meus
74. Casa
75. Os amigos
76. Doze
77. Existir
78. Alzheimer
79. Jaime
80. Dá
81. Lámen
82. Àquele
83. Falámos
84. Falamos
85. Andaime
86. Câmera
87. Bug
88. Abelha
89. Venho
90. Jeito
91. Meto
92. Sê
93. Prêmio
94. Prêmio
95. Meta
96. Sê
97. Émerson
98. Cafezinho
99. Si
100. Dia
101. País
102. Suíço
103. Rainha
104. Formosa
105. Formosos
106. Avó
107. Somente
108. Antônio
109. António
110. Avó
111. Formoso
112. Rua
113. Lúcido
114. Saúde
115. Taça
116. Manhã
117. Maior
118. Aquele
119. Da
120. Camões
121. Caveira
122. Incrível
123. Semáforo
124. Jure
125. Pequeno
126. Se
127. Júri
128. Meandro
129. E
130. Doe
131. Hospital
132. Sortudo
133. Evacuar
134. Boneco
135. Vi-o
136. Voo
137. Frio
138. João
139. Vila-Chã
140. Rio
141. Chã
143. Douro
144. Saia
145. Pais
146. Frequent
147. Quão
148. Mau
149. Cauã
150. Cabrunco
151. Trocadilho
152. Lagartixa
153. Saruê
154. Exata
155. Enxada
156. Caixa
157. Xadrez
158. Ficha
159. Coco
160. Cocó
161. Cocoricó
162. Corococó
163. Au au au
164. Pão
165. Pau

**WORD LIST 2:**

Consonants:
1. Mana
2. Manha
3. Sono
4. Sonho
5. Tina
6. Tinha
7. Hispânia
8. Espanha
9. Caço
10. Caso
11. Assar
12. Azar
13. Ouça
14. Ousa
15. Rixa
16. Rija
17. Acha
18. Haja
19. Cheia
20. Geia
21. Mancha
22. Manja
23. Falo
24. Falho
25. Rola
26. Rolha
27. Mala
28. Malha
29. Vela
30. Velha
31. Alada
32. Alhada
33. Julho
34. Júlio
35. Galho
36. Gálio

Consonant Clusters:
1. Pneu
2. Gnomo
3. Psicologia
4. Obnóxio
5. Admirar
6. Ritmo
7. Estigma
8. Étnico
9. Captar
10. Pacto
11. Obter
12. Adquirir
13. Prato
14. Branco
15. Trapo
16. Droga
17. Cravo
18. Graça
19. Plano
20. Ablução
21. Atleta
22. Claro
23. Glande
24. Frito
25. Palavra
26. Flor
27. Estar
28. Esperar
29. Decifrar
30. Separar
31. Devedor
32. Merecer
33. Despegar
34. Desprezar

Vowels and Diphthongs:
1. Queixa
2. Papéis
3. Pai
4. Herói
5. Boi
6. Azúis
7. Viu
8. Deus
9. Véu
10. Pauta register
11. Mãe
12. Refém
13. Compôes
14. Muito
15. mão

Sequences of glides and vowels:
1. Frieza
2. Viés
3. Real
4. Criança
5. Pior
6. Mioma
7. Miúdo
8. Realeza
9. Adiantar
10. Miudeza
11. Suinicultura
12. Voador
13. Criais
14. Fiéis
15. Leão

Codas:
1. Par
2. Mal
3. Más
4. Parte
5. Falta
6. Peste
7. Mesmo
8. Esvaído
9. Esperado
10. Inesperado
11. Feliz
12. Infeliz

Alternations:
1. Fáceis
2. Sótão
3. Homem
4. Prendem
5. Falaram
6. Pairam

Empty Onset Positions:
1. Elvira
2. Elefante
3. Ermida
4. Esperado
5. Olhar
6. Ornar

WORD LIST #

Vowel A:

[a]:
1. Sal
2. Mal
3. Cá
4. Lá
5. Má
6. Vá
7. Dá

[ɐ]:
1. Mas
2. Na
3. Banana
4. Lama
5. Cada
6. Mana
7. Chama
Vowel E:

[ɛ]:
1. Tejo
2. Boné
3. Mel
4. Ela
5. Janela
6. Café
7. Bebê

[e]
1. Ver
2. Mesa
3. Pêra
4. Dê
5. Lê
6. Pedro
7. Letro

[i]
1. Parte
2. Me
3. Se
4. Lhe
5. De
6. Come
7. Nove

[V]
1. Fedelho
2. Tenho
3. Queijo
4. Venho
5. Ovelha
6. Joelho
7. Cereja

Vowel I:

[i]
1. Imitar
2. Vi
3. Picar
4. Rima
5. Si
6. China
7. Sílabas

[j]
1. Vai
2. Sais
3. Foi
4. Estreia
5. Cais
6. Dois
7. Mais

[i]
1. Utilizando
2. Vigiar
3. Dissimular
4. Eliminar
5. Distribuição
6. Aquisição
7. Exigir

Vowel O:

[ɔ]
1. Pó
2. Bota
3. Oral
4. Corda
5. Porta
6. Gola
7. Óltima

[o]
1. Doce
2. Pôr
3. Cor
4. Bolo
5. Calor
6. Estou
7. Dou

[u]
1. Do
2. Tubo
3. Uso
4. No
5. Falo
6. Portugal
7. Aluno

Vowel U:

[u]
1. Tudo
2. Uva
3. Rua
4. Nu
5. Usa
6. Tu
7. Fumo

[w]
1. Eu
2. Causa
3. Mau
4. Abriu
5. Saiu
6. Valeu
7. Céu

Nasal sounds:

[ẽ]:
1. Cantar
2. Romã
3. Ambos
4. Cambiar
5. Amputar
6. Manhã
7. Fã

[ẽ]
1. Enviar
2. Tempo
3. Encarnado
4. Sentinela
5. Vento
6. Empilhar
7. Fluente
[Ĩ]
1. Fim
2. Vinte
3. Impossível
4. Sim
5. Invisível
6. Inverno
7. Pintar

[õ]
1. Comprimido
2. Computador
3. Bombom
4. Som
5. Contar
6. Construir
7. Ponte

[ũ]
1. Um
2. Mundo
3. Fundar
4. Segundo
5. Nenhum
6. Atum
Bibliography


