HIATUS RESOLUTION IN SPANISH: AN EXPERIMENTAL STUDY

A Dissertation in

Spanish

by

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ABSTRACT

In Spanish, adjacent vowels across and within word boundaries are either in hiatus or form a diphthong. Generally, when either of the unstressed high vowels /i/ and /u/ appears next to any of the other vowels /e/, /a/, or /o/ the result is a diphthong (i.e., *puerta* ‘door’ > [pwer.ta], *miel* ‘honey’ > [mjel], and so on). All other combinations of the vowels /i, e, a, o, u/ (along with their orthographically-accented counterparts where possible, /í, é, á, ó, ú/) typically remain in separate syllables and are said to be in hiatus (i.e., *teatro* ‘theater’ > [te.a.tro], *poeta* ‘poet’ > [po.e.ta], *país* ‘country’ > [pa.is], etc.).

When speaking, however, vowel combinations that are supposed to be in hiatus often are not, such that *teatro* [te.a.tro], for example, is reported to be pronounced [tea.tro] or even [tja.tro]; *se aman* [se.a.man] might become [sea.man] or [sja.man], and so on—a phenomenon referred to as hiatus resolution. Previous accounts of hiatus resolution have claimed that there are a number of different possible phonetic outcomes of hiatus resolution with most authors finding that hiatus resolution typically results in a) the formation of a diphthong, b) vowel deletion, or c) maintenance of hiatus (Jenkins 1999, Aguilar 2003, Alba 2006, Diaz-Campos et al. 2006). Some of these same accounts have also suggested that there are a number of factors that predict when hiatus resolution is likely to happen. These include which specific vowels are found in the VV sequence, and which vowel(s) (if any) receive stress (Jenkins 1999). Other factors have been investigated as possible catalysts for either hiatus resolution or maintenance
including dialectal differences (Lipski 1994, Jenkins 1999, Hualde 2005, Alba 2006, Díaz-Campos et al. 2006, Michnowicz 2007, among others), individual speaker differences (e.g., Quilis 1981, Hualde et al. 2002), and differences in socioeconomic levels (e.g., Matluck 1995, Díaz-Campos et al. 2006), speech rate, and carefulness of speech. It is readily agreed upon that the faster one speaks and the less care with which one speaks the more likely vowel sequences in hiatus are resolved (e.g., Navarro-Tomás 1968b, Harris 1969, Jenkins 1999, Alba 2006).

An additional factor that has been reported to affect hiatus resolution is frequency. Although it has received less attention in the traditional hiatus/diphthong literature, recently some authors have found that more frequent vowel sequences, words, and/or word strings tend to show both a higher propensity to resolve hiatus, as well as to show a higher degree of vowel resolution (Jenkins 1999, Aguilar 2003, Alba 2006, Díaz-Campos et al. 2006). Both Jenkins (1999) and Alba (2006) found that the more frequent word strings in their corpora showed greater tendency to resolve hiatus and to resolve it to a greater degree (i.e., more resolution, or even more unlike the original vowels in hiatus). These findings claim that hiatus resolution is not brought on only by fast and/or careless speech but that frequency might also be playing an important role in predicting what (and to what degree) vowel sequences, words, or word strings will undergo hiatus resolution.

A 2x2 experimental investigation of 36 Mexican Spanish speakers was conducted to investigate via word-naming tasks the role of frequency (high vs. low) and speech rate (fast vs. slow) in the resolution of within-word [ea] sequences in Spanish. Words and vowel sequences were measured for overall word duration and VV
sequence duration. Formant data was also measured for the vowel sequences to
determine the nature of the resolution (diphthong-like, or not). The results reveal that
fast speech rate significantly modulated both temporal measures as well as formant
measures. The results also reveal a significant modulation of temporal and formant
measures for the high frequency words. Phonetic environment also significantly
affected the modulation of the vowel sequences. The nature of the resolution in the fast
speech condition and in the high frequency words was away from diphthongization and
toward vowel coalescence. The results suggest that frequency is, indeed, and important
factor in the resolution of [ea] sequences in Spanish, and lend support to a usage-based
model of phonology which posits that high-usage items are likely to undergo more
phonological modifications than their low-usage counterparts.
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Chapter 1

Diphthongization and hiatus in Spanish

1.1 Overview

In Spanish, vowels that appear together within a word or across word boundaries are either in hiatus or form a diphthong. In general, when either of the unstressed high vowels /i/ and /u/ appears adjacent to any of the other vowels /e/, /a/, or /o/ the result is a diphthong. For example:

**Within-word diphthongs**
1) *puerta* ‘door’ > [pwer.ta]
2) *miel* ‘honey’ > [mjel]

**Across word diphthongs**
3) *mi abuela* ‘my grandma’ > [mi.a.βwe.la] > [mja.βwe.la]
4) *tu amigo* ‘your friend’ > [tu.a.mi.vo] > [twa.mi.vo]

All other combinations of the vowels /i, e, a, o, u/ (along with their orthographically-accented counterparts where possible, /í, é, á, ó, ú/) generally remain in separate syllables and are said to be in hiatus\(^1\). Consider:

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\(^1\) There are cases of exceptional diphthongization and hiatus, both of which will be discussed later.
Within word

5)  *teatro* ‘theater’ > [te.a.tro]

6)  *poeta* ‘poet’ > [po.e.ta]

7)  *pais* ‘country’ > [pa.is]

Across word

8)  *se aman* ‘they love each other’ > [se.a.man]

9)  *comi otro* ‘I ate another’ > [ko.mi.o.tro]

In speech, however, vowel combinations that are supposed to be in hiatus often are not, such that *teatro* [te.a.tro], for example, is reported to be pronounced [tea.tro] or even [tja.tro]; *se aman* [se.a.man] might become [sea.man] or [sja.man], and so on—a phenomenon referred to as hiatus resolution. In the Spanish linguistics literature, different terms have been used when discussing the process, including *synalepha* (also *sinalefa*, or *synaloepha*) when it refers to across-word hiatus resolution, and *sineresis* when referring to within-word hiatus resolution. In pedagogical references, it is also known as *linking*. Some have also referred to it as a *sandhi* phenomenon (Hutchinson 1974). For the purposes of this dissertation we will simply refer to the process as hiatus resolution.

Previous accounts of hiatus resolution have claimed that there are a number of different possible phonetic outcomes of hiatus resolution. For example, most authors have found that hiatus resolution typically results in a) the formation of a diphthong, b) vowel deletion, or c) maintenance of hiatus (Casali 1997, Jenkins 1999, Aguilar 2003, Alba 2006, Barberia 2006, Díaz-Campos et al. 2006). Some of these same accounts
have also suggested that there are a number of factors that predict when hiatus resolution is likely to happen. These include so-called internal factors (Alba 2006), such as which vowels are found in the VV sequence, and which vowel(s) (if any) receive stress (Jenkins 1999). Additionally, other external factors have been investigated as possible catalysts for either hiatus resolution or maintenance. These include dialectal differences (Lipski 1994, Jenkins 1999, Hualde 2005, Alba 2006, Diaz-Campos et al. 2006, Bakovic 2007, Michnowicz 2007, and Morrison et al. 2007, among others), individual speaker differences (e.g., Quilis 1981, Hualde et al. 2002), familiarity and intentionality in the speech act (Aguilar et al. 1995a, 1995b), and differences in socioeconomic levels (e.g., Matluck 1995, Díaz-Campos et al. 2006).

There are an additional three factors that have been said to affect hiatus resolution, two of which have been widely accepted and rarely challenged as the most influential factors in determining both the absence/presence of hiatus and the degree to which hiatus is resolved. In fact, the three areas just mentioned previously (dialectal, individual and socioeconomic difference) presuppose that at least one of these factors to be present. These factors are speech rate and carefulness of speech2. It is readily agreed upon that the faster one speaks and the less care with which one speaks the more likely vowel sequences in hiatus are resolved (e.g., Navarro-Tomás 1968b, Harris 1969, Jenkins 1999, Alba 2006)3. That fast and/or less careful speech tend to facilitate hiatus resolution is not challenged here. However, it has yet to be well-documented if vowel

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2 These are frequently considered to be the same factor. That is, that fast speech is usually less careful by nature, while slower speech is generally considered to exhibit more careful speech.

3 Adda-Decker et al. 2005, also discovered a larger proportion of closed syllables in French spontaneous radio speech; further evidence of the highly variable nature of vowel production in speech, in general.
sequences in hiatus can also show a degree of resolution independent of speech rate and
carefulness of speech.

This leads us to the other factor that has been reported to affect hiatus
resolution: frequency. It has traditionally received much less attention in the literature,
and as such, is yet to be accepted as a major contributor to hiatus resolution in Spanish.
Recently, however, some authors have found that more frequent vowel sequences,
words, and/or word strings tend to show both a higher propensity to resolve vowels in
hiatus, as well as to show a higher degree of vowel resolution (Jenkins 1999, Alba
for instance, recently reported that words with the vowel sequence /ea/ were more
likely to be realized as a diphthong than less frequent vowel combinations. Both
Jenkins (1999) and Alba (2006) found that the more frequent word strings in their
corpora showed greater tendency to resolve hiatus and to resolve it to a greater degree
(i.e., more resolution, or even more unlike the original vowels in hiatus). These are
important findings that claim that hiatus resolution is not brought on only by fast and/or
careless speech but that frequency might also be playing an important role in predicting
what (and to what degree) vowel sequences, words, or word strings will undergo hiatus
resolution.

In fact, research has been carried out that suggests that the sounds of frequently-
used forms are affected by their use (e.g., Bybee 2001, Krug 2001). This is one of the
major hypotheses of a usage-based model of phonology; that language use affects the
language itself. This effect is often observable in sounds becoming of shorter duration
or otherwise reducing, such as in vowel quality (Bybee and Hooper, 2001, Bybee
Another primary hypothesis of a usage-based model is that language use affects the cognitive mechanism of language. That is, although humans have the innate capacity for grammar, it is actual use and experience with language that creates and modifies grammar. Accordingly, a usage-based model claims that when items in a language are more frequent, those items tend to be affected both on the surface (i.e., a word may become shorter in duration) and in the mental representation (i.e., words or word strings of higher frequency have stronger mental representations) (Bybee 2001). Consequently, high frequency items can affect the actual structure of a language. In fact, it is hypothesized they can even begin to influence the emergence of new categories or structures (e.g., Krug 2001).

If frequency does affect speech forms, then it would be reasonable to hypothesize that the frequency of the speaker’s experience with particular forms may play an additional role in modulating hiatus resolution—along with the effect of speech rate and carefulness of speech. It could be, for instance, that a highly-frequent word such as teatro ‘theater’ would prove to show more hiatus resolution (either due to a durational difference, reduction of one or both of the vowels, diphthongization, etc.) than a low-frequency counterpart, such as beato ‘devout’. Further, it could be that high-frequency teatro would show a higher degree of resolution regardless of the speech rate (e.g., even in a slow speech condition). These would be important findings that would contribute significantly to the literature of hiatus resolution, because despite all that is already known about hiatus resolution in Spanish, surprisingly little is known about how frequency interacts with speech rate and carefulness of speech.
Indeed, many of the studies that have contributed to what is known about hiatus resolution have three possible drawbacks. One is that most studies involved with hiatus resolution have dealt only with across-word vowel sequences (e.g., Jenkins 1999, Aguilar, 2003, Alba 2006). While those investigations have yielded important contributions to the body of Spanish vowel sequence research, within-word vowel sequences have yet to be investigated with such rigor.

The second drawback is that many studies have relied on impressionistic coding methods to analyze the vowel sequences. That is, researchers have relied on analyses done ‘by ear’ (see Alba 2006, for example). Briefly stated, this is somewhat problematic because such approaches are highly subjective. In other cases, objective spectral analyses were done to measure the duration of the vowel sequences (as in Jenkins 1999, Hualde et al. 2002), but there was no mention of vowel formant measurements, trajectories or transitions (also in Jenkins 1999). In fact Hualde et al. (2002) claim that the difference between hiatus and diphthongs is a durational difference (227). This, too, is problematic since differences in hiatus and diphthongs are not just temporal differences; indeed, it has been shown that there are also formant transition and trajectory differences between the hiatus and diphthongs (e.g., Aguilar 1999, 2003), as well as central frequency and relative intensities of formant values (Borzone de Manrique 1976, 1979). If one is claiming that vowel sequences in hiatus sometimes become diphthongs, for example, it would seem important to perform a
spectral analysis and compare it with words that already have a similar diphthong in them\textsuperscript{4}.

Finally, previous studies have relied largely on introspective data (Harris 1969, 1973)\textsuperscript{5}, personal self-recordings (e.g., Navarro-Tomás 1968b) or on recordings of natural speech (e.g., Jenkins 1999, Alba 2006). Again, although such data can yield interesting data, it can also prove to be problematic. One drawback Alba (2006) mentions of his own free-conversation data, for instance, is that there was no control that could be exerted over what the speakers did or did not say. In other words, speakers could have spoken at length without ever producing the desired token. Some have attempted to ameliorate this by performing laboratory-based experiments (e.g., Aguilar 1999, 2003). In order to control for the desired variables (vowel sequence, frequency, and speech rate) this current study will use speech recorded from experimental tasks for data collection.

This dissertation, then, seeks to augment what is already known about hiatus resolution by investigating word-internal instances of high- and low-frequency vowel sequences in hiatus. It also seeks to inquire about and test experimentally the widely-accepted notion that hiatus resolution is only a property of fast and/or careless speech. This will be accomplished by performing spectral analyses that include both temporal and formant measurements of high- and low-frequency within-word vowel sequences. Further, this dissertation endeavors to test experimentally for the possible modulating

\textsuperscript{4} See Planas 1988, for a discussion of the characteristic distribution of the frequencies of the five Spanish vowels.

\textsuperscript{5} Some have criticized Chomsky’s work (1965, among others) for using introspective data.
effect of frequency on within-word hiatus resolution in Spanish. In so doing, the research here is framed by the following specific questions:

a) Does frequency affect hiatus resolution in Spanish?
b) How do speech rate and frequency interact with hiatus resolution?
c) How does the phonetic environment affect hiatus resolution?
d) Is diphthongization a likely outcome of hiatus resolution?
e) Is the difference between hiatus and diphthongs merely temporal?

Based on the predictions set forth in a usage-based approach, it is hypothesized that words of higher frequency will show a greater degree of hiatus resolution than words of lower frequency. This is likely to be observable in both the shorter VV duration in high-frequency words as well as in the more diphthong-like formant transition between the vowel sequences. Spectrographic measurements will be taken of the duration of the vowel sequences as well as of formant (F1 and F2) trajectories in order to test for degree of hiatus resolution.

It is also hypothesized that, based on predictions set forth in usage-based models of phonology, words of higher frequency will show a greater degree of hiatus resolution regardless of speech rate. That is, that even in a slow speech condition high-frequency words will show more hiatus resolution than their low-frequency counterparts.

If substantiated, these hypotheses would make novel contributions to the body of knowledge on the resolution of vowel sequences in hiatus by providing data about the behavior of within-word VV sequences in hiatus, an aspect heretofore understudied.
Further, they would also challenge the claim that hiatus resolution is only a fast and/or careless speech phenomenon, as has been widely accepted. This would suggest that hiatus resolution can be modulated by frequency independent of rate or carefulness of speech. This would lend support to a usage-based model of phonology which posits that frequent items in a language often undergo reduction while at the same time strengthen their mental representations (Bybee 2001).

To that end, the remainder of this chapter is structured as follows: section 1.2 provides a description of diphthongs and hiatus in Spanish, including cases of exceptional hiatus and non-standard diphthongization. Section 1.3 discusses more recent investigations of hiatus resolution in Spanish, some of which have begun to address how a usage-based model is well-equipped to both describe and predict hiatus resolution in Spanish. Section 1.4 will further elaborate on the notion of emergence as it relates to grammar, providing the reader with the assumptions underlying a usage-based approach to language processes. Finally, section 1.5, discusses the relevance and importance of experimental methods to our understanding of natural language phenomena and to our conception of the structure of the grammar.

Chapter 2 will describe the design and methodology of the experiments conducted in this study. This will include a detailed account of the methods used in measuring the vowel sequences, with examples. Chapter 3 reports the results of the experiments; Chapter 4 will report on a series of descriptive by-item analyses, and Chapter 5 will provide a summary of the dissertation and a discussion of the broader conclusions that can be drawn from this study.
1.2 Diphthongs and hiatus in Spanish

Spanish is typically described as enjoying fairly predictable short, tense, monophthong pronunciation of the five vowels /i, e, a, o, u/ when not in contact with another vowel (Teschner 2000). When two (or more—but for the purposes of this dissertation, we will only be concerned with vowel combinations of two) vowels are found next to each other, their pronunciation is also broadly assumed to be predictable.

When one of the vowels /i/ or /u/ is next to any other vowel /e/, /a/, or /o/, that vowel combination forms a diphthong (Macpherson 1975, Matluck 1995), in which one of the vowels, either /i/ or /u/ glides to [j] or [w], respectively while the other vowel provides the nucleus of the syllable. An example can be found in forms such as in piel ‘skin’ > [pjel], piano ‘piano’ > [pja.no], puerta ‘door’ > [pwer.ta], and so on. Glides are characterized as such because their articulatory and acoustic properties are gradual transitions to (or from) the primary vowel (e.g. Hadlich et al. 1968). The primary, or main, vowel in the combination constitutes the nucleus of the syllable, and is sometimes called a syllabic vowel (Hadlich et al. 1968). Figure 1-1 shows that any combination of unaccented vowels /i/ or /u/ and /e/, /a/, or /o/ are in the same syllable and result in the formation of a diphthong (shaded):

---

6 This may or may not be the case, as Navarro-Tomás (1968b) notes.
When the glide is the first element in the vowel combination the result is what is known as a rising diphthong;

10)  *piel* ‘skin’ > [pjél]
11)  *piano* ‘piano’ > [pjá.no]
12)  *bueno* ‘good’ > [bwé.no]
13)  *cuidado* ‘care’ > [kwi.ðá.ðo]
14)  *cuando* ‘when’ > [kwán.do]
15)  *cuota* ‘quota’ > [kwó.ta], etc.

When the glide is the second element in the vowel combination the result is a falling diphthong;

16)  *seis* ‘six’ > [séjs]
17)  *aire* ‘air’ > [áj.re]
18)  *deuda* ‘debt’ > [déw.ða]
19) *pausa* ‘pause’ > [páw.sa], etc.

This process is said to be highly predictable in Spanish (Navarro-Tomás 1968b, among others; see also Albright et al. 2001 for a discussion on the influence of segmental environments on phonological diphthongization). When the vowel combination contains both /i/ and /u/, the diphthong is said to be steady, as in *ciudad* ‘city’ [sju.ðað], and *cuidado* ‘care’ [kwi.ða.ðo], etc. Hualde (2005) proposes the following rule for gliding in Spanish, (80):

20) /i/, /u/ → [j], [w] if adjacent to a different V and not stress bearing

The occurrence of the glide as either the first or second element in the vowel combination affects the property of the vowel. This difference has led some to make a distinction between the two glides, and have applied the terms semivowel and semiconsonant exclusively according to which position in the combination the glide occupies, as there are clear differences between the two. Navarro-Tomás (1968b) describes the semivowels ([i] and [u]) as more closed than the semiconsonants ([j] and [w]), and that during their pronunciation the mouth goes from a relatively open position to a more closed position. The semiconsonants, on the other hand, are characterized by beginning with a more closed position and ending with a more open position. Thus /i/
and /u/ are pronounced as semiconsonants [j], [w] at the beginning of a diphthong and semivowels [i], [u] at the end of a diphthong.

Table 1-1 Examples of semivowels and semiconsonants

<table>
<thead>
<tr>
<th>Diphthong with semiconsonant</th>
<th>Diphthong with semivowel</th>
<th>Gloss</th>
</tr>
</thead>
<tbody>
<tr>
<td>labio [lá.βjo]</td>
<td></td>
<td>‘lip’</td>
</tr>
<tr>
<td>puerta [pwér.ta]</td>
<td></td>
<td>‘door’</td>
</tr>
<tr>
<td>baile [báj.le]</td>
<td></td>
<td>‘dance’</td>
</tr>
<tr>
<td>deuda [dew.ða]</td>
<td></td>
<td>‘debt’</td>
</tr>
</tbody>
</table>

Standard hiatus, on the other hand, occurs when any combination of the vowels /e, a, o/ are adjacent: real ‘real/royalty’ [re. ál], poeta ‘poet’ [po.é.ta], caos ‘chaos’ [ká.os], maestro ‘teacher’ [ma.és.tr], etc. Hiatus also occurs when /i/ or /ú/ are accented orthographically and are found adjacent to /e/, /a/, or /o/ as in, María ‘Mary’ [ma.ri.a], reúne ‘s/he meets’ [re.ú.ne], and so on as shown in Figure 1-2.

---

7 For the purposes of this investigation, I, like Hualde (2005), will not distinguish between the semivowel glide and the semiconsonant glide. This is not to lessen the importance between the two, but as will be shown, this question does not enter into the discussion of the current investigation. I will, therefore, use the symbols [j] and [w] to represent the glides.
As can be seen in figure 1-2, vowel sequences of identical vowels are also said to be in hiatus, such that *leer* ‘to read’, *creer* ‘to believe’, and *alcohol* ‘alcohol’ are syllabified as [le.ér], [kre.ér] and [al.ko.ól], respectively. In speech, however, sequences of identical vowels are typically shortened along a scale that can be understood at its extremes as comprising one long vowel or one simple vowel:

21) *leer* ‘to read’ [le.ér] > [le:r] > [ler]

22) *creer* ‘to believe’ [kreér] > [kre:r] > [krer]

23) *alcohol* ‘alcohol’ [al.ko.ól] > [al.ko:l] > [al.kol]

Although the examples above are all within-word vowel combinations, vowel-vowel contact also arises across words. Typically, when words are together in a string sometimes consonants or vowels that are at the end of a word will join the syllable of the following word (i.e., resyllabify). Consequently, if a word ends with a vowel, and the following word begins with a vowel, the result is also a diphthong or vowels in hiatus, as expected. Consider:
24) *el señor es* ‘the man is’ > [el.se.ɲo.res]

25) *yo insisto* ‘I insist’ > [jojn.sis.to]

As can be seen in (24) the final /r/ in *señor* is resyllabified as the onset of the following syllable, thus maintaining the preferred open-syllable structure. In (25), the /o/ is followed by the word-initial /i/ of *insisto*, creating the context for hiatus resolution in the resyllabified string. Specifically, the lack of stress on /i/ provides the context for the creation of the falling [oj] diphthong. The above are all examples of expected, standard syllabification and diphthongization.

### 1.2.1 Exceptional hiatus and non-standard diphthongization

Diphthongization and hiatus, as described above, follow a mostly predictable pattern. There are, however, examples of words that show non-standard or exceptional hiatus or diphthongs. As Hualde (2005) points out, many words that, by definition contain diphthongs can also be pronounced with hiatus:

<table>
<thead>
<tr>
<th>Exceptional hiatus</th>
<th>Diphthong</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>dueto</em> ‘duet’ &gt; [du.é.to]</td>
<td><em>duelo</em> ‘duel’ &gt; [dwé.lo]</td>
</tr>
<tr>
<td><em>pié</em> ‘I chirped’ &gt; [pi.é]</td>
<td><em>pie</em> ‘foot’ &gt; [pjé]</td>
</tr>
</tbody>
</table>

Table 1-2 Example word pairs showing exceptional hiatus and the expected diphthong
Not all speakers accept those instances of exceptional hiatus as viable, but the fact that some speakers do accept them as viable suggests that the rule for vowel sequence syllabification is not the same for all Spanish speakers. Even more interesting is that words such as *dueto* ‘duet’ that have exceptional hiatus [du.é.to] are not distributed randomly throughout the lexicon (Face et al. 2004, Hualde 2005).

While Hualde (2005) claims that exceptional hiatus is somewhat predictably distributed in the lexicon, non-standard diphthongization is much less predictable. Non-standard diphthongization occurs when a vowel sequence that is supposed to be in hiatus is produced as a diphthong. In other words, it is a possible outcome of hiatus resolution, as discussed earlier. Even though it is claimed to be less predictable, the process has been claimed to be very frequent (Matluck 1995, for instance). In the cases of non-standard diphthongization (hiatus resolution), the traditional definition states that an unstressed mid-vowel /e/ or /o/ in combination with a different stress-bearing vowel rises and becomes a glide. Conceptually, a theoretical intermediate step in the ultimate reduction indicates that the unstressed mid-vowels /e/ and /o/ first rise to become high vowels /i/ and /u/, respectively. This step enables them to now change their phonetic shape and become glides [j] and [w], respectively, as shown in Table 1-3.
Table 1-3 Examples of non-standard diphthongization in Spanish

<table>
<thead>
<tr>
<th>Standard syllabification</th>
<th>*Vowel raising</th>
<th>Diphthongization</th>
</tr>
</thead>
<tbody>
<tr>
<td>peor ‘worse’ [pe.ór]</td>
<td>*[piór]</td>
<td>[pjór]</td>
</tr>
<tr>
<td>poeta ‘poet’ [po.é.ta]</td>
<td>*[pué.ta]</td>
<td>[pwé.ta]</td>
</tr>
</tbody>
</table>

As with the other processes already discussed, non-standard diphthongization can also occur across word boundaries, as in Table 1-4:

Table 1-4 Examples of across-word non-standard diphthongization

<table>
<thead>
<tr>
<th>Standard syllabification</th>
<th>*Vowel raising</th>
<th>Diphthongization</th>
</tr>
</thead>
<tbody>
<tr>
<td>se aman ‘they love each other’</td>
<td>*[si.á.man]</td>
<td>[sjá.man]</td>
</tr>
<tr>
<td>cómo estás ‘how are you’</td>
<td>*[kó.mu.es.tas]</td>
<td>[kó.mwes.tas]</td>
</tr>
<tr>
<td>lo amo ‘I love him’</td>
<td>*[lu.á.mo]</td>
<td>[lwá.mo]</td>
</tr>
</tbody>
</table>

*This step is for illustrative purposes only; it never occurs in the surface form and is to be understood as an abstract step from a derivational perspective.

In these cases, because the /e/ and /o/ are unstressed and precede another vowel whose stress is more prominent, they are susceptible to becoming glides. Once glides and in a sequence with another, more prominent vowel, a diphthong is formed. Although the above descriptions of within- and across-word hiatus resolution are the one typically used when describing the phenomenon, many studies have found that
actual speech shows quite a bit of variability with regard to how speakers resolve vowels in hiatus.

1.3 Factors that influence exceptional hiatus and non-standard diphthongization

As just described above, sometimes speakers break the rules of hiatus and diphthong pronunciation. Drawing on findings from other authors (Navarro-Tomás 1968b, Monroy Casas 1980, among others) as well as on insights about Spanish, it is apparent that even the standard prescriptions of hiatus resolution mentioned above are oversimplified. In other words, the notion that certain vowel sequences in hiatus—given enough fast and/or careless speech—simply become diphthongs might not provide a complete picture of the phenomenon.

In fact, some researchers have discovered that there are many ways in which vowels in hiatus (even diphthongs) might be realized. For example, Hualde (2005) claims that instances of exceptional hiatus are not simply arbitrarily dispersed throughout the language, at least for some Peninsular Spanish speakers. He describes specific vowel sequence patterns that predict exceptional hiatus production. These patterns are summarized here with examples:

i) Vowel sequences of rising sonority and falling sonority may have hiatus when a morphologically related word has a lexically accented high vowel
   - rising: porfiaban ‘they disputed’ > [por.fi.á.βan] vs. porfían ‘they dispute’ > [por.fi.an]
• falling: oírè ‘I will hear’ > [o.i.ré] vs. oír ‘to hear’ > [o.ir]

ii) Hiatus can occur with unstressed high vowel if they are separated by a morphological boundary such as in the suffixes –oso, -al, -ario, as in virtuoso ‘virtuous’ > [bir.tu.ó.so]

iii) Hiatus can also occur in a few other examples, but it is always in vowel sequences of /i.a/ or /i.o/, as in biólogo ‘biologist’ > [bi.ó.lo.vo]

Underscoring the complexity and variability of the phenomenon, Hualde goes on to state that even within speakers of the same dialect there is little agreement about which words should be pronounced with a diphthong or a hiatus. Hualde also emphasizes that although certain dialects allow for exceptional hiatus, the rules above “tell us only where exceptional hiatus may be found, not that under those conditions we will necessarily have a hiatus” (84). What is especially interesting is his claim that in fast speech instances of exceptional hiatus are no longer found. What is found instead, is the prescribed diphthong (e.g., virtuoso > [bir.two.so]).

Not surprisingly, there is also much variability in how across-word vowels in hiatus are actually produced. Jenkins (1999) found that speakers of New Mexican Spanish exhibit several patterns of hiatus resolution. The applicable findings from his study are summarized in Table 1-5 below (53-54):

---

8 For a complete list of words with exceptional hiatus in Castilian Spanish, see Hualde (2005; 85).
9 See Jenkins (1999) for a more complete description.
Table 1-5 Jenkins (1999) raw numbers of across-word vowel sequence resolution, disregarding accent

<table>
<thead>
<tr>
<th>Vowels</th>
<th>diphthong</th>
<th>V2 del.</th>
<th>V1 del.</th>
<th>Hiatus</th>
<th>coalesc.</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>ea</td>
<td>164</td>
<td>7</td>
<td>16</td>
<td>17</td>
<td>12</td>
<td>216</td>
</tr>
<tr>
<td>ae</td>
<td>2</td>
<td>81</td>
<td>54</td>
<td>11</td>
<td>47</td>
<td>195</td>
</tr>
<tr>
<td>oe</td>
<td>46</td>
<td>96</td>
<td>15</td>
<td>11</td>
<td>2</td>
<td>170</td>
</tr>
<tr>
<td>oa</td>
<td>57</td>
<td>13</td>
<td>7</td>
<td>11</td>
<td>2</td>
<td>90</td>
</tr>
<tr>
<td>ao</td>
<td>13</td>
<td>1</td>
<td>14</td>
<td>8</td>
<td>1</td>
<td>37</td>
</tr>
<tr>
<td>eo</td>
<td>15</td>
<td>1</td>
<td>2</td>
<td>18</td>
<td>-</td>
<td>36</td>
</tr>
<tr>
<td>total</td>
<td>297</td>
<td>199</td>
<td>108</td>
<td>76</td>
<td>64</td>
<td>744</td>
</tr>
</tbody>
</table>

Noteworthy in the findings of Jenkins (1999) is that diphthongization as a whole was favored over other types of resolution; also, diphthongization was highly favored in /ea/ sequences, but virtually non-existent in /ae/ sequences. Vowel sequences also showed preferences for vowel deletion, maintenance of hiatus, and vowel coalescence\(^{10}\). Other patterns he found included that if /e/ is deleted if following a stressed vowel, (está en el camino ‘it’s on the way’ > [es.ta.nel.ka.mi.no]); and that hiatus is maintained when a stressed vowel precedes a vowel other than /e/, (nací aquí ‘I was born here’ > [na.si.a.ki]), among others.

While Jenkins (1999) used natural speech to gather data, Aguilar (2003) conducted lab-setting experiments with Peninsular Spanish speakers for all across-word hiatus resolution possibilities: [aa, áa, áá], [ae, áe, áé], and [ai, ái, áí]. She found that all the vowel sequences showed hiatus, and unlike Jenkins (1999), that hiatus maintenance was the most common type of resolution. She also observed the following patterns, among others:

\(^{10}\) See Jankins (1999:40-43) for a discussion of how the coalescence category differs from the categories of deletion.
iv) Stressed + unstressed VV sequences showed the highest degree of reduction.

v) Unstressed VV sequences showed the highest degree of monophthongization; however, monophthongization was not observed in [áá], [aé], [áé], [ái], [ai], and [ái].

vi) Unstressed + stressed VV and stressed + stressed VV tended to maintain hiatus.

Aguilar (2003) also performed temporal measurements of the vowel sequences. She observed, for example, a systematic reduction in duration when going from sequences wherein both vowels are stressed to sequences wherein V₁ is unstressed but V₂ is stressed, then to sequences wherein V₁ is stressed and V₂ is unstressed, and finally to sequences wherein both vowels are unstressed. That is, stressed vowels tended to be of longer duration than unstressed vowel sequences. Again, such results highlight the fact that production of vowels in hiatus is more complex than is typically reported.

Of course the data from these two studies is not representative of all Spanish speakers, but it speaks to the variability with which vowels in hiatus can be resolved. Sometimes vowel sequences were produced as diphthongs, other times as hiatus; sometimes a vowel was deleted, other times not, and so on. Thus, capturing all the variables that could possibly affect hiatus resolution has proven to be a daunting task (Aguilar 2003). However, even though there is variability there are two factors that stand out as the most important predictors of hiatus resolution, at least for across-word vowel sequences. These are vowel sequence and stress placement (e.g., Alba 2006).
Hiatus resolution is preferred in vowel sequences that have the potential of becoming rising diphthongs (e.g., /ea/ > [ja]) over those that could become falling diphthongs (e.g., /ae/ > [aj]). Further, vowels that are stressed (lexically or orthographically) resist reduction and, hence, diphthongization (comí otro ‘I ate another’ > [ko.mi.o.tro]).

While the two studies mentioned above speak to linguistic factors that sometimes predict hiatus resolution, other non-linguistic factors have also been claimed to affect hiatus resolution. Alba (2006) provides a summary of the variety of factors that have been found to affect the variation found in the production of hiatus in Spanish. His report is summarized in-part here, with additional commentary where needed (6):

Dialectal Differences. The studies of Hualde (2005), Aguilar (2003), Jenkins (1999), and Alba (2006) mentioned above can also be considered dialectal investigations. Hualde reported the exceptional hiatus patterns of Peninsular Spanish speakers, Aguilar the hiatus resolution also found in Peninsular Spanish speakers. Jenkins, on the other hand, reported on New Mexico Spanish speakers. Alba (2006) also used the same New Mexico Spanish recordings as Jenkins for his study. Not surprisingly, he found that across-word hiatus resolution patterns similarly to that which has been said to be found in other dialects; namely that stress, vowel quality, word class, string class, number and form of the previous mention, as well as string frequency affect hiatus resolution in Spanish. Others, however, have also acknowledged that hiatus is resolved differently among speakers of different dialects

11 In some cases, I have only included a sampling of the references for each summary. I refer you to Alba (2006) for a more complete list.

Some of the results from studies on specific dialects are expected. For instance, in a study of Chicano Spanish, Martínez-Gil (2000) found that when two like vowels are together they become one vowel (e.g., *vive en* ‘s/he lives in’ > [bi.βen]); vowels /e/ and /o/ tend to glide before other vowels of similar backness and roundness; and that in most cases of hiatus resolution the first vowel reduces, becomes a glide, and forms a diphthong (*gente amable* ‘nice people’ > [xen.tja.ma.βle]). Similarly, reporting on the Spanish in Caracas, Venezuela, Díaz-Campos et al. (2006) found that diphthongization was favored when the second vowel was a low or mid-back vowel, but was disfavored when the first vowel is stressed, (e.g., *nací aquí* ‘I was born here’ > [na.si.a.ki]). They also found that vowel combinations of /ea/ showed more propensities to diphthongize than other vowel combinations in hiatus, as did Aguilar (2003).

Sometimes, however, dialectal studies turn up unexpected results. For example, Martínez-Gil (2000) found that the low vowel /a/ is always resolved before another vowel (*la esposa* ‘the wife’ [la.es.po.sa] > [les.po.sa]).

*Socioeconomic Level.* As Alba (2006) indicates, many authors either state explicitly or imply that resolution types that involve reduction are more likely among speakers with less education and of lower socioeconomic classes (e.g., Navarro Tomás 1990, Matluck 1995). Díaz-Campos et al. (2006), for example, found that lower and middle socioeconomic background speakers in Caracas, Venezuela are more prone to diphthongize vowels in hiatus.
**Individual Speaker Differences.** Some authors also cite differences among individual speakers and how hiatus is resolved (e.g., Navarro-Tomás 1990, Quilis 1981, Hualde et al. 2002). For instance, Hualde et al. (2002) had one participant whose patterns were unique to the other participants in the study.

**Ambiguity.** Hiatus resolution could sometimes cause ambiguity (e.g., *su ave* ‘her bird’ as > [swa.βe] and *suave* ‘smooth’ > [swa.βe]; *crear* ‘to create’ as > [krjar] and *criar* ‘to raise’ > [krjar]). Thus, some resolutions might be avoided by not resolving hiatus in order to prevent ambiguity (e.g., Monroy Casas 1980).

**Emphatic Stress.** Some have suggested that hiatus resolution usually does not occur when one of the vowels in hiatus occurs in a word that receives emphatic stress in the phrase (e.g., Navarro Tomás 1990, D’Introno et al. 1995, Martínez-Gil 2000).

There are two additional factors that are of greatest interest for the purposes of this current study. One is frequency and the other is discourse style/speech rate. **Frequency** has gained some ground in the hiatus resolution literature, due in part to the surge of research done in the usage-based tradition. In fact, some of the studies already discussed mentioned that higher-frequency items tended to exhibit more hiatus resolution than their low-frequency counterparts. Díaz-Campos et al. (2006), for instance, found that the most frequent vowel sequence from their data was /ea/. They also claim that not only was /ea/ the most frequent vowel sequence, but it was also the sequence that showed the greatest propensity to diphthongize.

Similarly, the data in Table 1-5 of Jenkins’ (1999) also shows that the most frequent across-word vowel combination (/ea/) also exhibited the most diphthongization; the least-frequent sequence, /eo/, was more likely to maintain hiatus.
In fact, Jenkins (1999) also observed that the high-frequency items in his data had a high tendency to undergo diphthongization. He also found that pairs of words that had a high frequency of co-occurrence demonstrated a relatively high degree of variability in the resolution of hiatus between them. He further found that certain items that were often repeated in his corpus (e.g., *la escuela* and *me acuerdo*) had a high tendency to be reduced compared to other items that did not occur as often\(^\text{12}\).

In an analysis of some 1,912 instances of across-word hiatus extracted from recordings of New Mexico Spanish\(^\text{13}\), Alba (2006) found (as did Jenkins 1999) that high-frequency items reduced significantly and systematically more than low-frequency items (229). He claims that such reduction is more likely in high-frequency items because they are subjected more to the reductive processes of articulatory and perceptual processes; processes, he claims, that gradually create gradient phonetic variations. It is precisely the more reduced forms, then, that high-frequency items store mentally as the stronger and more-accessible forms (229).

Frequency has also been found to be a predictor of exceptional hiatus, as well. Based on a few of the examples in Aguilar (1999), Hualde et al. (2002), also later in Hualde (2005), Face et al. (2004) investigated the lexical and acoustic factors that influence the perception of words displaying exceptional hiatus in Spanish. According to Hualde (2005) words such as *biólogo* ‘biologist’ → [bi.ó.lo.ɣo] and *cliente* ‘client’ [kli.én.te] are classified as exhibiting exceptional hiatus because although the vowel sequences contain the high unstressed vowel /i/, the words contain hiatus in place of an

\(^{12}\) Jenkins (1999) and Alba (2006) refer to such instances as effects of *previous mention*. Previous mention, however, can be viewed as a contributor to frequency.

\(^{13}\) Alba (2006) used the same corpus of New Mexico Spanish that Jenkins (1999) used for his study.
expected diphthong. Face et al. (2004) hypothesized that subjects listening to words with exceptional hiatus and diphthongs in Spanish would have difficulty discerning the difference between the two since mean durations of the vowel sequences are not categorically distinct (Aguilar, 1999, Hualde et al. 2002).

Further, they hypothesized that certain words might be perceived as belonging to either the category of words with diphthong or hiatus, respectively, even though the experimental task to which they listened contained words whose vowel sequences had been interchanged. To test this, they had subjects perform a task wherein they listened to words like limpiando ‘cleaning’, normally produced with a diphthong [lim.pjan.do] with hiatus [lim.pi.an.do] and piando ‘chirping’, normally produced with hiatus [pi.an.do] with a diphthong [pjan.do], and then had decide how many syllables they had heard in each word. A following task presented the subjects with only the vowel sequence, and after hearing each had to decide if it was a vowel combination with a diphthong or in hiatus. A final task contained the vowel combinations within the words as they were originally produced. In isolation the subjects accurately identified the tokens correctly 78.9% of the time\(^\text{14}\). Subjects were nearly perfect, however, at correctly identifying the vowel sequence when it was presented within the word in which they were produced (97.5%). Finally, when subjects were presented with words whose vowel combination had been interchanged there was a significant preference to perceive the vowel combination as a diphthong both when there was a diphthong in a hiatus word and when there was a hiatus in a diphthong word.

\(^{14}\) See Face and Alvord (2004) for a discussion on this percentage.
This surprising result led them to conclude that not only are Spanish speakers sensitive to vowel sequence duration (hiatus being longer than diphthongs) and lexical category (piando is classified as a hiatus word), they were also incredibly attuned to a very highly-nuanced effect that frequency had on their perception of certain vowel sequences. They hypothesize that since Spanish speakers are more likely to encounter diphthongs in vowel sequences where the high vowel is unaccented, they will be more likely to perceive diphthongs in just such vowel combinations, even when what was produced was a hiatus. Their conclusion is that “…Spanish speakers/hearers make use of the frequency of the dominant pattern in the lexicon to make linguistic predictions, meaning that even the most common patterns are stored lexically as proposed in usage-based models of lexical storage” (564). This result adds considerably to the observations of Hualde (2005), and to those of hiatus resolution (Jenkins 1999, Aguilar 2003, Alba 2006) suggesting that frequency is an important predictor for hiatus resolution.

Finally, nearly every account of hiatus resolution points to speech rate and/or carefulness of speech as perhaps the key ingredient in the resolution of vowels in hiatus (e.g., Navarro-Tomás 1968b, Harris 1969, Jenkins 1999, Techner 2000, Hualde 2005, Alba 2006). It is widely agreed upon that in fast and/or careless speech, vowels in hiatus are often resolved in any of the ways already discussed. Again, that notion is not challenged. Still, what is interesting is how categorically authors dismiss the notion that hiatus resolution could be present in anything but fast and/or careless speech. In fact, Jenkins (1999) and Alba (2006) did not even take into consideration data that was not produced quickly, even if there were instances of vowels in hiatus. Sometimes,
authors studying hiatus resolution make no prediction at all about speech rate and style. Aguilar (2003), for instance, gave participants no instruction about how to produce the tokens in the experimental tasks, and speech rate was not discussed in her analysis. All three approaches are problematic. On the one hand, Jenkins (1999) and Alba (2006) could have found instances of hiatus resolution in slower speech samples. On the other hand, since Aguilar (2003) did not control for speech rate in her experiments, it is difficult to draw any conclusions about how speech rate might have affected how the vowel sequences were resolved.

It appears that because speech rate/style have been so widely accepted, the notion that hiatus resolution might also be found in slow, careful speech has received little attention. No investigations known presently to this author have researched whether or not hiatus resolution can also be found in slow, careful speech. One of the primary goals of this dissertation is investigate whether or not high-frequency vowel sequences in hiatus might show resolution even in a slow speech condition. Again, this is a novel approach to the phenomenon of hiatus resolution in Spanish.

In sum, many factors have been claimed to affect hiatus resolution (or maintenance) in Spanish. These include linguistic factors, such as the vowels found in the sequence, and which vowels are stressed. Other non-linguistic factors have been suggested to affect hiatus resolution. Those discussed were dialectal differences, socioeconomic level, individual speaker differences, ambiguity, emphatic stress, frequency and speech rate/style. Of those, frequency and speech rate/style will be of most interest for this current study for the reasons already discussed.
1.4 A Usage-based model, frequency, and emergentism

Noteworthy throughout the previous discussion is the fact that the behavior of Spanish vowel combinations might not be as predictable as has been thought. Studies such as Jenkins (1999), Alba (2006), and Face et al. (2004) note that attempting to propose a rule that predicts the actual production of vowels in hiatus is at best difficult. Indeed, traditional accounts of such exceptional vowel sequence production (e.g., Espinosa 1924, Harris 1969, Monroy Casas 1980, Quilis 1981, D’Introno et al. 1995, Martínez-Gil 2000, Hualde 2005, among others) have had difficulty in fully describing and predicting the exceptional production of vowel sequences. It seems impractical (and improbable that human language functions in this way), for example, to list a series of 10 rules to describe hiatus resolution, as did Navarro-Tomás (1968b), or even a series of 7 rules, as Monroy Casas (1980) has done in order to describe and predict hiatus resolution in Spanish. Nonetheless, such accounts that attempt to capture hiatus resolution and exceptional hiatus via lists of constraints or rules have proven helpful in understanding the many factors that are claimed to affect and predict the behavior of vowels in hiatus in Spanish.

Thus, what is proposed is to use a model that is capable of dealing with how language use affects both language structure and its mental representations. In support of such a model Pierrehumbert (2001) observed that, “over the last decades, a considerable body of evidence has accumulated that speakers have detailed phonetic knowledge of a type which is not readily modeled using the categories and categorical rules of phonological theory” (2001: 137). She goes on to say that a usage-based model of phonology can easily account for such patterns of variation by hypothesizing that
experience with speech contributes to how phonological targets are represented mentally (137).\textsuperscript{15}

The two central ideas to a usage-based model of language that are most applicable to this current study are that experience affects representation and that frequency affects structure (Torres Cacoullos 1999, Bybee 2001). Under traditional approaches of language, representations of rules or constraints of a given language are static and fixed, all being accessible to the same degree regardless of their usage. A usage-based model hypothesizes that high-frequency items have a stronger mental representation, are more readily accessible (Alvarez et al. 2001)\textsuperscript{16}, and less-likely to undergo analogical change (Bybee 2001)\textsuperscript{17}. The other notion especially applicable for this discussion is that the frequency of an item can affect its structure. Structure refers to both the phonology (i.e., reduction of sounds) and to how highly-frequent word strings can form such a tight connection so as to become processed more as chunks than as individual items, for instance. Therefore, not only is structure viewed as being affected by repetition, but structure can actually emerge from repetition. A usage-based model readily accounts for such language processes since, under such a view, languages are slowly but constantly changing under the weight of use (Bybee 2001).

\textsuperscript{15} See also Pierrehumbert (1999).
\textsuperscript{16} Experiments testing priming effects are often cited as evidence for strong mental representation of words, etc., and accessibility (as in Carreiras et al. 2002). See Ozubko et al. (2007) for some counterpoints to these claims.
\textsuperscript{17} These assertions also have second language acquisition implications. See Bley-Vroman (2002), Ellis (2002), and Gollan et al. (2008) as starting points.
1.4.1 Frequency effects in language

As noted above, a major hypothesis of a usage-based model of language is that experience affects mental representation. Items such as syllables or words are believed to have strong mental representations, for instance, when speakers show quick reaction times in lexical decision tasks or word naming tasks (Meyer et al. 1971). This is related to our discussion on frequency because it proposes that if responses to high-frequency items are quicker than responses to low-frequency items, then that would lend support to the hypothesis that frequency can strengthen mental representations. In fact, Carreiras et al. (1998) did find that when the first syllables of disyllabic words in Spanish were of high-frequency they were named quicker than words beginning with syllables of lower frequency. They also showed that even pseudowords in Spanish whose first syllables were of high frequency were named faster than those with lower frequency initial syllables (Carreiras and Perea 2003).

Frequency has not only been suggested to contribute to the mental representation strengthening of individual syllables (Stenneken et al. 2007) and words (Bybee 1994, Laganaro et al. 2006, Knobel et al. 2008, among others), but also to the mental strengthening at the morpho-syntactic level (Bybee 1985). Bybee (2001), for example, found that the well-attested phenomenon of French liaison (a process typically referred to as syntactic cohesion) is simply frequency of co occurrence of the two elements. Specifically, she found that the more frequent the item, the more likely it is to maintain liaison. She argues that those connections are stored in memory and that
frequency of use reinforces them and that frequent sequences get processed together, thus eroding their connections with other items.\footnote{See Bybee and Hooper (2001) for a more detailed description of French liaison.}

The other major point of a usage-based model of language is that frequency can affect structure (Jurafsky et al. 2001). In simple terms, frequency refers to the number of times a certain form occurs. There are two types of frequency that are typically discussed within the usage-based model.\footnote{Frequency can also lead to reduction in meaning and emancipation, though those two facets will not be discussed fully here. See Bybee (2001) for a more in-depth discussion.} Those are \textit{token frequency} and \textit{type frequency} (Conrad et al. 2008). Type frequency has to do with the frequency of a particular pattern, such as vowel combinations, stress patterns, and the like. For example, about 95\% of Spanish nouns and adjective that end in a vowel have penultimate stress (\textit{abuela} ‘grandma’ $\rightarrow$ [a.βwé.la]) while words with antepenultimate stress occur far less frequently (\textit{claúsula} ‘clause’) (Bybee 2001). Thus, the penultimate stress pattern has a high type frequency in Spanish (Bybee 2001).

Token frequency refers to the number of occurrences of a specific item. For example, Bybee (2001) found that word final [t] and [d] are less likely to be pronounced in words that are high-frequency (\textit{just, and, and went}), as opposed to low-frequency words (i.e., \textit{bent, thrust}). Another example of token frequency from English demonstrates that high-frequency words such as \textit{family, memory, and camera} tend to reduce the unstressed schwa (\textit{famly, memry, camra}) to a higher degree than phonetically similar words of lower frequency (i.e., \textit{artillery, mammary}) (Hooper 1976, Bybee 2001). The idea is that the high frequency of items such as \textit{just, family} (as opposed to all words ending in \textit{–ust or –amily}) yields different patterns of production.
than what we find in low-frequency items. Central to these findings is that high
frequency can lead to reduction in many tokens. Given enough reduced tokens, then, it
is the reduced form that becomes the dominant form.

Similarly, in a study of word boundary palatalization in English, Bush (2001)
found that the /d/ and /j/ sequence found in would you typically palatalizes to [wodʒə]
between the string; but the sequence found in the string good you does not. He reports
that a statistical analysis of word boundaries with and without palatalization reveals that
palatalization is more likely to occur between words of high frequency. He then argues
that such a result suggests that a result of string frequency is a “chunking phenomenon
which causes frequently-used sequences of lexical material to acquire lexical storage as
single agglutinated mental representations” (256).20

Other findings support Bush’s (2001) conclusion. In a study of the highly-
frequent sequences going to, have to, got to, and want to in English, Krug (2001)
suggests that these highly-frequent strings are in the process of becoming modified
modals in English. He claims that the radical reduction of those word strings to gonna,
hafta, gotta, and wanna, respectively, demonstrates not only the process of chunking,
but also that they are in the process of becoming lexically autonomous from their
original two-worded string. To illustrate this, Krug cites results that show that younger
English speakers are increasingly preferring gonna over going to (vs older speakers),
especially when the construction is gonna + infinitive verb (321). He believes this
suggests that there is a “functional split” (322) of use between the two forms for the

20 See Newmeyer (2003) for more points and counterpoints (Gahl et al. 2006, Myers et al. 2009) to
claims such as these.
differing age categories. Simply put, the main idea from this data is that those word strings have undergone a process due to their high-frequency: first, *going to, have to, got to,* and *want to* have reduced phonologically to *gonna, hafta, gotta,* and *wanna,* respectively. Next, they underwent chunking and are now stored and retrieved as single mental representations (Bush 2001). In addition, they have also started to behave differently syntactically. That is, they are lexically separated from their original forms of *going to, have to, got to,* and *want to* because they are systematically preferred for certain syntactic constructions for some speakers. The process shown in these English modals by Krug is the very way in which frequency is claimed to be a function of emergent linguistic structures. The conclusions drawn by these authors are in keeping with the hypothesis that “…emergent structures are unstable and are manifested stochastically…[and the notion of emergence] relativizes structure to speakers’ actual experience with language, and sees structure as an on-going response to the pressures of discourse rather than as a pre-existent matrix” (Bybee and Hooper 2001:2-3).

1.4.2 Predictions about frequency and hiatus resolution

Given the literature reviewed above, as well as the wide range of discoveries in the emergentist literature more generally, we can make specific predictions regarding hiatus resolution in Spanish. Consider Alba (2006), for example, who found that the across word vowel combination of the most frequent word string in his data, *la escuela* ‘the school’ [la.es.kwe.la], was often reduced to *lescuela* [les.kwe.la], but the low-frequency string *la importancia* ‘the importance’ [la.im.por.tan.sja], however, was
never reduced (it remained [la.im.por.tan.sja]). Drawing on such evidence, we can predict that frequency should also affect the behavior of vowel sequences that appear within words. Thus, the hiatus in a high frequency word *real* ‘real’ [re.al] should be more often pronounced [rjal] than in a similar but less frequent word such as *leal* ‘loyal’. This is a novel inquiry since no investigations know to this author to date have studied the effect that frequency might have on within-word hiatus resolution.

Based on these observations, I hypothesize that within-word hiatus is more likely to be resolved (and to a higher degree) in words that are of higher frequency. I also hypothesize that hiatus resolution in high-frequency words will be of shorter duration and will show less steady-state formant measurements for the two vowels. In some cases, the resolution might be so advanced such that the vowel formant trajectories approach those found in diphthongs. I further hypothesize that if there is an effect of frequency for the high-frequency items then speech rate will not be as reliable a predictor of hiatus resolution. That is, if high-frequency words show hiatus resolution even in slow speech, then speaking quickly/less carefully might not be as strong of a predictor of hiatus resolution as has been thought. A temporal and spectral analysis will carried out to validate this hypothesis.

These hypotheses, if substantiated, would suggest that to presume that hiatus resolution is unique to fast/careless speech is only partially correct. Rather, it is also the result of a streamlined expertise effect; one developed over hundreds and thousands of repetitions of high-frequency words over low-frequency words. They would also lend support to a usage-based model of phonology which states that repetition can lead
to reduction. Further, the results could contribute to what is believed about the way in which certain high-frequency items are stored and accessed mentally.

### 1.5 Experimentally-based language research

Data can be gathered either naturalistically or in an experimental setting in the laboratory. As some have thought otherwise (i.e., Alba 2006), it bears mentioning the motivation behind choosing an experimentally-based investigation of hiatus resolution. As argued against above, investigations that rely on ‘imaginary’ speakers or solely on one’s own experience or intuitions of a language are severely limited. Followers of usage-based models of language (functionalists and variationists) continue with the principle that what is most interesting and fruitful to investigate about language is real language use. Functionalists are viewed as those that use experimental methods to study language; variationists use natural speech\(^{21}\). Further, they do not always approach the study of language use in the same way, however. There are two principally distinct methods of how to obtain language as it is used; language in naturally-occurring speech and language obtained via experimentally-based tasks, usually performed in a laboratory setting.

Evaluating natural speech, as done by variationists, comes with it a host of benefits. One of these is the possibility of evaluating speech in connected discourse. They employ a variety of techniques to elicit natural speech. These include sociolinguistic interviews and spontaneous conversations, among others (c.f. Alba

\(^{21}\) See Alba (2006) for a more detailed summary of variationist approaches to usage-based studies of language use.
2006). Alba (2006) states that variationists view naturalistic, connected discourse as providing the best data for analysis because it employs the most natural patterns of usage (60).

One of the major drawbacks to natural, spontaneous speech, however, is just the thing for which it is often celebrated; loss of control. When recordings are made of speakers in natural speech, it is virtually impossible to know whether or not the speaker is going to use the structure that the investigator is researching. This is easily seen in Jenkins (1999) and Alba (2006) who are constrained to use only the data (and only the data) available to them in the New Mexico Spanish corpus, although they are able to make any predictions about the behavior of any words or structures that do not appear in the corpus. They might argue that a word or form did not appear in the corpus then it is not important to study. An experimentally-based approach would view unused forms as a potentially interesting area of study: what would New Mexico Spanish speaker do with X form? And, what does that say about the cognitive language processes of those speakers?

To gain some control, Aguilar (1999) employed a so-called map task, wherein subjects look at a map and then speak extemporaneously and naturally about the direction to arrive at a certain locale as indicated in the instructions. The words that the investigator wishes to study is a point of interest located somewhere on the map that are obligatorily referred to in order to fulfill with the task (i.e., give correct directions). From a practical viewpoint, naturalistic language studies also pose a significant challenge as it might take hours of speech before a person utters the item of interest.
Experimentally-based investigations do not aim at taking away from naturalistic methods of data collection, only to contribute. For the purposes of this experiment, I have chosen an experimentally-based method of data collection for the following reasons: it is much easier to maintain control of the objectives of the experiment, it is easier to elicit the desired forms, it is possible to modulate speech rate and word frequency, and that because of these it is possible to induce the strategies that subjects will use to manage speech rate and word frequency. Additionally, some of the factors that have been said to contribute to hiatus resolution can be manipulated, such as stress and phrasal intonation (i.e., if there is no sentence to produce, phrasal intonation can be ruled out as a possible contributing factor to hiatus resolution. If words in isolation show an effect for frequency—that would be an interesting result and one that would enable us to make a more precise judgment about the way in which frequency affects hiatus resolution).

One possible downside to experimentally-based investigations is that even having as much control as is possible, participants are still free to behave as they please. Another is that some speakers feel as if they must speak as ‘correctly’ as possible in the laboratory for fear of being judged because of the way they speak. This can lead participants to alter their speech.

Weighing the options of the various methods of data collection, it was determined that experimental tasks would be the best, most efficient way to study this particular aspect of hiatus resolution, for the reasons just discussed. What will be interesting to report is if there is a result for frequency effect in spite of the inherent limitations of such an approach.
1.6 Summary

In this chapter I discussed the rules for vowels in hiatus and in diphthongs in Spanish. I reviewed the literature on hiatus resolution and have shown that the issue is complex and at times surprising, with numerous outcomes and multiple factors modulating the way in which hiatus is resolved (or not resolved).

More recently, authors have attempted to account for such variability not only in hiatus resolution (specifically as it pertains to hiatus across words) but also in many other structures of language using a usage-based model of language. The main hypotheses of a usage-based model of language are that repetition can lead to reduction of forms, strengthening of forms, or in some cases, the emergence of new forms. Applying these hypotheses to an experimentally-based investigation of hiatus resolution in Spanish, it is hypothesized that speech rate or carefulness of speech are not the only factors that influence the degree of hiatus resolution; instead, I hypothesize that frequency also affects hiatus resolution, with words with a vowel combination in hiatus of higher-frequency showing a higher degree of resolution between the vowels than those of lower frequency.

In the next Chapter I discuss the methods used for the creation and implementation of the experiments, including how critical (test), control, and filler items (i.e., word lists) were chosen based on Spanish corpus data, and how and where the date were collected. I will also discuss the design of the study, including the specific tasks the participants completed. Then, I will provide information about the
speakers who participated in the study. Additionally, I will discuss how the data was extracted, what techniques were used to measure the data, and the process by which the data was further analyzed.
Chapter 2

Methods

2.1 Overview

The data to be discussed for this dissertation come from results of a within-subject 2 x 2 experimental design completed by native speakers of Mexican Spanish, as shown in Table 2-1.

Table 2-1 Experiment design

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<thead>
<tr>
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<th>High-frequency words</th>
<th>Low-Frequency words</th>
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<tr>
<td>Experiment 1: Slow speech word naming</td>
<td>HF words in slow speech condition</td>
<td>LF items in words speech condition</td>
</tr>
<tr>
<td>Experiment 2: Fast speech word naming</td>
<td>HF words in fast speech condition</td>
<td>LF words in fast speech condition</td>
</tr>
</tbody>
</table>

Experiment 1 consisted of a slow-speech word-naming task while experiment 2 consisted of a fast-speech word-naming task. Both experiments contained high- and low-frequency words in Spanish that were matched for number of syllables, placement of stress and VV sequence. The high- and low-frequency tokens in their responses were recorded and analyzed for overall word duration as well as vowel duration and spectrographically for vowel formant measures. All participants completed both experiments.
2.1.1 Participants

A total of 36 participants completed the experiments (24 female). Participants ranged in age from 18 to 26, with the mean age being 20.9. All were recruited at the Universidad Iberoamericana in Puebla, Mexico, where they were enrolled as students. All participants completed a Language History Questionnaire to ensure that they were L1 native speakers of Spanish from Mexico who used Spanish daily as their dominant language. None reported any hearing or uncorrected visual impairments. As with most university students, all participants had studied at least one other language in school. Two self-reported as early bilinguals (one Spanish/French and one Spanish/German). All participants were remunerated for their participation.

2.1.2 Equipment

The experiments were conducted in a quiet room at the Universidad Iberoamericana in Puebla, Mexico. Stimuli were presented using E-Prime on a Dell Pentium PC. Responses were recorded with a Marantz PMD 660 professional solid state recorder, with the sound digitized at 44 KHz with 16 bit sampling using a Shure SM-10A cardioid microphone.

2.1.3 Variables

The dependent variable in the experiment was the behavior of the VV sequence as produced by the participants in the tasks. This variable is continuous because the
VV sequence is measurable, both in terms of the duration of the VV sequence as well as the values of the formants F1 and F2 (in Hertz) across the span of the VV sequence.

There were two independent variables. One was the manipulation of speech rate; the other was the frequency of the words. Fast and/or so-called careless speech has been argued to be a primary contributing factor in hiatus resolution in Spanish, while slow and/or careful speech has been claimed to contribute to hiatus maintenance (Navarro-Tomás 1968a, Harris 1969, Jenkins 1999, Hualde 2005, Alba 2006). In order to test the hypotheses that high-frequency tokens will show greater degree of hiatus resolution independent of speech rate over their low-frequency counterparts, participants named words in two experiments, one designed to induce slower, careful speech, and the other designed to induce fast speech.

2.2 Experiments

Participants completed two experiments that were designed to elicit two different types of speech; slow speech and fast speech. The rationale for eliciting two rates of speech was to determine what the effect that word frequency would have on hiatus resolution. It is generally assumed that speech rate affects not only the presence or absence of hiatus resolution, but also the degree to which a VV sequence is resolved. It was believed that word-naming tasks with high- and low-frequency words in both a fast and slow speech condition would provide data that would determine the role that word frequency has on hiatus resolution, while at the same time testing in a controlled
fashion for the extent to which speech rate modulates hiatus resolution. For the experiments, all subjects completed the slow speech task before the fast speech task.

2.2.1 Experiment 1: Slow speech

The production of slow speech was induced via a delayed naming task presented via E-Prime. In this condition, critical items (words with the desired hiatus combination), control items (words that already had a diphthong) and filler items appeared one-by-one in random fashion on a computer screen. Prior to beginning the experiment, participants were instructed to read the word and prepare to say it, and then read out loud the word in a careful but natural manner when prompted to do so. At test, participants saw a fixation point (a + sign) which remained on the computer screen for 1000 ms. This was followed by the target word which also remained on the screen for 1000 ms over a white background. After 1000 ms, the background color of the screen changed and remained on the screen for 3800 ms. The color change was the prompt indicating that the participants were to name the word. The participants had been told in the instructions and had practiced in the trial forms such that they did not have to name the form as quickly as possible; rather, they named the word in a careful yet natural fashion. The target word remained on the screen for 3800—enough time so the participants could produce the target fully before it disappeared. This was a novel technique. In typical voice-keyed naming tasks, the word disappears as soon as the microphone picks up the voice of the speaker.
In piloting this design, it was determined that to have the word disappear suddenly while the speaker was producing it was distracting in the careful speech condition. The rationale for the presentation of the stimuli in this manner was that if the participants had ample time to produce the word that appeared on the computer screen, they would not rush their answers and would produce a slower, more careful type of speech.

To ensure that participants had understood the procedure of the tasks, they completed a practice block of ten words prior to starting the recording. In the actual experiments, critical, control, and filler items appeared in randomized fashion. When participants made errors (such as producing the incorrect word, or false starting) in the experiments, the responses were discarded and not taken into account in the analysis of the data.

### 2.2.2 Experiment 2: Fast speech

Fast speech was induced by manipulating the presentation of the stimuli via E-Prime. As before, participants were instructed to read each word out loud as it appeared on the screen. In this condition, however, they were instructed to say the word as quickly as possible. The voice key response triggered the disappearance of the word and the appearance of a + fixation in the middle of the screen for 1000 ms, followed by the appearance of the next stimulus. The goal of this design was to induce participants to respond as quickly as possible, thus yielding faster speech forms than those in the careful speech experiment.
As in the slow speech condition, participants completed a practice block of ten words to ensure they had understood the procedure of the tasks prior to starting the recorder. Experimental items appeared in randomized fashion, and production errors were not included in the analysis of the data.

### 2.3 Word list selection

The experiments completed by the participants were composed of word lists made up of critical items (25), control items (13), and filler items (106), for a total of 144 items plus 10 practice items. Critical items that appeared in the experiments were selected to provide high- and low-frequency word pairs that were matched for vowel combination, for stress placement, for number of syllables, and as closely as possible, for phonetic environment.

Control items were also chosen based on their vowel combinations, stress placement, and their frequency values so as to closely resemble those found in the critical items. Unlike critical items, control items were words whose vowel combinations that already contained a diphthong. It was believed that these items would serve as a baseline for comparing the degree of hiatus resolution that was hypothesized would be found in the critical items. If the hiatus becomes (or approaches becoming) a diphthong, then having data from words that already have a diphthong in them would prove useful. For example, if the high frequency critical item *ideal* ‘ideal’ is found to have diphthongization as a result of hiatus resolution, a spectrographic
comparison with the diphthong in the control word *mundial* ‘worldwide’ ([.djäl]) would indicate whether or not /ea/ in *ideal* is truly becoming like the diphthong [ja].

It was believed that pairing high- and low-frequency critical items (with hiatus) with control items (with diphthong) would allow for the following:

a) Experimentally test the findings that suggest that VV sequences in hiatus in high-frequency words are often resolved as diphthongs (Jenkins 1999; Aguilar 2003; Alba 2006, among others).

b) Comparing the degree of hiatus resolution with words of a similar stress pattern that already had a diphthong.

c) Investigate what the nature of the resolution is if the VV sequences are not becoming more diphthong-like.

Filler items were all words in the experiments that did not have the VV sequence /ea/. These included words with the VV sequences /oa/, /eo/, /oe/ as well as words with neither VV sequences nor diphthongs. Filler items had approximately the same number of syllables and similar stress patterns as their critical and control item counterparts.

### 2.3.1 VV sequence

As discussed in Chapter 1, the quality of the two vowels and the placement of stress in VV sequences are primary contributors of hiatus resolution in Spanish. It has been suggested that hiatus resolution is facilitated when unstressed /e/ or /o/ is followed by a more sonorous vowel, as in /ao/, /eo/, /ea/, and /oe/, for instance (Navarro-Tomás...
1968a, Hualde 2005, among others). Further, these are vowel combinations in which a rising diphthong is a possible outcome of hiatus resolution: /oa/ \(\rightarrow\) [wa], /eo/ \(\rightarrow\) [jo], /ea/ \(\rightarrow\) [ja], and /oe/ \(\rightarrow\) [we]. For these reasons, words with the vowel combinations /ao/, /eo/, /ea/, and /oe/ were sought out to be included in the experiments.

Although words containing each of the four VV sequences /oa/, /eo/, /ea/, and /oe/ were included in the word lists, only data from /ea/ words was investigated here. The other VV sequences /oa/, /eo/, and /oe/ served as filler items in the experimental tasks. The primary reason for this is that /ea/ has been determined to be the most frequent VV sequence in hiatus in Spanish. Jenkins (1999) and Diaz-Campos et al. (2006) found that not only was /ea/ the most frequent VV sequence in the different corpora they used, but that hiatus resolution was more common in words with and /ea/ sequence, such as in the word real ‘real’ \(\rightarrow\) [rjal].

In order to confirm these claims, the online resource “the Corpus del Español” (Davies 2007; henceforth CdE) was used to determine the frequency of occurrence of Spanish VV sequences. The CdE contains searchable data from both a variety of genres (written and oral-based texts) as well as centuries (1200s -1900s). Although the entire corpus is made up of some 100 million words, the data for this current investigation came from the 1900s selection, the size of which is 22.8 million words. This was thought to best represent the current usage of the words chosen for the experiments by the average educated Spanish speaker\(^2\). The frequency counts obtained from the CdE confirm the claims made by Jenkins (1999) and Diaz-Campos et al. (2006).

\(^2\) While it was believed that the data retrieved from the online corpora provided adequate counts for the purposes of this dissertation, all corpora have limitations. Nonetheless, for the purposes of a laboratory experiment such as this one, the general agreement as to the relative high- and low-frequency of the target items arguably provides valid criteria for selection.
al. (2006). Table 2-2 shows the raw frequency count, the per million count, the log frequency, as well as the percentage of the corpus of the four VV sequences /oa/, /oe/, /eo/, and /ea/.

Table 2-2 Frequency counts of the VV sequences /oe/, /oa/, /eo/, and /ea/

<table>
<thead>
<tr>
<th>VV sequence</th>
<th>Raw Frequency</th>
<th>Per Million</th>
<th>LOG</th>
</tr>
</thead>
<tbody>
<tr>
<td>/oa/</td>
<td>11,606</td>
<td>508.5</td>
<td>4.065</td>
</tr>
<tr>
<td>/oe/</td>
<td>13,890</td>
<td>608.6</td>
<td>4.143</td>
</tr>
<tr>
<td>/eo/</td>
<td>65,923</td>
<td>2,888.5</td>
<td>4.819</td>
</tr>
<tr>
<td>/ea/</td>
<td>131,261</td>
<td>5,751.4</td>
<td>5.118</td>
</tr>
</tbody>
</table>

As can be seen, words with the VV sequence /ea/ are much more frequent than the VV sequences /oe/, /oa/, and /eo/, occurring at over 5,751 times per million words, according to the CdE. As discussed in Chapter 1, under a usage-based model of language repetition (frequency) can lead to phonological reduction. Therefore, if frequency effects in hiatus resolution were to be found, it was anticipated that they would most likely be found not only in the higher frequency words as compared to low-frequency words with the same VV sequence, but also that they would be found to a higher degree in high-frequency VV sequences as compared to low-frequency VV sequences.

Words with the VV sequence /ea/ were not the only items considered for the experiment. A subset of words with the VV sequence /ea/ was also included in the word lists; namely, words that end in /-ear/. These were also included in the list of critical items largely because they facilitated finding high- and low-frequency pairings.

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23 The CdE is an NEH-funded corpus of Spanish comprised of approximately 100,000,000 words.
due in part to their relative abundance. Indeed, the CdE records 5,830 instances of words ending in /-ear/ in the 1900s selection (255.5 per million and log frequency of 3.766), thus providing ample options from which to choose. The key reason, however, was that matching high-and low-frequency words was more successful due to their phonetic similarities (e.g., all words end in /r/, thus removing a variable of phonetic environment similarity). A complete list of the critical /ea/ and /ear/ words are found below in Tables 2-3 and 2-4.

2.3.2 Frequency of items

A goal of this dissertation is to test for the effects of word frequency on hiatus resolution. Therefore, after determining the most frequent VV sequence in Spanish, as well as the usefulness of /-ear/ words, it was necessary to choose critical items based on frequency counts with /ea/ and /-ear/ sequences to be used in the experiments. The CdE was also used to obtain frequency information in order to pair words for similarities in VV sequence, stress, and number of syllables, but that differed in frequency (high vs low). A word was deemed high-frequency if it recorded a raw frequency count that was higher than 100 occurrences. Conversely, a word was considered low-frequency if it recorded a raw frequency count below 50 occurrences. Log transformations were also calculated for the original raw frequency counts. Table 2-3 shows the high- and low-frequency /ea/ items included in the tasks with their raw frequency and per million words count, and their log frequencies, according to the 1900s of the CdE.

24 The one exception to these parameters is leal (‘loyal’), which recorded a raw frequency of 148. Nonetheless, it was still designated as a low frequency item since its high frequency counterpart, real (‘real’) is of such high frequency (raw frequency of 3619).
Table 2-3 Raw, per million, and log frequency counts of the high- and low-frequency /ea/ words

<table>
<thead>
<tr>
<th>High-Frequency Word</th>
<th>Gloss</th>
<th>Raw Frequency</th>
<th>Per Million</th>
<th>LOG</th>
</tr>
</thead>
<tbody>
<tr>
<td>teatro</td>
<td>‘theater’</td>
<td>4025</td>
<td>176.4</td>
<td>3.605</td>
</tr>
<tr>
<td>creado</td>
<td>‘created’</td>
<td>766</td>
<td>33.6</td>
<td>2.884</td>
</tr>
<tr>
<td>real</td>
<td>‘real’</td>
<td>3619</td>
<td>158.6</td>
<td>3.559</td>
</tr>
<tr>
<td>ideal</td>
<td>‘ideal’</td>
<td>773</td>
<td>33.9</td>
<td>2.888</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Low-Frequency Word</th>
<th>Gloss</th>
<th>Raw Frequency</th>
<th>Per Million</th>
<th>LOG</th>
</tr>
</thead>
<tbody>
<tr>
<td>floreal</td>
<td>‘floral’</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>peal</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Low-Frequency Word</th>
<th>Gloss</th>
<th>Raw Frequency</th>
<th>Per Million</th>
<th>LOG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peano</td>
<td>‘Peano’</td>
<td>(last name)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>craneal</td>
<td>‘cranial’</td>
<td>18</td>
<td>0.8</td>
<td>1.255</td>
</tr>
<tr>
<td>beato</td>
<td>‘devout’</td>
<td>35</td>
<td>1.5</td>
<td>1.544</td>
</tr>
<tr>
<td>leal</td>
<td>‘loyal’</td>
<td>148</td>
<td>6.5</td>
<td>2.170</td>
</tr>
</tbody>
</table>

In this Table we see that based on frequency counts from the 1900s selection of the CdE, high-frequency /ea/ words chosen for the experiments are more frequent than the low-frequency /ea/ words, some of which recorded no occurrences in the CdE. It was important to find low-frequency counterparts that recorded very low counts without resorting to using nonce words, as testing nonce words with real words was not the intent of this investigation.

The following Table 2-4 contains the high- and low-frequency /-ear/ words with their raw frequency and per million words count, and their log frequencies, according to the 1900s section of the CdE.
Table 2-4 Raw, per million, and log frequency counts of the high- and low-frequency /-ear/ words

<table>
<thead>
<tr>
<th>High-Frequency Word</th>
<th>Gloss</th>
<th>Raw Frequency</th>
<th>Per Million</th>
<th>LOG</th>
</tr>
</thead>
<tbody>
<tr>
<td>golpear</td>
<td>‘to hit’</td>
<td>173</td>
<td>7.6</td>
<td>2.238</td>
</tr>
<tr>
<td>pasear</td>
<td>‘to take a walk’</td>
<td>210</td>
<td>9.2</td>
<td>2.322</td>
</tr>
<tr>
<td>nuclear</td>
<td>‘nuclear’</td>
<td>686</td>
<td>30.1</td>
<td>2.836</td>
</tr>
<tr>
<td>emplear</td>
<td>‘to employ’</td>
<td>266</td>
<td>11.7</td>
<td>2.425</td>
</tr>
<tr>
<td>pelear</td>
<td>‘to fight’</td>
<td>171</td>
<td>7.5</td>
<td>2.233</td>
</tr>
<tr>
<td>desear</td>
<td>‘to desire’</td>
<td>114</td>
<td>5</td>
<td>2.057</td>
</tr>
<tr>
<td>plantear</td>
<td>‘to pose’</td>
<td>215</td>
<td>9.4</td>
<td>2.332</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Low-frequency Word</th>
<th>Gloss</th>
<th>Raw Frequency</th>
<th>Per Million</th>
<th>LOG</th>
</tr>
</thead>
<tbody>
<tr>
<td>mantear</td>
<td>‘to throw up w/ a sheet’</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>prear</td>
<td>‘to steal’</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>bracear</td>
<td>‘to move quickly between arms’</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>coclear</td>
<td>‘spiral shaped’</td>
<td>2</td>
<td>0.1</td>
<td>0.301</td>
</tr>
<tr>
<td>sablear</td>
<td>‘to borrow money’</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>quesear</td>
<td>‘to make cheese’</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>palear</td>
<td>‘to dig w/ a shovel’</td>
<td>3</td>
<td>0.1</td>
<td>0.477</td>
</tr>
<tr>
<td>milpear</td>
<td>‘to care for maiz’</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

In this Table we see that the high-frequency /-ear/ words chosen for the experiments are more frequent in the 1900s selection of the CdE than the low-frequency words. As with the /ea/ words, many of the low-frequency /-ear/ words also recorded no occurrences in the CdE.
Paring words based on frequency (high vs low) to be used experimentally in fast and slow speech word naming tasks is a novel approach. Previous accounts of hiatus resolution have either relied on frequent items to emerge from the natural speech of participants (e.g., Jenkins 1999), or have not controlled for frequency (as in Aguilar 2003).

2.3.3 Stress, number of syllables, and phonetic environment

The /ea/ and /-ear/ high-and low-frequency words chosen above were also selected based on stress placement at the word level. Because stressed vowels in Spanish are sometimes altered in speech (see previous chapter), a concerted effort was made to ensure that critical and control items paired for frequency also shared similar stress placement. Not only that, but critical item pairings were also matched for number of syllables. Again, because vowels are often altered when stressed, and because stress placement is affected by how many syllables composing a word, it was important to find high- and low-frequency word pairs that also shared how many syllables were in each word. For example, *ideal* ‘ideal’ has three syllables and primary stress over the final syllable [i.ðe. ál]. Similarly, its low-frequency counterpart, *craneal* ‘cranial’ also has three syllables and primary stress over the final syllable [kra.ne. ál]. The control word counterparts already have a diphthong; therefore, they have one less syllable than their critical word counterparts. Still, they shared similar primary stress placement: *mundial* ‘worldwide’ > [mun.djá].
It was also necessary to select high- and low-frequency word pairs whose phonetic environment surrounding the /ea/ and /-ear/ was similar. This was done to control for the possible effect that the surrounding phonemes might have on the acoustics of the VV sequences in question. While it was not possible to match the phonetic environment exactly for each pair, every effort was made to find pairs that were as similar phonetically as possible. For example, high-frequency teatro ‘theater’ was paired with low-frequency beato ‘devout’ because both words begin with a stop consonant. High-frequency golpear ‘to hit’ was paired with low-frequency milpear ‘to care for maiz’ because, although they do not share the same word-initial consonant, they do share the same CC sequence preceding the VV sequence; /l/ and /p/, and so on. All the high- and low-frequency pairings are shown in Table 2-5, along with sample high- and low-frequency control items and filler items.
<table>
<thead>
<tr>
<th>Critical /ea/ item</th>
<th>Sample Control /ja/ item</th>
<th>Filler</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High Freq.</strong></td>
<td><strong>Low Freq.</strong></td>
<td></td>
</tr>
<tr>
<td>teatro</td>
<td>vs beato</td>
<td></td>
</tr>
<tr>
<td>creado</td>
<td>vs peano</td>
<td></td>
</tr>
<tr>
<td>real</td>
<td>vs peal</td>
<td></td>
</tr>
<tr>
<td>ideal</td>
<td>vs craneal,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>vs floreal</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Critical /-ear/ item</th>
<th>Sample Control /ja/ item</th>
<th>Filler</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High Freq.</strong></td>
<td><strong>Low Freq.</strong></td>
<td></td>
</tr>
<tr>
<td>golpear</td>
<td>vs milpear</td>
<td></td>
</tr>
<tr>
<td>pasear</td>
<td>vs bracear</td>
<td></td>
</tr>
<tr>
<td>nuclear</td>
<td>vs coclear, sablear</td>
<td></td>
</tr>
<tr>
<td>emplear</td>
<td>vs prear</td>
<td></td>
</tr>
<tr>
<td>pelear</td>
<td>vs palear</td>
<td></td>
</tr>
<tr>
<td>desear</td>
<td>vs quesar</td>
<td></td>
</tr>
<tr>
<td>plantear</td>
<td>vs mantear</td>
<td></td>
</tr>
</tbody>
</table>

### 2.4 Measurement of phonetic properties

A major component of the analysis of this investigation was the acoustic (i.e., spectrographic) measurement of the VV sequences in question. It was believed that this type of objective measuring would provide a much more accurate depiction of the acoustic signal as it is modified due to word frequency and speech rate. Alternatively, some have used impressionistic coding, performing ‘by ear’ evaluations of hiatus resolution phonological variation (Alba 2006). Although employed by Alba (2006) he admits that “this method can…be problematic for distinguishing between the different
types of hiatus reduction, which often sound very similar to the ear” (71). Seeing this as a major limitation of impressionistic evaluations, it was determined that hiatus resolution would be more accurately measured via objective acoustic computational means.

Therefore, acoustic analyses were performed on the critical and control items using the speech analysis software Praat (Boersma & Weenink 2008). All critical items in both experiment 1 (slow speech) and experiment 2 (fast speech) from all participants were measured for overall word duration, VV sequence duration, and formant values (F1 and F2) of the VV sequences (1,800 total critical items). Overall word duration measurements were taken as a means of assessing the effectiveness of the experimental conditions of careful and fast speech while the durations of the VV sequences themselves were taken as a means of closely comparing the effects of rate and frequency on the realization of the combined vowels. Vowel formant measurements were taken to determine if VV sequences in hiatus were resolved to become more diphthong-like (/ea/ > [ja]), more like each other (/ea/ > [aa]), or if they maintained hiatus (/ea/ > [e.a]).

2.4.1 Word duration

Critical items were measured from the beginning to the end of the acoustic signal for each individual word in Praat (Boersma & Weenink 2009). Together with audio input, visual input from both the sound waves and spectrograms were used to determine the beginning and the end of the acoustic signal for each critical item. For
many items, measuring for overall word duration was straightforward, as the beginning and end of the signal were easily identifiable. Measuring for overall word duration in some items, however, proved to be more challenging. These challenges included:

1) Determining the end of the acoustic signal for word-final /r/

2) Accounting for prevoicing of word-initial /b/

3) Determining the end of the acoustic signal in cases of word-final vowel loss, as in /beato/ > [beat]

Participants produced word-final /r/ in a variety of different manners. Some produced multiple trills [ɾ], while others produced a voiceless sibilant [s], as would be expected given speakers of this Mexican Spanish dialect (Lipski 1994). Visual and audio input was used to determine when production of the /r/ had ended; and word duration measurements of the /-ear/ items were taken consistently to that point for each item. For example, Figure 2-1 is a spectrogram of sablear, indicating where the measurement was taken for a sibilant word-final /ɾ/.

Figure 2-1 Spectrogram of sablear
Some participants also produced the word-initial /b/ with a significant amount of prevoicing. For these items the overall word measurement was taken at the release of the stop consonant, as shown in Figure 2-2. The reason for this measurement is that there may have been stop closure not accompanied by audible energy in other tokens that is not measureable. By taking the measure from the release of the [b], there is consistency across all tokens beginning with [b] and not inducing spurious extra length in some tokens.

![Spectrogram of beato](image)

Figure 2-2 Spectrogram of *beato*

Further, some speakers reduced or elided word-final vowels. This was also anticipated because of dialectal tendencies of these Mexican Spanish speakers (Lipski 1994). In these cases, the endpoint of the overall word duration was determined in a similar manner as other variability; that is, using both visual and audio input together to determine the beginning and end of the signal.
While measuring overall word duration was an important component of data analysis, the VV sequences themselves were of particular interest. Two separate measurements were taken of each of the VV sequences. The first was the duration of the VV sequence. The second involved measuring the first (F1) and second (F2) formants of the VV sequences under scrutiny.

It was anticipated that VV sequences in the fast speech condition would be of shorter duration than those in the slow speech condition. Further, and as previously mentioned, frequent words often undergo phonological reduction (Bybee 2001). Hiatus resolution often manifests itself as a shortening (in duration) of the VV sequence. Therefore, we expect /ea/ sequences in high-frequency words to be shorter in duration and /ea/ sequences in low-frequency words regardless of speech rate. As was done with measurements for word duration, VV sequence measurements were also taken based on visual and audio input. For VV sequences, durational measurements were started at the
beginning of the production of the /e/, and ended at the completion of the /a/, as shown in the following:

![Figure 2-4 Example of VV duration measurement](image)

Not only do we expect shorter duration of /ea/ sequences due to speech rate and frequency, but also because of the diphthongization process. Data collected by Aguilar (1999) suggests that diphthongs are shorter in duration than vowels in hiatus. Therefore, if vowels in hiatus are resolved as diphthongs, we might also expect shortening due to diphthongization, as well as speech rate and frequency.

In order to determine if VV sequence shortening was in part due to diphthongization, a second measurement was taken of the VV sequences. This measurement was of the formants F1 and F2. If diphthongization is happening, not only might we expect durational differences in the VV sequences, but also that the F2 measurements will be higher if, in fact, the first vowel of the sequence is rising. This is because the F2 for /i/ is higher (as in diphthongs) than the F2 of /e/ (found in hiatus). Additionally, we might expect F1 to be lower, since vowel height is inversely related to the value of F1. This is clearly visible in Figures 2-5 and 2-6. Figure 2-5 shows a
spectrogram of the VV sequence /ea/ from the word *leal* ‘loyal’, while Figure 2-6 shows a spectrogram of the diphthong [ja] from the word *piano* ‘piano’.

![Spectrogram](image)

**Figure 2-5** Spectrogram of the vowel sequence [ea] (*leal*)
Figure 2-6 Spectrogram of the vowel sequence [ja] (piano)

Note the relative F2 height of [j] (~2600 Hz) of piano compared to the height of F2 for [e] (~2400 Hz) in leal. If vowels in hiatus are being resolved as diphthongs, we would anticipate that the F2 of the first vowel [e] would raise and become more like [j] in Figure 2-6.

Not only do we expect a higher F2 if vowels in hiatus are diphthongizing, but we also expect there to be F2 trajectory differences between the VV sequences (or glide-vowel sequences) (Aguilar 1999). For instance, vowels in hiatus have longer steady-state horizontal F1 and F2 measurements, followed by a transition to the next vowel, then more steady-state F1 and F2. Diphthongs, on the other hand, show little
steady-state F2 measurements from either vowel; instead, a quick transition up to (or away from) the sonorous vowel is often observed. This can be seen in the F1 and F2 trajectories of a standard production of an /ea/ sequence (ideal) and a diphthong (mundial) of Figure 2-7.

![Graph of F1 and F2](image)

**Figure 2-7** Graph of F1 and F2 of [ja] (mundial) and [ea] (ideal)

In Figure 2-7 we see the following: 1) the diphthong has both higher F2 and lower F1 Hz values than the /ea/ sequence; 2) the transition from [j] to [a] of the diphthong is less gradual than in the /ea/ sequence (i.e., more steady state in /ea/); and, 3) the diphthong is shorter. The following Figure (2-8) highlights the diphthong-/ea/ sequence slope difference in a trendline of the F2 values.
Figure 2-8 Graph of linear trendlines of F2 of diphthong and /ea/ sequence

In this graph we observe a quick transition of the diphthong as represented by the steepness of the slope of the trendline, while the /ea/ sequence in hiatus shows a more gradual trendline. This tells us that if, in the experiments, /ea/ sequences return values that are more diphthong-like, it will be observable both in the F1 and F2 values of the vowels, as well as in the steepness of the F2 slope trajectories. This type of formant tracking and subsequent graphing and analysis were performed on all critical items from both experiments and all participants.

2.5 Summary

In summary, thirty-six native Mexican Spanish speakers participated in two word-naming laboratory experiments to test whether or not frequency affects hiatus resolution in Spanish. One experiment was designed to elicit slow speech; the other,
fast speech. They produced a total of 1,944 tokens\textsuperscript{25}; all of which were measured for overall word duration, /ea/ VV sequence duration, and formant trajectory in order to determine the role of frequency in hiatus resolution. Words with /ea/ sequences were chosen based on their high frequency of occurrence in Spanish. Critical item pairs were chosen based on their vowel sequence, stress placement, number of syllables, and frequency (high vs low). Control items were chosen based on similar criteria as the critical items with one important difference; control items already contained a rising diphthong /ja/. Filler items were included to mask the intent of the experiment.

Measurements of overall word duration were performed via the software program Praat for every word; duration was also measured for each /ea/ token, as was formant trajectory. Statistical analyses of the various measurements were calculated, the results of which will be discussed at length in the next chapter.

\textsuperscript{25} Thirty six speakers produced 27 tokens twice (critical items and two control items, \textit{piano} and \textit{cambiar}); once in the fast speech task, once in the slow speech task.
Chapter 3

Results

3.1 Overview

This chapter presents and discusses the results of the two experiments conducted to test the effect of word frequency and speech rate on hiatus resolution in Spanish. Recall that experiment one was a word naming task designed to elicit slow speech from the participants. Experiment two was also a word naming task; however, it was designed to elicit fast speech from the participants. The word lists named in the tasks were composed of high-frequency and low-frequency critical words, control words, and filler words.

Each experiment yielded two kinds of data; overall word and vowel sequence duration values, and vowel sequence formant measurement values. Each of these two broad types of data can be further broken down into results based on speech rate (fast vs. slow) and word frequency (high vs. low), such that there is data from the following criteria:

- Overall word duration for high frequency words in the fast speech condition
- Overall word duration for low frequency words in the fast speech condition
- Overall word duration for high frequency words in the slow speech condition
- Overall word duration for low frequency words in the slow speech condition
- VV sequence duration for high frequency words in the fast speech condition
• VV sequence duration for low frequency words in the fast speech condition
• VV sequence duration for high frequency words in the slow speech condition
• VV sequence duration for low frequency words in the slow speech condition
• Overall word duration and VV sequence duration for words with the diphthong [ja].

Formant data was also obtained from the following criteria:

• F1 and F2 values of VV sequences of high frequency words in the fast speech condition
• F1 and F2 of VV sequences of low frequency words in the slow speech condition
• F1 and F2 of VV sequences of high frequency words in the slow speech condition
• F1 and F2 of VV sequences of low frequency words in the slow speech condition
• F1 and F2 of VV sequences of [ja] words in the slow and fast speech conditions

These various data contribute to the evaluation of the hypothesis that word frequency as well as speech rate affect the degree to which vowel sequences in hiatus are resolved in Spanish. Further, the data also afford the opportunity to look closely and critically at the precise nature of the vowel sequence acoustic signals as functions of frequency and speech rate. Previous investigations have relied upon impressionistic evaluative techniques in order to judge hiatus resolution in Spanish, and as such, have not been able to take detailed durational and formant trajectory spectrographic measurements as have been done in this present study. It was believed that such detailed spectrographic measurements would contribute to a better understanding of the nature of speech rate and word frequency effects on hiatus resolution.
The remainder of this chapter will report first on the results of the measurements of the overall word and VV sequence durations, including the impact that speech rate and word frequency had on the overall word and VV sequence durations. Next, results of the formant (F1 and F2) measurements of the VV sequences will be reported and discussed, including also the results of word frequency and speech rate effects on formant trajectories of the VV sequences. A discussion and summary of the findings of this chapter will follow.

3.2 Results: duration

3.2.1 Word duration

This section reports on the effectiveness of the speech rate manipulation strategy in eliciting fast and slow speech from the subjects. Recall that speech rate has been suggested to be a primary force in the presence and degree of hiatus resolution in Spanish, with faster speech inducing more hiatus resolution (e.g., Navarro-Tomás 1968b, Harris 1969, Jenkins 1999, Alba 2006). Thus, experiments elicit fast and slow speech from the participants, as was discussed in section 2.2. There were two primary measurements of the critical items upon which statistical analyses were performed in order to determine if participants did, indeed, speak faster in the fast-speech condition than in the slow-speech condition. These were overall word duration by speech condition and by participant and overall VV sequence duration by speech condition and by participant. We now look at how successful the experimental design was in eliciting fast and slow speech.
3.2.1.1 Speech rate and frequency

A one-way repeated measures ANOVA was performed to compare overall word duration of high and low frequency words in the fast and slow speech condition. There was a significant main effect on overall word duration for speech rate, $F(1, 35) = 66.05, p < .0005$. There was also a significant main effect on overall word duration for frequency, $F(1, 35) = 34.91, p < .0005$. There was no significant interaction between speech rate and frequency, $F(1,35) = 1.16, p = .290$. This can be seen in the following:

![Figure 3-1 Overall mean word durations, high and low frequency words, fast and slow speech conditions](image)

As shown in Figure 3-1, word duration of both the high ($M = .4906, SD = .0503$) and low frequency words ($M = .5028, SD = .0514$) in the slow speech condition were significantly longer than their fast speech counterparts (high frequency, $M = .4250, SD = .0584$, and low frequency $M = .4409, SD = .0587$). This suggests that the
methods employed in the experiments to elicit fast and slow speech were successful; overall word durations in the slow speech condition were statistically significantly longer than those in the fast speech condition for both the high- and low-frequency words.

Additionally, word durations of the high frequency words in both the fast ($M = .4250, SD = .0584$) and slow speech ($M = .4906, SD = .0503$) conditions were significantly shorter than their low frequency counterparts in both speech conditions (fast $M = .4409, SD = .0587$, and slow $M = .5028, SD = .0514$). These results suggest that not only did speech rate affect overall word duration, but frequency of the words used in the experiment also affected overall word duration with the higher frequency words being shorter in duration than the lower frequency words. Overall word duration was modulated as hypothesized; namely, that faster speech and words of higher frequency would yield more temporal compression than their slow speech and low frequency counterparts.

3.2.2 Phoneme and syllable count

Mean phonemes and mean syllables per word were calculated and analyzed for the high and low frequency words in order to determine whether or not the effect for word frequency was due to a difference in the number of phonemes and/or syllables between the words chosen for the high and low frequency word lists. An independent-samples t-test was conducted to compare the phoneme and syllable counts for high and low frequency words. There was no significant difference in number of phonemes for high frequency ($M = 6.18, SD = .95$) and low frequency words, $M = 6.07, SD = 1.21$; $t$
(26) = .268, \( p = .79 \) (two-tailed). Similarly, there was no significant difference in number of syllables for high frequency (\( M = 2.91, SD = .26 \)) and low frequency words, \( M = 2.79, SD = .43; t(26) = .906, p = .37 \) (two-tailed). Descriptively, both the mean phoneme and syllable counts are slightly higher for the high frequency words. This is shown in Figure 3-2:

![Figure 3-2 Mean number of phonemes and syllables, high and low frequency words](image)

The difference attributed to frequency is statistically insignificant, but since the high frequency words had slightly more phonemes and syllables than the low frequency words it shows that their shorter duration was not because they were composed of less phonemes and/or syllables. Indeed, finding that word frequency modulated word duration in spite of their slight increase in number of mean phonemes and syllables lends further support to the hypothesis that high frequency words would be shorter than low frequency words.
3.2.3 VV duration

3.2.3.1 Speech Rate and frequency

A one-way repeated measures ANOVA was performed to compare the vowel sequence durations contained in the high and low frequency words in the fast and slow speech condition. There was a significant main effect on vowel sequence duration for speech rate, $F(1, 35) = 13.93, p < .005$. There was also a significant main effect on vowel sequence duration for frequency, $F(1, 35) = 29.69, p < .0005$. There was no significant interaction between speech rate and frequency, $F(1,35) = 1.95, p = .171$. This is observable in the following:

![Figure 3-3 Overall mean vowel sequence duration, high and low frequency words, fast and slow speech conditions](image)

As the graph shows, both high and low frequency words in the slow speech condition ($M = .22, SD = .0271$, and $M = .2103, SD = .0239$, respectively) were significantly longer than their fast speech counterparts (high frequency, $M = .1975, SD$...
= .0389, and low frequency, $M = .1909, SD = .0367$). These results suggest that, like the results obtained for the effect of speech rate on overall word duration, the method employed to elicit fast speech was successful. Further, they show that temporal shortening of the overall word is occurring in parallel fashion with the vowel sequences. It can be concluded, therefore, that at the very least when words in the task were shortened due to speech rate the shortening was occurring in the vowel sequences.

The direction of the difference for the frequency effect, however, was opposite from what had been hypothesized. Vowel sequences of the high frequency words in the slow speech condition ($M = .22, SD = .0271$) were significantly longer than vowel sequences of the low frequency words in the slow speech condition ($M = .2103, SD = .0239$). Also unexpectedly, vowel sequences of the high frequency words in the fast speech condition ($M = .1975, SD = .0389$) were significantly longer than vowel sequences of the low frequency words in the fast speech condition ($M = .1909, SD = .0367$). While these results did run counter to the hypothesis, descriptively speaking the durational differences are very slight - on the order of one glottal pulse. Perhaps what is most interesting is that there is clearly no temporal compression in the high frequency vowel sequences.

As mentioned, because vowel sequences in the high frequency words were statistically significantly longer than their low frequency counterparts, additional analyses were performed to determine the nature of the results. Since overall word durations of the high frequency words were shorter than the low frequency words, but not for the vowel sequences, it then follows that the temporal shortening occurring across the entire words is located somewhere other than the target vowel sequence.
Although specific measurements were not taken to determine exactly where the shortening of the word durations was taking place, it is possible to determine how much (percentage) the vowel sequences contributed to the overall word durations. Indeed, further analyses of the data revealed that vowel sequence durations contributed the most to overall word duration of the high frequency words in the fast speech condition (46.46%). Again, it was expected that for this group of words, vowel sequences would be the shortest since their overall word durations were the shortest of all the word groups. Instead, the words that were produced fastest by the subjects in the experiments have proportionally longer vowel sequences than any of the other three word groups. Conversely, vowel sequences contributed the least to the overall word duration of the low frequency words in the slow condition (41.82%). Once again, because mean overall word duration for this group was the longest of the word groups, it was believed that this would lead to having the longest vowel sequences as well. This was not the case. These results are observed in the following Table (3-1):

<table>
<thead>
<tr>
<th></th>
<th>Mean overall word duration</th>
<th>Mean VV duration</th>
<th>Difference between WD - VV</th>
<th>% VV of WD</th>
</tr>
</thead>
<tbody>
<tr>
<td>High frequency Fast</td>
<td>0.425</td>
<td>0.197</td>
<td>0.228</td>
<td>46.46%</td>
</tr>
<tr>
<td>Low frequency Fast</td>
<td>0.441</td>
<td>0.191</td>
<td>0.250</td>
<td>43.30%</td>
</tr>
<tr>
<td>High frequency Slow</td>
<td>0.491</td>
<td>0.220</td>
<td>0.271</td>
<td>44.85%</td>
</tr>
<tr>
<td>Low frequency Slow</td>
<td>0.503</td>
<td>0.210</td>
<td>0.293</td>
<td>41.82%</td>
</tr>
</tbody>
</table>
3.3 Results: formant values

This section reports on the effect of hiatus resolution on the formants of the experimental item vowel sequences. Recall that measurements of word and vowel combination duration were hypothesized to reveal only part of what speech rate and word frequency do to influence hiatus resolution in Spanish. It is generally agreed upon that the resolution of vowel sequences in hiatus occurs in the way in which one (or both) of the vowels is changed. Authors such as Jenkins (1999) and Alba (2006) claim that vowels in hiatus can be resolved in any number of different ways: coalescence, vowel deletion, diphthongization, and hiatus maintenance, among others. Therefore, correctly identifying the exact nature of the hiatus resolution via spectrographic analyses of the vowel formants allows a more precise acoustic analysis of the vowel sequences.

As previously discussed, the relative distance in Hertz between F1 and F2 values reflects the dimension of vowel height and frontness/backness and thus, vowel quality. Values of F1 are inversely proportional to vowel height during vowel production. That is, a higher tongue position registers lower F1 values and, consequently, higher (or more closed) vowels (i.e., [i]). Conversely, higher F1 values correspond with lower (or more open) vowels (i.e., [a]). F2 values are influenced by tongue body frontness and backness. High F2 values indicate higher, closed vowels (i.e., [i]; tongue body front) while low F2 values correspond with lower, open vowels (i.e., [a]; tongue body back). It is a combination of these two values that makes up a vowel in Spanish, therefore both F1 and F2 values were analyzed for this study; however, it is the distance between F2 and F1 that more accurately indicate tongue
body frontness and backness. In other words, the greater the distance between F2-F1, the more fronted the vowel. Thus, this data was also analyzed for this study.

The way in which this knowledge was applied in the analysis of the vowel sequences produced by the participants in this current study is novel. As previously mentioned in the Methods chapter, in order to determine the qualities of the first vowel in the sequence ([e]) the distance (in Hz) between F2 and F1 values was calculated based on the values of seven averaged maximum F2 and seven averaged minimum F1 values. These measurements, then, represented the formant values that were then analyzed for the vowel [e]. It was believed that this was the most efficient and accurate method that 1) represented the steady-state of the vowels, and 2) provided an efficient way to measure the distance between those F1 and F2 steady-state values. Further, a similar calculation of the mean F2 and F1 values of the second vowel in the sequence ([a]) also provided the values that were analyzed in order to determine the behavior of the [a].

So as to provide the reader with a visual representation of the method employed in the calculation of the F2 and F1 formant values, the following Figure (3-4) is included. It displays a spectrogram of the vowel sequence [ea] of the word leal (‘loyal’) in which the steady-state values of the [ea] combination are clearly visible. It can be observed that the trajectories, or the steepness of the transitions between the F1 and F2 formants, are somewhat abrupt going from the [e] to the [a].
Data points generated automatically and hand-checked by the formant tracking function in Praat from spectrograms such as the one above provided the values from which the F2 and F1 data was calculated. Those data points were then plotted in graphs which afforded the ability to assess visually the data points assigned by Praat. It also facilitated the process by which the F2 and F1 values were calculated (i.e., via the means of 7 data points along the most steady-state areas of the vowels). An example of this process is represented in the graph below (derived from the plots provided by the spectrogram above) of the F1 and F2 values of the [ea] sequence of the word *leal* in the slow speech condition (Figure 3-5):
The diphthongs ([ja]) found in the control words were also measured spectrographically and compared descriptively to the other VV sequences in hiatus\textsuperscript{26}. Because [ja] sequences typically measure high F2 values and low F1 values for the [i], there is more relative distance between the maximum F2 and minimum F1 values than those typical of [e] vowels. Therefore, a difference between those relative distances for the VV and [ja] sequences respectively, would provide evidence that would suggest

\textsuperscript{26} The diphthongs in the control words were not compared statistically to the critical items, they are meant to provide a point of comparison only.
whether or not VV sequences are becoming more diphthong-like. This is observed in the following spectrogram of the diphthong [ja] in the word *piano*.

![Spectrogram of the vowel sequence [ja] in *piano*](image)

*Figure 3-6 Spectrogram of the vowel sequence [ja] (piano)*

We can observe in this Figure that there is more distance between the F2 (more than 2500 Hz) and F1 (less than 500 Hz) than there is between the maximum F2 (less than 2500 Hz) and minimum F1 (over 500 Hz) of the [e]. Additionally, it also shows the higher minimum F2 (~2000 Hz) of the [a] found in the diphthong example when compared to the [a] of the VV sequence in hiatus (Figure 3-4). The F1 and F2 values found in the diphthong in Figure 3-7 are also visible in the spectrogram of the same (Figure 3-6). When the two example spectrograms are compared, it is readily visible...
that the [ea] sequence spectrogram displays clearer steady-state values, while the spectrogram of the diphthong [ja] reflects the lack of a steady state for the glide and shows instead the constant change from the onglide to the [a] nucleus of the syllable. The following figure is an example representing a graph of the F1 and F2 values seen in the spectrogram above of the [ja] sequence in the word *piano*.

![Figure 3-7 Schematic representations of the approximate calculation of steady-state F1 and F2 values of diphthong [ja] (piano)](image)

To summarize briefly, the graphs and spectrograms above visually demonstrate a variety of points. First, they validate the need for detailed spectrographic analyses of the F1 and F2 values when studying hiatus resolution. Because hiatus resolution has been suggested to result in a variety of different outcomes, looking directly at the spectrograms of those VV sequences helps us to determine in exactly what ways hiatus is being resolved. Second, they suggest that comparing F1 and F2
values of VV sequences to diphthongs is an effective way to determine whether or not these VV sequences are being resolved as diphthongs. That is, if during hiatus resolution the VV sequence vowel is becoming more like a diphthong (as many have suggested), we would expect this to be visible in the F1 and F2 values of the spectrograms as well as the values given by those spectrograms. Third, they lend support to the methodology employed in this study whereby a single steady-state value was calculated from the mean of seven value points based on maximum and minimum F1 and F2 values. Finally, they suggest that it is useful to compare not only the differences between maximum F2 and minimum F1 values as well as the differences between minimum F2 and maximum F1 values, but also those four data points individually. This was done in order to determine both which vowel was changing and which formant was contributing most to the nature of the change.

The next section will report on the differences in formant values due to speech rate and word frequency. First, analyses of F1 and F2-F1 values of the [e] vowel will be reported for speech rate and word frequency. Next, analyses of F1 and F2-F1 values of the [a] are reported for speech rate and word frequency.

### 3.3.1 Results for F1 of [e]: height dimension

#### 3.3.1.1 By-subject results of F1, [e]

A one-way repeated measures ANOVA was also performed to compare the averaged F1 values in the [e] vowel in Hertz for speech rate and word frequency. There was a significant main effect for speech rate on F1 values of [e], $F_1(1, 35) = 18.78, p < .005$. 
There was no main effect for frequency of the F1 values of [e], $F(1, 35) = .153, p = .698$.

There was also no interaction, $F(1, 35) = .11, p = .743$. 

---

**Figure 3-8 F1 values ([e]) for speech rate, by subject**

<table>
<thead>
<tr>
<th>Speech Rate</th>
<th>Fast</th>
<th>Slow</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>570.94</td>
<td>557.43</td>
</tr>
</tbody>
</table>

---

**Figure 3-9 F1 values ([e]) for frequency, by subject**

<table>
<thead>
<tr>
<th>Frequency</th>
<th>High Frequency</th>
<th>Low Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>564.64</td>
<td>563.73</td>
</tr>
</tbody>
</table>
F1 values of the [e] vowel in the fast speech condition were significantly higher in Hz than those same vowel sequences in the slow speech condition. This was true for both the high frequency words in the fast speech condition \((M = 571.17, SD = 55.69)\) and the high frequency words in the slow speech condition \((M = 558.11, SD = 52.03)\), as well as the low frequency words in the fast speech condition \((M = 570.71, SD = 52.66)\) and the low frequency words in the slow speech condition \((M = 556.74, SD = 52.00)\), as seen above. These findings suggest that producing the words more quickly, regardless of their relative frequencies, caused the tongue body to become slightly lower during production of the [e] vowel. Further, this suggests that tongue height during production of the [e] vowel was virtually unaffected by word frequencies.
3.3.1.2 By-item results of F1, [e]

A between-variable repeated measures ANOVA was also performed to compare F1 values of the [e] vowel by item for speech rate. These subsequent by-item analyses generally confirmed the results of the by-subject data. F1 values of the [e] vowel were significantly higher in fast speech over slow speech, $F_2(1, 23) = 22.05, p < .005$; but only marginally in the high frequency items over the low frequency items, $F_2(1, 23) = 1.47, p = .238$. There was no interaction, $F_2(1, 23) = .234, p = .633$. This can be seen below:

![Figure 3-11 F1 values ([e]) for speech rate and frequency, by item](image)

3.3.2 Results for F2 - F1 of [e]: frontness/backness dimension

3.3.2.1 By-subject results of F2-F1, [e]

The previous section reports on the height dimension of the [e] vowel. This section reports on the frontness/backness dimension of the [e]. A one-way repeated measures ANOVA was conducted to determine the effect of speech rate and word.
frequency on the F2 - F1 values. There was a significant main effect both for speech rate $F_1(1, 35) = 46.61, p < .0005$ and for word frequency for F2 - F1 differences, $F_1(1, 35) = 56.7, p < .0005$. There was no interaction, $F_1(1, 35) = .047, p = .830$. This can be seen below:

![Figure 3-12 Difference in Hertz of F2-F1 of [e], by subject](image)

We can see in the graph that both rate and frequency modulate the backness dimension; there was significantly less difference between F2 and F1 values for the [e] vowel in the high frequency words produced in the fast speech condition ($M = 1409.07, SD = 190.16$) and the slow speech condition ($M = 1480.64, SD = 193.59$). There was also significantly less distance between F2 and F1 values for the [e] vowel in the low frequency words produced in the fast speech condition ($M = 1461.99, SD = 215.09$) and for the vowels in the slow speech condition ($M = 1531.31, SD = 205.52$).

As with speech rate, word frequency significantly modulated the difference between F2 and F1 values for the [e] vowel. There was significantly less difference
between F2 and F1 values for the [e] vowel in the fast speech condition of the high ($M = 1409.07, SD = 190.16$) and low frequency words ($M = 1461.99, SD = 215.09$) as well as for the vowels in the slow speech condition of the high ($M = 1480.64, SD = 193.59$) and low frequency words ($M = 1531.31, SD = 205.52$).

In other words, faster speech and high frequency words similarly affected the frontness/backness dimension of [e]; both yielded less distance between the F2 and F1 values. Specifically, speech rate and frequency yielded a more centralized [e] vowel. Taken together, these values suggest that the [e] vowel was undergoing minor (but significant) centralizing under pressure both from speech rate and frequency.

### 3.3.2.2 By-item results of F2 - F1, [e]

A between-variable repeated measures ANOVA was performed to compare values of F2 - F1 differences of the [e] vowel by item for speech rate. As with the by-subject results, there was a significant main effect for speech rate, $F_2(1, 23) = 39.06, p < .005$ in the by-item analysis. By-item analyses revealed a marginally significant main effect for frequency, $F_2(1, 23) = 3.741, p = .065$. There was also no interaction, $F_2(1, 23) = .719, p = .405$, and is observed below:
These results generally confirm the by-subject results; there was significantly less distance between F2 and F1 of the [e] vowel in the fast speech condition than in the slow speech condition. Similarly, there was nearly significantly less distance between F2 and F1 values of the [e] vowel in the high frequency words than those in the low frequency words.

### 3.3.3 Results for F1 of [a]: height dimension

#### 3.3.3.1 By-subject results of F1, [a]

The F1 values for [a] were also analyzed via one-way repeated measures ANOVA for speech rate and frequency. These values were calculated from the 7 highest data points of the F1 values. A significant main effect was found for speech rate, $F_{1}(1, 35) = 52.78, p < .0005$:
There was also a significant main effect for word frequency, $F_{1}(1, 35) = 13.83$, $p < .005$:

![Figure 3-15 F1 values ([a]) for frequency, by subject](image)

There was no interaction, $F_{1}(1, 35) = .345$, $p = .56$. 
Figure 3-16 F1 values of [a] for speech rate and frequency, by subject

F1 values of the [a] of the high frequency words in the fast speech condition ($M = 739.53, SD = 96.98$) were significantly lower than the high frequency words in the slow speech condition ($M = 766.38, SD = 94.75$). This was also true for the low frequency words in the fast and slow speech conditions ($M = 746.61, SD = 94.20$ and $M = 774.86, SD = 94.82$, respectively). Further, F1 values of the vowel [a] of the high frequency words in the fast speech condition ($M = 739.53, SD = 96.98$) were significantly lower than the low frequency words in the fast speech condition ($M = 746.61, SD = 94.20$). Similarly, F1 [a] values of the vowel sequences in the high frequency words in the slow speech condition ($M = 766.38, SD = 94.75$) were significantly lower than those in the low frequency words in the slow speech condition ($M = 774.86, SD = 94.82$).

These results suggest that a faster speech rate as well as high frequency had the same modulating effect on F1 values of the vowel [a]. Specifically, the vowel [a]...
produced in both high frequency words and fast speech are higher than those produced in slow speech and in low frequency words.

### 3.3.3.2 By-item results of F1, [a]

A between-variable repeated measures ANOVA was conducted to compare F1 values of the [a] vowel by item for speech rate. There was a significant main effect for speech rate, $F_2(1, 23) = 59.47, p < .005$. However, there was no significant main effect for frequency, $F_2(1, 23) = 1.20, p = .285$. There was no interaction, $F_2(1, 23) = 2.45, p = .131$, and is shown below:

![F1 values (a) for speech rate and frequency, by item](image)

These by-item results generally confirmed the by-subject results of speech rate; F1 values of the [a] vowel were significantly lower in fast speech over slow speech. However, F1 values of [a] were only marginally lower in the high frequency items over the low frequency items, although descriptively, the direction of the differences were the same as those found in the by-subject analyses.
3.3.4 Results for F2 - F1 of [a]: frontness/backness dimension

3.3.4.1 By-subject results of F2 - F1, [a]

A one-way repeated measures ANOVA was conducted to determine the effect of speech rate and word frequency on the F2 - F1 values of the [a] vowel. There was a significant main effect for speech rate $F(1, 35) = 40.36, p < .0005$. A main effect for word frequency was also found for differences between F2 and F1 of the [a] vowel, $F(1, 35) = 15.33, p < .0005$. An interaction was not found, $F(1, 35) = 1.05, p = .314$. These results are summarized in the following Figure 3-18:

![Figure 3-18 Difference in Hertz of F2-F1 of [a], by subject](image)

There was significantly more difference between F2 and F1 values of the [a] vowel in the high frequency words produced in the fast speech condition ($M = 954.47,$
SD = 135.17) and the slow speech condition (M = 904.48, SD = 120.94). There was also significantly more distance between F2 and F1 values for the [a] vowel in the low frequency words produced in the fast speech condition (M = 977.05, SD = 140.46) and for the vowels in the slow speech condition (M = 921.34, SD = 124.94).

Word frequency significantly affected the difference between F2 and F1 values for the [a] vowel; however, there was significantly less difference between F2 and F1 values for the [a] vowel in the fast speech condition of the high (M = 954.47, SD = 135.17) and low frequency words (M = 977.05, SD = 140.46) as well as for those in the slow speech condition of the high (M = 904.48, SD = 120.94) and low frequency words (M = 921.34, SD = 124.94).

While fast speech drove a greater distance between F2 - F1, indicating a more fronted vowel, high frequency words did not work in tandem with the fast speech condition. High frequency vowels showed less distance between F2 - F1 values, suggesting that there was a preservation of the back quality of the [a] vowel. In absolute terms, the differences are small, although reliable by the statistical task. In short, this result suggests that rate differentially affects the frontness to backness dimension of [a] vowels with faster speech exerting a fronting effect but high frequency yielding a backing effect.

3.3.4.2 By-item results of F2 - F1, [a]

A between-variable repeated measures ANOVA was performed to compare values of F2 - F1 differences of the [a] vowel by item for speech rate. Like the by-subject results, there was a significant main effect for speech rate, $F_2(1, 23) = 30.51, p$
< .005 in the by-item analysis. However, there was no significant main effect for frequency, \( F_2(1, 23) = .053, p = .820 \) in the by-item analysis. There was also no interaction, \( F_2(1, 23) = .077, p = .784 \), and can be seen below:

![Figure 3-19 Difference in Hertz of F2-F1 of [a], by item](image)

<table>
<thead>
<tr>
<th></th>
<th>High Frequency</th>
<th>Low Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast</td>
<td>959.95</td>
<td>963.38</td>
</tr>
<tr>
<td>Slow</td>
<td>913.30</td>
<td>923.10</td>
</tr>
</tbody>
</table>

These by-item results also confirm the by-subject results; there was significantly more distance between F2 and F1 of the [a] vowel in the fast speech condition than in the slow speech condition. However, F2 - F1 values of [a] were only slightly lower in the high frequency items over the low frequency items. Descriptively, however, the direction of the differences was the same as those found in the by-subject analyses.

### 3.3.5 Example spectrographs

The following example spectrograms display actual visual representations of the key results reported above. As a point of reference, spectrograms of the diphthong [ja] (from the word piano, piano) are included with each series of spectrograms. This was done so as to be able to determine whether or not the nature of the hiatus resolution in
the critical items, as a result of fast speech and word frequency, was more diphthong-like or less diphthong-like. As reported above, diphthongs were measured for descriptive statistics only, and were not included in any statistical analysis. The first Figure (3-20) displays the effect of speech rate on the vowel sequence [ea] of a high frequency word (creado, ‘created’). All spectrographic groupings are from the same speaker. There are a few notable observations that can be made; first, the duration of the vowel sequence in fast speech is shorter than in slow speech. Second, relative to each other, there is much more height between the F2 and F1 values of the vowel [e] in the slow speech example than in the fast speech example. Third, relative to the F2-F1 heights observable in the example diphthong of the glide ([j]), there is less F2-F1 height of the [e] vowel in the fast speech example. This is especially notable in the F2 readings of the [e] vowel.

![Figure 3-20 Side-by-side spectrograms of [ea] (creado, fast and slow) and [ja] (piano, fast)](image)

The same observations just reported for a high frequency word can also be seen in a low frequency word (beato, ‘devout’); shorter duration of sequence in fast speech,
more F2-F1 height of [e] in slow speech, and less F2-F1 height of [e] in fast speech relative to the diphthong. These can be seen below:

![Figure 3-21 Side-by-side spectrograms of [ea] (beato, fast and slow) and [ja] (piano, fast)](image)

The last series of spectrograms show the effect of frequency on the vowel sequences produced in the fast speech task. Notable observations of these spectrograms include, first, that there is no appreciable difference in duration of the vowel sequences for these example spectrograms. Still, significant difference in formant values can be seen. Second, the low frequency word (*peano*, ‘Piano’) displays more F2-F1 height of the [e] vowel relative to the [e] of the high frequency word (*creado*, ‘created’). Third, relative to the F2-F1 height of the diphthong in *piano* ‘piano’, there is less F2-F1 height of the [e] vowel in *creado*. These results are noteworthy because, like the vowel sequence values observed in the fast vs. slow speech examples, frequency is not causing these vowel sequences to become more diphthong-like in general.
3.3.6 Vowel plot

In order to provide a more comprehensive overview of the nature of the vowels reported above as a result of speech rate and word frequency, F2-F1 and F1 of both the [e] and [a] vowels were plotted. This was done for fast high frequency sequences, fast low frequency sequences, slow high frequency sequences, and slow low frequency sequences. Values of F2-F1 and F1 from a vowel sequence with a diphthong ([j]) were included for the purpose of comparison. The following Figure (3-23) was derived by plotting F2-F1 of the [e] vowel and glide [j] on the horizontal (x) axis and F1 on the
vertical (y) axis.

Figure 3-23 Plots of glide [j] for speech rate; vowel [e] for speech rate and frequency

In this Figure we see that faster speech resulted in a slight lowering and centralizing of the [e] vowel. This was also true as a result of high frequency. In fact, the high frequency words in the fast speech condition produced the most ‘centralized’ [e] vowels, while the low frequency words in the slow speech condition produced the highest, most front [e] vowels. The [j] glide is showing a similar pattern; slight lowering and centralizing in fast speech. Although the general patterning is similar between the vowel [e] and the glide [j], it is clear that the trend of the [e] vowel is away from diphthongization with faster speech and high frequency words.

The following Figure (3-24) shows the effects of speech rate and frequency on both the [e] and [a] vowels.
While the [e] vowel is clearly lowering and centralizing as a result of fast speech and high frequency words, the picture is somewhat less clear with regard to the [a] vowel. Nonetheless, a closer look shows that fast speech and high frequency words are modulating the [a] vowel, although the effects are not similar. Fast speech results in a slight raising of the [a] vowel. High frequency words yield a modest backing of the [a] with regard to their low frequency counterparts. Taking the results of [e] and [a] together, then, the [e] vowel is becoming slightly more similar to the following [a] vowel as a result of fast speech and high frequency. The [a] vowel is becoming slightly more like [e] (higher) with regard to vowel height, but slightly less like [e] (more back) with regard to frontness/backness. This can be seen clearly in the Figure below (3-25) where the arrows indicate the direction of the modulation as a result of speech rate and frequency.
3.4 Summary

In this chapter I reported the results of the experiments on the duration of the VV sequences and the overall words. I also reported the results of the formant analyses of the high and low frequency words in both the fast and slow speech condition. Frequency was found to be a factor in the duration of the vowel sequences in these experiments. Overall word duration in the high frequency words was found to be significantly shorter than the low frequency words. However, vowel sequence duration of the high frequency words was found to be significantly longer than those in the low frequency words. Frequency also significantly modulated some of the acoustic properties of the vowels in these experiments. The first and second formant values
were measured in the spectrographs in order to determine this. Those values were then combined to determine the position of the vowels in the vowel space. To summarize the results of frequency on the F1 and F2-F1 of vowels [e] and [a]: F1 [e] - no main effect for frequency, but descriptively larger F1 value in high frequency words; F2-F1 [e] - significant main effect for frequency; less difference between F2-F1 in high frequency words than in low frequency words; F1 [a] - significant main effect for frequency; lower F1 values in high frequency words; and, F2-F1 [a] - significant main effect for frequency; less distance between F2-F1 for high frequency words.

The by-item analyses generally confirmed what had been discovered in the by-subject analyses. Descriptively speaking the results confirmed what was found in the by-subject analyses even though no significant main effect was found for frequency in any of the formant dimensions. To summarize: F2-F1 [e] - nearly significant main effect for frequency, there was descriptively less difference between F2-F1 in the high frequency words; F1 [a] - no main effect for frequency, but there were marginally lower F1 values in high frequency words; and, F2-F1 [a] - no main effect for frequency, but descriptively there was less distance between F2-F1 in the high frequency words.

The effect of fast speech on the vowel sequences was significant in all dimensions measured. Fast speech was found to significantly shorten the overall duration of the words as well as the duration of the vowel sequences.

Fast speech was also found to significantly affect the F1 and F2-F1 measurements of both the [e] and the [a] vowel, summarized here: F1 [e] - significant main effect for speech rate; higher F1 values in fast speech; F2-F1 [e] - significant main effect for speech rate; less distance between F2-F1 in fast speech; F1 [a] - significant
main effect for speech rate; lower F1 value in fast speech; and, F2-F1 [a] - significant effect for speech rate; more distance between F2-F1 in fast speech.

The next chapter will report on a series of exploratory analyses performed to determine whether or not the phonetic environment surround the VV sequences influenced the modulation of the vowel production.
Chapter 4

By-item Descriptive Analysis

4.1 Overview

The previous chapter reported on the results of the subject and item analyses performed on the formant values of the experimental items. As discussed, speech rate and word frequency were found to significantly modulate the nature of the VV sequences, with fast speech and frequency found to exert a centralizing influence on the [e]. Fast speech also yielded a slightly more central and higher [a], while [a] in the high frequency words was also found to be raised slightly but was located further back in the vowel space. By-subject analyses confirmed significant main effects for both speech rate and frequency, while item analyses only confirmed significant main effects for speech rate.

The experimental tasks were not explicitly designed to test specific hypotheses regarding the phonetic environments in which the VV sequences occurred. Upon analysis of the data, however, it became apparent that the particular words chosen for the experiments showed some degree of variability with regard to the nature of the hiatus resolution of the VV sequence. One possibility is that the resolution of the VV sequences was also modulated in part by either the phoneme preceding or the phoneme following the VV sequence. In this chapter I explore possible influences of phonetic context on the patterns of hiatus resolution addressed in the previous chapter.
4.2 The effect of phonetic environment

4.2.1 By-item descriptive account: F1, F2-F1 of [e]

Recall that data was gathered on 25 critical items that contained the [ea] sequence, plus an additional two items with the diphthong [ja]. These were:

Table 4-1 Critical items used in the experimental tasks

<table>
<thead>
<tr>
<th>High Frequency [ea] words</th>
</tr>
</thead>
<tbody>
<tr>
<td>creado, desear, emplear, golpear, ideal, nuclear, pasear, pelear, plantear, real, teatro</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Low Frequency [ea] words</th>
</tr>
</thead>
<tbody>
<tr>
<td>beato, bracear, coclear, craneal, floreal, leal, mantear, milpear, palear, peal, peano, prear, quesea, sablear</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Words with diphthong [ja]</th>
</tr>
</thead>
<tbody>
<tr>
<td>cambiar, piano</td>
</tr>
</tbody>
</table>

In order to assess the effect that phonetic environment may have had on the nature of the hiatus resolution, the F1 and F2-F1 values for [e] and [a] of each individual word in the fast and slow speech conditions were examined. In so doing, a series of figures were created that represent the mean values of the F1 and F2-F1 measures for [e] and [a] of all participants for each word in both the fast and slow speech conditions. The first figure shows the F1 values of vowel [e] by word in the fast and slow speech condition. The slow speech values are used as the baseline. High frequency words are marked with an asterisk.
In this figure we see first that the F1 values of the [e] in the words in the fast speech condition exhibit a similar pattern to their slow speech counterparts, albeit with slightly higher F1 values, suggesting that the [e] is lowered in the fast speech condition in most of the words. We can also see that a pattern for word frequency is somewhat observable; the high frequency words tend to yield slightly higher F1 values for [e], thus their general grouping toward the right-hand side of the graph. This suggests that the [e] is lowering slightly for the words whose values are high on the vertical axis and far to the right on the horizontal axis, such that *sablear* has a higher [e] vowel relative to *craneal*. 

---

**Figure 4-1** F1 values of [e], fast and slow speech, by individual word
Looking at each word individually in the context of the consonant preceding the VV sequence, there appears to be no immediately observable pattern emerging that would indicate that the preceding consonants are systematically affecting the F1 of [e] in the VV sequence. Likewise, observing the items in the context of the consonant following the VV sequence also reveals no immediately noticeable pattern. Nevertheless, a one-way repeated measures ANOVA revealed that there was a significant effect of individual word for the values of F1 of [e], $F(24, 12) = 13.51, p < .05$. There was also a significant effect for speech rate, $F(1, 35) = 8.26, p < .05$. There was an interaction, $F(24, 12) = 3.46, p < .05$, which can be attributed to words whose F1 values of [e] were lower in the fast speech condition than they were in the slow speech condition (i.e., bracear, mantear, plantea). The ANOVA shows that the words are different from one another and that difference is not due simply to chance. While this does not inform us specifically about the phonetic context and its possible effects, it does invite us to examine phonetic context as a possible contributor to explaining the variance in the data.

In general, similar observations can be made about the F2-F1 values of [e] in the individual words, as seen below:
In this graph we observe that there is less similarity between the fast and slow speech data than that of the F1 [e] data, although it is also clear that the fast speech values are always lower for each word than the slow speech values. In this sense there is great consistency in the values. Further, the high frequency words are still grouping somewhat toward the left-hand side of the graph (less distance between F2-F1), as expected due to the higher F1 values. These values also suggest that the [e] in the words found low on the vertical axis and on the left-hand side of the horizontal axis (i.e., golpear) are slightly more back in the vowel space relative to those that are high on the vertical axis and on the right side of the horizontal axis (i.e., palear). In fact, a
one-way repeated measures ANOVA revealed that there was a significant main effect for individual words, $F(24, 12) = 16.04, p < .05$. There was also a significant main effect for speech rate, $F(1, 35) = 39.75, p < .05$. There was no interaction, $F(24, 12) = 1.68, p > .05$.

Like those in Figure 4-1, the values in Figure 4-2 do not reveal any easily discernable pattern regarding preceding consonant either. With regard to the consonant following the VV sequence, however, we do observe that the words whose VV sequences are followed by [r] are somewhat grouped toward the left side of the graph, indicating a smaller F2-F1 value. This will receive more attention in section 4.8.

With the F1 and F2-F1 values we can now plot those vowels in a chart representing the vowel space, thus providing a more complete view of the nature of the modulation of the vowel [e] in each individual word. The figure below shows the values of [e] for the individual words in the fast and slow speech condition.
Figure 4-3 Vowel plot of individual words, fast and slow speech for vowel [e]

In this figure displaying the individual words we can confirm both what was reported in Chapter 3 as well as the data just discussed; namely, that higher speech rate generated a centralizing force on the [e] vowel. High frequency exerted a similar centralizing force. This can be seen in the figure wherein many of the high frequency words (circled) are grouped more toward the center of the vowel space than their low frequency counterparts. It also confirms the lack of any easily observable patterning of the influence of the phonetic environments either preceding or following the VV sequence due to the random nature of how the items are dispersed throughout the vowel space with regard to phonetic environment.
4.2.2 By-item descriptive account: F1, F2-F1 of [a]

Although it was believed that the preceding consonant would affect primarily the first vowel in the sequence, [e], due to its adjacency to the [e] vowel it is also of interest to examine the F1 and F2-F1 values of the [a] vowel in order to determine what (if any) effect the consonant preceding the vowel sequence might have on the [a]. Generally speaking, F1 and F2-F1 values for [a] of the individual words display less predictability than their counterparts from vowel [e]. In Figure 4-4 we can observe the variability of the F1 values of [a] in the fast and slow speech conditions. Values from the slow speech condition are used as the baseline; high frequency items are labeled with an asterisk.
Figure 4-4 F1 values of [a], fast and slow speech, by individual word

There are very few observable similarities of the F1 values of [a] between the fast and slow speech data. The F1 values in the fast speech are, overall, lower than those of their slow speech counterparts. This suggests that the [a] is rising slightly in most words as a result of fast speech and it is precisely the words found on the left of the horizontal axis whose values of [a] have become higher. Some of the words share similar F1 values relative to the other individual words and the speech rate counterpart; *coclear, emplear, prear*, and *peano*, to name a few. Further, the phonemes preceding the VV sequence are not displaying any recognizable pattern. A one-way repeated measures ANOVA confirmed the observed variability; there was a significant main
effect both for the words, $F(24, 12) = 7.18, p < .05$, as well for speech rate $F(1, 35) = 41.91, p < .05$. There was also an interaction, $F(24, 12) = 6.32, p < .05$, likely due to the lack of a relative parallel line in the plots. In other words, the effect of rate on the words varied greatly, with some words behaving very differently from others under the rate manipulation.

As with the findings for F1 values, F2-F1 values of [a] also display little obvious predictability, as seen below:

![Figure 4-5 F2-F1 values of [a], fast and slow speech, by individual word](image)

Additionally, values of [a] in the fast speech condition mirror only roughly the values in the slow speech condition, with some exceptions (i.e., creado, prear, sablear,
craneal, etc.). Values of F2-F1 for [a] in the fast speech condition are, on average, greater than their slow speech counterparts. As has been previously reported, the greater the magnitude of the difference between F2-F1, the more the vowel is pushed forward in the vowel space. Hence, the fast speech condition is exerting a kind of centralizing force. In this case, the [a] vowel is moving forward towards a less extreme back position in the fast speech condition. A one-way repeated measures ANOVA revealed that there was a significant main effect for the words, $F(24, 12) = 8.32, p < .05$. There was also a significant main effect for speech rate $F(1, 35) = 41.74, p < .05$. There was no interaction, $F(24, 12) = 1.80, p > .05$. Nevertheless, neither frequency nor preceding consonant appears to bear any discernible relevance with regard to an emerging pattern or grouping of the individual words.

In the next figure we will see the F1 and F2-F1 plots together of the [a] vowel for each individual word in the fast and slow speech conditions.
Figure 4-6: Vowel plot of individual words, fast and slow speech for vowel [a].
With this figure we can confirm the findings of the previous chapter with regard to how speech rate and frequency affected the production of [a]; that in the fast speech condition [a] is rising and becoming more front and, in relation to the preceding [e], more centralized. The [a] in the high frequency words is also rising, but it is also being realized slightly further back. Looking at the consonants that precede and follow the VV sequence, we can also see how broadly distributed throughout the vowel space the words appear.

4.3 **Phonetic environment groupings: consonant preceding the VV sequence**

Recall that it was reported in the *Methods* section that effort was made to ensure that the high and low frequency item pairings share, as closely as possible, phonetic environments\(^{27}\). No special attempt was made a priori, however, to find high and low frequency word pairs that represented all possible phonetic environments. Reviewing the words used in the experimental tasks, however, we find that a total of nine different phonemes preceded the VV sequences of the critical items. These were: [l], [s], [p], [t], [b], [d], tapped [ɾ], trilled [ɾ̄], and [n].

Based on F1 and F2-F1 data the phonetic environments showed little to no observable propensity for particular groupings based on phonetic similarities of the preceding consonant. However, some words did share the same preceding consonant. Based on shared preceding consonants we can group the words and perform a subsequent series of post-hoc explorations to determine if there are differences between

\(^{27}\) Special attention was given to the consonant preceding the VV sequence under investigation. I reasoned that if the VV sequence were to show and effect from the phonemes that surround it, it would most likely be from the phonemes directly preceding the vowels.
the formant values of the vowel sequences as a result of the preceding consonants.

Although some of the preceding consonants shared phonetic properties ([b] and [p] are both bilabial stops, for example), after reviewing the data it became clear that the values of the formants with regard to the preceding consonant did not support grouping the preceding consonants based solely on place and/or manner of articulation. In other words, even though [b] and [p] share both place and manner of articulation, their formant values were not similar enough to warrant combining them into one single group. Even when the phonetic properties of the preceding consonants differed even less, as with the tapped and trilled rhotic [r], they still showed themselves to be distinct enough from each other so as to treat them separately.

I therefore reasoned that grouping the words based on the exact shared preceding consonant would yield the most accurate results about the effect that the preceding consonant had on the resolution of the VV sequences in question. These groupings can be seen below:

<table>
<thead>
<tr>
<th>Preceding Consonant</th>
<th>Words</th>
</tr>
</thead>
<tbody>
<tr>
<td>[p]</td>
<td>*golpear, milpear, peal, peano</td>
</tr>
<tr>
<td>[s]</td>
<td>brasear, *desear, *pasear, quesear</td>
</tr>
<tr>
<td>[r] tapped</td>
<td>*creado, floreal, prear</td>
</tr>
<tr>
<td>[t]</td>
<td>mantear, *plantea, *teatro</td>
</tr>
<tr>
<td>[b]</td>
<td>beato</td>
</tr>
<tr>
<td>[d]</td>
<td>*ideal</td>
</tr>
<tr>
<td>[n]</td>
<td>craneal</td>
</tr>
<tr>
<td>[r̆] trilled⁴⁸</td>
<td>*real</td>
</tr>
</tbody>
</table>

* High frequency word

⁴⁸ Also appears as [#/r] in some subsequent graphs.
These groupings provide a reasonable basis for post-hoc exploration of the data; namely, to explore the effect that these particular consonant groupings have on the vowel sequences in these specific words.

4.3.1 Preceding consonants grouped: effect on F1 of [e]

A one-way repeated measures ANOVA revealed a significant main effect for preceding consonant on the height dimension (F1) of the vowel [e], $F(1, 35) = 4.93, p < .05$. There was also a main effect for speech rate on the same dimension, $F(8, 28) = 29.19, p < .05$. There was no interaction, $F(8, 28) = 5.70, p > .05$. This can be seen in the figure below.

![Figure 4-7 F1 values of [e] by preceding consonant grouping, fast and slow speech condition](image-url)
Although there was a main effect both for preceding consonant and speech rate, visual inspection of the data in Figure 4-7 indicates that the actual differences of F1 of the [e] between the fast and slow speech data are relatively small. They also show remarkable similarities in their values and ordering, with the preceding consonant [d] showing the lowest F1 values and [n] recording the highest F1 values; the lower values suggesting a slightly higher production of [e], and the higher values indicating a slight lowering of [e], hence the lack of an interaction. Not all consonant groupings were significantly different that the others within their respective speech rates. The following summary shows the results of a pairwise comparison wherein there were significant differences:

<table>
<thead>
<tr>
<th></th>
<th>[d_]</th>
<th>[l_]</th>
<th>[s_]</th>
<th>[b_]</th>
<th>[p_]</th>
<th>[r_]</th>
<th>[t_]</th>
<th>[ɹ_]</th>
<th>[n_]</th>
</tr>
</thead>
<tbody>
<tr>
<td>[d_]</td>
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<td>[l_]</td>
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<td>[s_]</td>
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<td>[b_]</td>
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<tr>
<td>[p_]</td>
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<tr>
<td>[r_]</td>
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<tr>
<td>[ɹ_]</td>
<td>x</td>
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<td>[n_]</td>
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<td>x</td>
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<td>x</td>
</tr>
</tbody>
</table>

As would be expected, consonants whose F1 values were the lowest ([d], [l], [s], etc.) were generally significantly lower than those whose F1 values were the highest ([p], [ɹ], [t], [n]). In fact it is precisely the preceding consonants at either ends of the continuum that are the most noteworthy; [d] and [n]. It can be seen in the graph that
when [e] followed [d] the values for F1 were quite low, indicating a higher tongue position. Conversely, F1 values of [e] following [n] were high, indicating a lower tongue position.

4.3.2 **Preceding consonants grouped: effect on F2-F1 of [e]**

A one-way repeated measures ANOVA revealed a significant main effect for preceding consonants grouped on the frontness/backness dimension (F2-F1) of the vowel [e], $F(1, 35) = 38.50, p < .05$. There was also a main effect for speech rate on the same dimension, $F(8, 28) = 36.59, p < .05$. There was an interaction, $F(8, 28) = 4.93, p < .05$, likely due to the difference in magnitude between the fast and slow speech values, especially for the values of [b].
In this figure we observe, as expected, a smaller distance between F2-F1 of [e] in the fast speech than in the slow speech. As reported above, this suggests a slight centralizing of [e] as a result of fast speech. We also see that of the groupings created for preceding consonant, [n] (and [l] somewhat) had the biggest effect on relative frontness of [e] following these consonants, suggesting that when [e] followed [n] it became more front. Conversely, when [e] followed [s], for example, it was slightly more back in the vowel space. Only the following preceding consonants’ F2-F1 values of [e] actually differed significantly from each other:
Table 4-4 Significant differences, F2-F1 [e] for preceding consonant groupings

<table>
<thead>
<tr>
<th></th>
<th>ɾ̄</th>
<th>t̄</th>
<th>s̄</th>
<th>p̄</th>
<th>r̄</th>
<th>l̄</th>
<th>b̄</th>
<th>d̄</th>
<th>n̄</th>
</tr>
</thead>
<tbody>
<tr>
<td>ɾ̄</td>
<td></td>
<td>x</td>
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<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
</tbody>
</table>

With knowledge of both the height dimension (F1) and the frontness/backness dimension (F2-F1) values of the [e] vowel grouped according to shared phonetic properties of the consonants preceding the VV sequence, we can now plot those values in a representation of the vowel space. This can be seen below:
Figure 4-9 Vowel plot of [e] for preceding consonant groupings, fast and slow speech

We can now see the relative effect that the grouped preceding consonants had on the production of [e] in the fast and slow speech conditions. The following observations can be made: fast speech exerts a centralizing effect on the vowel [e], as do [t], [d], [b], [p], [ɹ], and [r]. The consonant [n] exerted a large fronting and lowering effect on [e]\(^{29}\), consistent both with the high F1 and F2-F1 values registered for [e] following [n]. In some sense, [n] appears clearly to be qualitatively different from the other consonants with regard to its influence on [e]. It is also worth noting that when comparing fast and slow speech conditions, the magnitude of the speech rate effect seems to be greater in the frontness/backness dimension than in the height dimension.

\(^{29}\) This result was somewhat surprising. Of all the critical items measured and analyzed for these experiments, the VV sequence in *craneal* sounded most diphthong-like. These results suggest that in terms of vowel height, however, [e] was not becoming more like [j]. This provides further evidence that impressionistic coding can sometimes yield false observations.
That is, the centralizing tendency is more pronounced in the front/back measures across all consonant groups.

4.3.3 **Preceding consonants grouped: effect on F1 of [a]**

While an effect of preceding consonant is more likely to appear on a vowel that immediately follows a consonant, it was believed that the preceding consonant could also affect the second vowel of the VV sequence. To test for this a one-way repeated measures ANOVA revealed a significant main effect for preceding consonant on the height dimension (F1) of the vowel [a], $F(1,35) = 59.99, p < .05$. There was also a main effect for speech rate on the same dimension, $F(8, 28) = 13.32, p < .05$. There was no interaction, $F(8, 28) = 1.57, p > .05$. 
Figure 4-10 F1 values of [a] by preceding consonant grouping, fast and slow speech condition

This data reveals that the consonant preceding the vowel sequence in hiatus significantly affected the height dimension of the [a] vowel. As can be seen in Figure 4-10, F1 values were significantly lower in the fast speech condition than in the slow speech condition. Words with an [s] preceding the vowel sequence recorded the lowest F1 values in the slow speech condition, while the vowel [a] with [t] and [d] (and nearly [l]) preceding the vowel sequence recorded the lowest F1 values in the fast speech condition. In terms of vowel height, this suggest that the vowel [a] was produced slightly lower when preceded by [s], and [t, d] (and so on up the continuum), while words with [r] preceding the vowel sequence showed the highest F1 values for [a] in
both the fast and slow speech conditions, suggesting that [r] modulated the production of [a], inducing a slightly higher production of [a].

The following shows that although there was a main effect for preceding consonant, a closer look at the data reveals that not all preceding consonants differed significantly from each other.

Table 4-5 Significant differences, F1 [a] for preceding consonant groupings

<table>
<thead>
<tr>
<th>[s_]</th>
<th>[t_]</th>
<th>[l_]</th>
<th>[n_]</th>
<th>[b_]</th>
<th>[p_]</th>
<th>[r_]</th>
<th>[d_]</th>
<th>[ɾ_]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[t_]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td></td>
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<tr>
<td>[l_]</td>
<td>x</td>
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<td></td>
<td>x</td>
<td></td>
<td></td>
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<tr>
<td>[n_]</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[b_]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[p_]</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[r_]</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[d_]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>[ɾ_]</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

As can be observed, [n] was not found to be significantly different than any of the other preceding consonants while those on either end of the line did differ from each other. Further, this data suggests that when [s] preceded the vowel sequence in hiatus the result was a slight rising of the [a] vowel as a consequence. Conversely, F1 values for [a] remained higher when [r] preceded the vowel sequence.

4.3.4 Preceding consonants grouped: effect on F2-F1 of [a]

A one-way repeated measures ANOVA revealed a significant main effect for preceding consonant on the frontness/backness dimension (F2-F1) of the vowel [a], $F(1,35) = 49.73, p < .05$. There was also a main effect for speech rate on the same dimension, $F(8, 28) = 18.92, p < .05$. There was an interaction, $F(8, 28) = 3.61, p < .05$. 
likely because of the diverging values of [l] and [d] in the fast speech condition relative to their slow speech counterparts.

In Figure 4-4 we can observe that when [r] preceded the vowel [a] the F2-F1 difference was lower than the other preceding consonants in both the fast and slow speech condition. This suggests that [a] was produced slightly more back when the vowel sequence was preceded by [r]. On the other end, we see that when [n] preceded the vowel sequence, the production of [a] was markedly affected. The high F2-F1 value seen associated with the preceding consonant [n] suggests that the vowel [a] was produced more front when the sequence was preceded by [n]. Recall that only one
word had the vowel sequence preceded by [n], *cranial*. Thus, it is difficult to make any claims about all [n] preceding the vowel sequence [ea]; nevertheless its effect is clear in this data.

The following summary shows which preceding consonant groupings differed significantly from each other.

| Table 4-6 Significant differences, F2-F1 of [a] for preceding consonant groupings |
|-----------------------------------------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| [r̄]                                           | [r̄]            | [b̄]           | [p̄]           | [d̄]           | [t̄]           | [l̄]           | [s̄]           | [n̄]           |
| [n̄]                                           |                |                |                |                |                |                |                |                |
| [r̄]                                           |                |                |                |                |                |                |                |                |
| [b̄]                                           |                |                |                |                |                |                |                |                |
| [p̄]                                           |                |                |                |                |                |                |                |                |
| [d̄]                                           |                |                |                |                |                |                |                |                |
| [t̄]                                           |                |                |                |                |                |                |                |                |
| [l̄]                                           |                |                |                |                |                |                |                |                |
| [s̄]                                           |                |                |                |                |                |                |                |                |
| [n̄]                                           |                |                |                |                |                |                |                |                |

We can see that, as expected, the consonants whose values fell on the left (low values) end of the spectrum differed significantly from those whose values placed them on the right (high values) end of the spectrum. As reported, F2-F1 [a] values for [n] were significantly greater than all other preceding consonants’ F2-F1 [a] values.

Taking both F1 and F2-F1 values of [a] we now plot those values to represent the vowel space. This is shown in the following figure:
As observed, fast speech is drawing the [a] vowel more towards the front and higher in the vowel space. Similar to the results found with regard to vowel [e], the consonant [n] also appears to be exerting a force over [a] that is resulting in a more front production of [a]. Consonants [b], [p], and [r], meanwhile, appear to exert a lowering and backing force on [a] relative to the other preceding consonant groupings.

Plotting both [e] and [a] vowels for grouped preceding consonant provides a complete view of the nature of the VV sequence resolution with regard to preceding consonant. This is displayed in the following figure.
Figure 4-13 Vowel plot of [e] and [a] for preceding consonant groupings, fast and slow speech
With values for both [e] and [a] values plotted together in the vowel space, we can make a few key observations. First, the centralizing effect of the fast speech condition is once again immediately apparent; the [e] vowel is moving back and slightly more central while the [a] vowel is moving higher and closer to [e], resulting in moderate vowel leveling. In none of the cases reported here [e] neither became higher (more closed) nor became more fronted, again suggesting that the vowel sequences were not becoming more diphthong-like.

When the trilled [ɹ] preceded the VV sequence it exerted the largest centralizing effect on the production of [e] than any of the other preceding consonants. Recall that only one critical item contained a trilled [ɹ] before the VV sequence; *real*. It is noteworthy that the word whose [ea] sequence showed the most modulation in the fast speech condition is also a word of high frequency. The effect of frequency on the VV sequences according to the phonetic environment is discussed below.

Another observation is the effect that [n] had on both vowels when it preceded [e]. In both cases (but especially for [e]) when [n] preceded the VV sequence the vowels were moderately more front. The [e] vowel was also much lower when preceded by [n] than when it was preceded by any other consonant. Conversely, [d] had the highest fronting and rising effect on the production of [e]. It also brought about the largest change in [a] between the fast and slow speech samples. In fact, a subtle pattern can be seen to be emerging from both vowels. For example, both vowels after [s] are higher and more front while after [r] both are lower and further back in the vowel space. The other consonants affected the vowels in a somewhat more variable manner.
One final observation is worth noting; [a] appears to have been modulated by the preceding consonant much more than was anticipated. Prior to these additional analyses, it was believed that [a] would resist being modulated both because it is the more tonic vowel of the sequence and because it appears further away from the preceding consonant. This also suggests that traditional accounts of hiatus resolution that do not take into account the modulation effect (of speech rate or frequency) on the second vowel in the sequence are somewhat limited in their ability to fully describe the resolution.

In this section I showed the results and discussed of the effect of speech rate and preceding consonants on the resolution of the VV sequences when combining the words that shared the same consonant before the VV sequence. In the next section I show and discuss the results of the effect on the VV sequence based on the consonants that followed the vowels.

4.4 Phonetic environment groupings: consonant following VV sequence

Just as no special attempt was made to account for every possible consonant that preceded the VV sequence, none was made to account for every possible consonant that followed the VV sequence. Several words that ended in [-ear] were chosen, however, because that allowed for the opportunity to choose from numerous words for which much of the phonetic environment was controlled. The words used in the experiments can thus be grouped according to shared consonant following the VV sequence in the following:
Table 4-7 Critical items according to shared consonant following vowel sequence

<table>
<thead>
<tr>
<th>Following Consonant</th>
<th>Words</th>
</tr>
</thead>
<tbody>
<tr>
<td>[t]</td>
<td>beato, *teatro</td>
</tr>
<tr>
<td>[d]</td>
<td>*creado</td>
</tr>
<tr>
<td>[n]</td>
<td>peano</td>
</tr>
</tbody>
</table>

*High frequency word

It bears mentioning again that these analyses are primarily for exploratory purposes. As such, the groupings in the above table (4-7) are not representative of all [ea] vowel sequences followed by these specific consonants. Words whose VV sequences are followed by [r] make up the largest group with a total of 15 words while [l] followed the VV sequence in 6 words. Consonant [t] followed the sequence in 2 words and [d] and [n] followed it in one word each.

4.4.1 Following consonants grouped: effect on F1 of [e]

In order to determine if the consonants following the VV sequence significantly modulated the vowels themselves a one-way repeated measures ANOVA was performed. It revealed that Mauchly’s test indicated that the assumption of sphericity had been violated, \( \chi^2(299) = 491.93, p < .05 \), therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (\( \varepsilon = .341 \)). The results show that there was no significant effect of following consonant for the values of F1 of [e], \( F(2.92, 102.25) = 1.50, p > .05 \). There was, however, a significant effect for speech rate, \( F(1, 35) = 9.09, p < .05 \). There was no interaction, \( F(2.21, 77.31) = 2.06, p > .05 \). This can be seen in the following figure.
In this figure we see that F1 values for [e] were slightly higher in the fast speech, and although there are observable differences between the consonant groupings, these differences were not found to be significant. Descriptively, when [d] followed the VV sequence, F1 values of [e] were moderately higher. The opposite is true when [n] followed the VV sequence.

**4.4.2 Following consonants grouped: effect on F2-F1 of [e]**

Another one-way repeated measures ANOVA revealed a significant main effect for the grouped consonants following the VV sequence, $F(4, 32) = 7.92, p < .05$ as well as a significant main effect for speech rate, $F(1, 35) = 31.32, p < .05$. There was also an interaction, $F(4, 32) = 3.29, p < .05$, again because of the diverging values of [l] in the fast speech condition relative to values of [l] in the slow condition. This is seen in the figure below.
As expected, fast speech recorded smaller F2-F1 differences than slow speech. While the differences between the smallest F2-F1 distance ([n]) and the largest ([d]) are small, there was a significant main effect for grouping the consonants in this manner. The interaction is due to how the consonant groupings differentially affected the VV sequences in the two speech rates. For example, [l] recorded a smaller F2-F1 difference in fast speech than [r], but the opposite was true in the slow speech condition. The following table shows which of the consonant groupings following the VV sequence were significantly different from each other.

<table>
<thead>
<tr>
<th></th>
<th>[n]</th>
<th>[r]</th>
<th>[l]</th>
<th>[t]</th>
<th>[d]</th>
</tr>
</thead>
<tbody>
<tr>
<td>[n]</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>[r]</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[l]</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[t]</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[d]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>
In this table we can see that [\_d] was not significantly different than any other consonant groupings following the VV sequence.

Significant differences between [l] and the other consonant groupings are due to the small F2-F1 value when [l] followed [ea] in the fast speech condition. The consonant [d] was not found to be significantly different than any of the other groupings. When both the F1 and F2-F1 values are plotted we can see how this grouping of the consonants following the VV sequences modulates the resolution of [e]. This can be seen in the following figure:

![Figure 4-16 Vowel plot of [e] for following consonant groupings, fast and slow speech](image-url)
In this figure we can also see the centralizing effect of the fast speech condition over the vowel [e]. We can also see that when [n] followed the VV sequences vowel [e] became slightly more back and closed. Consonant s [d] and [l] appear to move [e] a bit more open and front, relative to the other following consonant groupings.

4.4.3 Following consonants grouped: effect on F1 of [a]

An additional one-way repeated measures ANOVA revealed a significant main effect for the grouped consonants following the VV sequence, $F(4, 32) = 13.49, p < .05$ as well as a significant main effect for speech rate, $F(1, 35) = 51.23, p < .05$. It also revealed an interaction, $F(4, 32) = 3.18, p < .05$. This can be observed in the following figure.

![Figure 4-17 F1 values of [a] by following consonant groupings, fast and slow speech condition](image)

In this figure we see that when [r] followed vowel [a] F1 values were lower than for any other grouping. On the other hand, when [d] came after [a] the values were higher than for any other grouping. We can also see how the fast speech condition
recorded overall lower F1 values of [a] than those in the slow speech condition. However, an interaction is apparent because of the high F1 values of [a] before [n] in fast speech relative to the other consonant groupings in fast speech. The next table shows which following consonant groupings different from each other with regard to the F1 values of [a].

Table 4-9 Significant differences, F1 of [a] for following consonant groupings

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>[_r]</td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>[_t]</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td></td>
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<tr>
<td>[_l]</td>
<td>x</td>
<td></td>
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<td></td>
<td>x</td>
</tr>
<tr>
<td>[_n]</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>[_d]</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Here we see again that the consonant groupings that are found on either end of the continuum show significant differences.

4.4.4 Following consonants grouped: effect on F2-F1 of [a]

A final one-way repeated measures ANOVA revealed a significant main effect for the grouped consonants following the VV sequence, $F(4, 32) = 25.21, p < .05$. There was also a significant main effect for speech rate, $F(1, 35) = 35.18, p < .05$, as well as an interaction, $F(4, 32) = 5.15, p < .05$, likely because of the difference in magnitude for the consonants between the two speech rates. The following figure shows this.
Figure 4-18 F2-F1 values of [a] by following consonant grouping, fast and slow speech condition

This shows us that F2-F1 values of [a] were smaller in the fast speech condition than in the slow speech condition. We can also see that when [d] followed [a] the result is a much smaller F2-F1 value; but when [r] followed [a] a bigger F2-F1 value was recorded, at least in slow speech. Conversely, in fast speech the grouping of [l] as the consonant following [a] recorded the greatest F2-F1 difference, thus accounting for the interaction. The next table displays the consonant groupings following the VV sequences whose values were significantly different from each other.

<table>
<thead>
<tr>
<th></th>
<th>[d]</th>
<th>[n]</th>
<th>[t]</th>
<th>[l]</th>
<th>[r]</th>
</tr>
</thead>
<tbody>
<tr>
<td>[d]</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>[n]</td>
<td></td>
<td>x</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>[t]</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>[l]</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>[r]</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

This table shows the significant differences in F2-F1 values for each following consonant grouping.
We observe more significant differences between the consonant groupings for those that followed [a] than for those that followed [e]. This suggests that the consonants that followed [a] were exerting more influence over the production of [a] than over [e]. This is not surprising given the proximity of [a] to the consonants that followed.

With both F1 and F2-F1 values of [a] we now plot those values to represent [a], as modulated by the consonant groupings that followed [a] in the vowel space. This is shown in the following figure:

![Figure 4-19 Vowel plot of [a] for following consonant groupings, fast and slow speech](image-url)
Here we can see again the centralizing force that fast speech has over the F2-F1 values of [a]. We can also see that when [n] followed [a] the result was a slightly lower and further back production of [a]. Other possible patterns are not readily discernable.

As before, plots of both [e] and [a] vowels for grouped consonants following the VV sequence allows for a complete view of the nature of the VV sequence resolution with regard to the following consonant. This can be seen in the following figure.

![Figure 4-20 Vowel plot of [e] and [a] for following consonant groupings, fast and slow speech](image)

In this final figure we can see values for [e] and [a] grouped by the consonant that followed the VV sequence. As has been observed throughout the chapter, the effect that fast speech has on how the VV sequences are coming together, or leveling,
in terms of their height and frontness/backness can be seen immediately. Another 
observation is the amount of relative vowel space that the values for vowel [a] occupy 
in comparison to those of vowel [e]. This suggests that the consonants that directly 
followed [a] affected the production more than it did for vowel [e]. We can also see 
that when [a] was followed by [l] it was produced further front in the vowel space, 
relative to the other following consonant groupings. Consonants [t] and [r] appear to 
have exerted a centralizing force over [a], more so in the fast speech condition than in 
the slow speech condition. Other groupings do not appear to demonstrate any readily 
visible patterns.

4.5 Summary

To summarize briefly up to this point, the big picture is that the fast speech rate 
is exerting a centralizing effect on the two vowels. Alternatively, slow speech is 
exerting a tendency towards more extreme or peripheral articulations which enhances 
differences between the vowels. In none of the cases reported here for [e] did it 
become higher (more closed) or more fronted in the fast speech condition and in the 
high frequency words, again suggesting that the vowel sequences were not becoming 
more diphthong-like. Based on the data, when the trilled [ɭ] preceded the VV sequence 
it accentuated the centralizing effect in the faster speech on the production of [e] more 
than any of the other preceding consonants which are not enhancing the centralizing 
effect. When [n] preceded the VV sequence the vowels were moderately more front. 
The [e] vowel was also lower much lower when preceded by [n] than when it was 
preceded by any other consonant. Conversely, [d] had the highest fronting and rising
effect on the production of [e] and it also brought about the largest change in [a] between the fast and slow speech samples.

When [a] was followed by [l] it was produced further front in the vowel space, relative to the other following consonant groupings. Consonants [t] and [r] appear to have exerted a centralizing force over [a], more so in the fast speech condition than in the slow speech condition. The other following consonants did not enhance the centralizing of [a]. It is worth noting that all of the following consonants were coronal sounds, suggesting that the results are not simply a result of the place of articulation of the following consonants.

Although fast speech clearly appears to be inducing efficiency that is not to say that the non-fast speech forms are hyper-articulated because the participants were instructed to speak naturally but not overly carefully. It also bears mentioning that upon listening to the speech, one does not get the impression of hyper-articulated production.

In this section I reported on the exploratory analyses performed on the VV sequences in order to determine the effect of pre- and post-VV sequence phonetic environment in the fast and slow speech conditions. In the next section I will report on the same measures but also taking into account how frequency affected the VV sequences in light of the phonetic environments.
4.6 Phonetic environment groupings for frequency: consonant preceding VV sequence

The results above provide important information about the effect that the preceding and following consonants had on the vowel sequences in the fast and slow speech conditions; however, they did little to explore the effect that frequency might have had on the consonant groupings in the different speech conditions. Thus, a final series of exploratory analyses were performed to examine if the high and low frequency words differed significantly in the production of the vowel sequences when they are grouped by matching preceding and following consonant, respectively. I will first report the results of the ANOVA analyses for the effects of preceding consonant and frequency on each of the vowels for both the fast and slow speech conditions. Each report will then be followed by a graph wherein the F1 and F2-F1 values are plotted of the preceding consonant groupings for frequency.

4.6.1 Preceding consonants grouped: effect of frequency on [e]

Two one-way repeated measures ANOVA revealed a significant main effect for preceding consonant and frequency for both the F1 ($F(4, 32) = 16.78, p < .05; F(1, 35) = 34.35, p < .05$) and F2-F1 values ($F(4, 32) = 7.14, p < .05; F(1, 35) = 49.85, p < .05$) of [e] in the fast speech condition. There was also an interaction in both formant measures ($F(4, 32) = 22.12, p < .05$; and $F(4, 32) = 6.93, p < .05$, respectively). This was due to a difference in magnitude between the high and low frequency measures for the preceding consonant [r_] for F1 (low values for the high frequency words), as well as a difference in magnitude for [p_] and [s_] (also low in the high frequency words).
This can be seen in the following figure wherein the values from F1 and F2-F1 are plotted together to provide a representation of the space they occupy in the vowel space.

Figure 4-21 Vowel plot of [e] for preceding consonant groupings and frequency, fast speech

Overall, we see a lowering and centralizing of the [e] in the high frequency words (as already discussed). In this graph we can also see that even when we look at the consonants preceding the VV sequences, there is a clear effect for frequency in the fast speech. Consonants [s] and [p] have exerted a powerful centralizing force over vowel [e] when in the high frequency words and in the fast speech condition, relative to the differences between the high and low frequency values of the other pre-VV consonants. In other words there is less difference between the high and low frequency values from [ɹ_], for example. Preceding consonants [n_], [d_], and [ɹ_] had no opposite frequency counterpart and were not included in the analysis.
Additional ANOVAs further show that there was also a significant main effect for preceding consonant and frequency on the vowel [e] in both the F1 ($F(4, 32) = 12.40, p < .05; F(1, 35) = 27.02, p < .05$) and F2-F1 ($F(4, 32) = 14.07, p < .05; F(1, 35) = 31.13, p < .05$) measures in the slow speech condition. Each formant measure also recorded an interaction ($F(4, 32) = 18.02, p < .05$; and $F(4, 32) = 13.77, p < .05$, respectively), for the same differences in magnitude reported for the fast speech condition above.

Figure 4-22 Vowel plot of [e] for preceding consonant groupings and frequency, slow speech

As in the fast speech condition, there is a centralizing effect on [e] in the high frequency words even in the slow condition. Also, this centralizing effect is more apparent when [s] and [p] precede the VV sequences (i.e., [s] and [p] are the most central in the fast speech condition).
4.6.2 Preceding consonants grouped: effect of frequency on [a]

Overall, frequency did not affect the [a] vowel as much as the [e], which was not entirely unexpected. In fact, even though ANOVAs revealed a significant main effect for preceding consonant in the F1 \( (F(4, 32) = 10.30, p < .05) \) and F2-F1 \( (F(4, 32) = 5.76, p < .05) \) measures in the fast speech condition, neither measure recorded a significant main effect for frequency in the fast speech condition \( (F(1, 35) = 1.64, p > .05; \) and \( F(1, 35) = 1.87, p > .05, \text{ respectively}) \. Each measure did, however, reveal an interaction \( (F(4, 32) = 4.48, p < .05; \) and \( F(4, 32) = 9.15, p < .05, \text{ respectively}) \. For the F1 measure the interaction was due to the difference in magnitude for the preceding consonant grouping [p] (low values high values in the low frequency words) as well as for the low values of [s] in the low frequency words relative to their high frequency counterparts. For the F2-F1 measure the interaction was due to a large difference in magnitude of the values of [r] (very low values in the high frequency words), as well as relatively higher values of [p] in the high frequency words compared to their low frequency counterparts. These values are represented in the figure below:
We can see that there is very little movement of the [a] becoming more fronted when in the high frequency words; but there is vertical movement, notably in the [p] and [l]. There were no significant differences for frequency and descriptively, their differences are small, on the order of just a few tens of Hertz.

In the slow speech condition there was a significant main effect for both preceding consonant ($F(4, 32) = 15.65, p < .05$) and for frequency ($F(1, 35) = 22.30, p < .05$) in the F1 measure. However, for the F2-F1 measure there was also a significant main effect for preceding consonant ($F(4, 32) = 28.65, p < .05$), but there was not for frequency ($F(1, 35) = 2.49, p > .05$). Both measures revealed an interaction ($F(4, 32) = 6.06, p < .05$; and $F(4, 32) = 11.13, p < .05$, respectively) for the same reasons as those found for the fast speech condition. This can be seen represented in the following figure:
The fact that there is a main effect for frequency in the slow speech condition is noteworthy because an effect for frequency in the slow speech conditions suggests that the traditional views of speech rate cannot be attributed to the hiatus resolution found here. Also notable is the overall area that the [a] occupies in the vowel space with regard to that of the fast speech items. Whereas the fast speech items measured values within the range of only 725 to 765 Hz on the vertical axis, the slow speech items recorded values nearly into the 800s Hz. Additionally, the slow speech items were considerably further back on the horizontal axis than their fast speech counterparts. Therefore, even though there was a main effect for frequency in the slow speech condition, the items in the slow speech condition were overall lower and further back than those in the fast speech condition.
In the next figure we can see a combination of the F1 and F2-F1 values for both the [e] and [a] vowels together.

With both vowels plotted a few key observations can be made. First, VV sequences in the high frequency words in the fast speech condition are clearly centralizing (labeled △). That is, [e] is being produced slightly more back and low
while [a] is being produced slightly higher and front. Conversely, the VV sequences in the low frequency words in the slow speech condition are exerting a more peripheral vowel articulation. Furthermore, the consonants [p], [s], and [t] are exerting a more powerful centralizing force than the other preceding consonants. On the other hand, [l] and [r] are having a relatively less centralizing effect on the VV sequences.

4.7 Phonetic environment groupings for frequency: consonant following VV sequence

This section reports on the exploratory analyses performed on the consonant groupings that followed the VV sequences in order to determine the effect of frequency on the phonetic environment of the vowels. In this section the results for frequency and speech rate are combined into one graph for each of the formant value reports. This was possible due to the lower number of following consonant groupings.

4.7.1 Following consonants grouped: effect of frequency on [e]

When the consonants that followed the VV sequences were grouped according to matched phoneme there was no main effect for the following consonant on the F1 of [e] in the fast speech condition ($F(2, 34) = 1.90, p > .05$). There was, however, a main effect for frequency on the same measure ($F(1, 35) = 9.59, p < .05$). An interaction was also revealed ($F(2, 34) = 40.58, p < .05$) due to the values of [l] being higher in the low frequency words than the high frequency. This is the opposite from what the other following consonant groupings measured.
The F2-F1 values of [e] revealed a main effect both for following consonant and for frequency ($F(2, 34) = 13.24, p < .05; F(1, 35) = 44.25, p < .05$). There was no interaction ($F(2, 34) = .06, p > .05$).

In the slow speech condition the previous F1 and F2-F1 of [e] measures revealed the same main effects; following consonant ($F(2, 34) = .331, p > .05$; and $F(2, 34) = 9.33, p < .05$, respectively) and frequency ($F(1, 35) = 10.50, p < .05$; and $F(1, 35) = 50.64, p < .05$, respectively). The F1 values also revealed an interaction ($F(2, 34) = 34.33, p < .05$) also due to the inverted values of [l] relative to the other following consonant groupings. The F2-F1 did not have an interaction ($F(2, 34) = .58, p > .05$).

These results are represented in the values plotted in the vowel space seen below:
In this we see that even when the consonants following the VV sequences are considered, there is still a visible effect of frequency on the production of \([e]\). When \([t]\) and \([r]\) followed the vowel \([a]\) in the high frequency words the \([e]\) was produced both lower and further back than its low frequency counterparts. As in other measures, low frequency words produced in the slow speech condition overall yielded the highest and most fronted production of \([e]\).

### 4.7.2 Following consonants grouped: effect of frequency on \([a]\)

Based on the exploratory findings reported above it was believed that the \([a]\) vowel would be more affected by the following consonant groupings than the \([e]\) vowel. However, there was no main effect for following consonant nor for frequency
for the F1 ($F(2, 34) = 1.81, p > .05, F(1, 35) = 2.04, p > .05$) and F2-F1 measures ($F(2, 34) = 2.81, p > .05, F(1, 35) = 4.00, p > .05$) in the fast speech condition. Neither revealed an interaction ($F(2, 34) = 1.84, p > .05, F(2, 34) = 1.61, p > .05$).

In the slow speech condition, however, both the F1 and F2-F1 revealed a main effect for following consonant ($F(2, 34) = 16.64, p < .05$; and $F(2, 34) = 6.97, p < .05$, respectively). Values for F2-F1 also have a main effect for frequency ($F(1, 35) = 7.69, p > .05$), but those for F1 do not ($F(1, 35) = .15, p > .05$). Both the F1 and F2-F1 measures revealed an interaction ($F(2, 34) = 11.49, p < .05$; and $F(2, 34) = 12.22, p < .05$, respectively) because the values for [ _r ] were reversed in the F1 dimension relative to the other following consonant groupings. In the F2-F1 measure the magnitude of difference between the high and low frequency words was smaller for [ _r ] than the other following consonant groupings.
Figure 4-27 Vowel plot of [a] for following consonant groupings and frequency, fast and slow speech

Similar to the results for the preceding consonant groupings and their effect on [e], these results also show a significant effect for the slow speech condition (but not the fast) for the consonant groupings following [a]. Visual inspection of the figure above reveals that, as before, the high frequency words produced in the fast speech condition yielded relatively higher and more fronted production of [a]; however, those values occupy a relatively smaller area in the vowel space. Those produced in the slow speech condition are spread throughout more of the vowel space; and throughout a lower and further back area, as well.

The final figure displays the values of both [e] and [a] vowels in the high and low frequency words in both the fast and slow speech conditions.
In the fast speech condition (represented by □ and △) we can once again see the centralizing effect of the faster speech, although the effect for following consonant grouping in the fast speech condition was non-significant. Moreover, the high frequency words produced in the fast speech condition are not uniformly more centralized than their low frequency counterparts; nor are the high frequency items always more centralized than the low frequency items in the slow speech condition. Descriptively speaking, [a] was more centralized when followed by [t] and [r]. When [l] followed [a], however, the result was somewhat less predictable and we can see that
in the fast speech production of [a] was more front before [l], but was slightly more back in the high frequency words.

4.8 Summary and conclusion

In this chapter I reported on a series of exploratory analyses designed to determine whether or not the phonetic environments surrounding the VV sequences were influencing the production of the vowels. In all of the analyses performed it was clear that the fast speech condition induces efficiency by promoting a more centralized production of the vowels; [e] lowers and becomes more backed while [a] raises and becomes more fronted. It also bears noting once again that none of the analyses performed and reported in this chapter suggest that these vowel sequences are being resolved as diphthongs.

I began the chapter by showing a series of graphs of the individual words plotted together for the formant measures and vowels in relation to the consonants that both preceded and followed the VV sequence. This was done in order to see visually how the surrounding consonants affected the formant values of the vowels. In those graphs it could be seen that virtually no immediately visible patterns emerged that would indicate that a certain phonetic environment predictably effected the production of the vowels. In other words, the words wherein [t] preceded [e] were just as dispersed throughout the continuum as the other preceding consonants, and so on.

Nonetheless, several words did share the same pre- or post-VV sequence consonants and it was determined to perform a series of additional exploratory analyses to know if, once grouped, any sort of pattern would emerge with regard to the
production of the vowels. As would be expected, the consonants that preceded the VV sequence had more impact on the production of [e] than of [a] (although production of [a] was modulated more by the preceding consonant that would have been expected). Conversely, the consonants that followed the VV sequence impacted the production of [a] more than [e].

Specifically, trilled [ɾ̃] had the most centralizing effect in the fast speech condition on the production of [e]. Recall that the one word that had a trilled [ɾ̃] that preceded the [e], real, is also a high frequency word. Therefore we might expect that its centralizing effect is also accentuated by its high frequency. Then consonant [n] caused the vowels to be moderately more fronted in their production. Vowel [e] was also much lower when preceded by [n] than when it was preceded by any other consonant. On the contrary, when [d] preceded [e] it had the highest fronting and rising effect. It also brought about the greatest difference in [a] between the fast and slow speech samples.

In the analysis of the consonants that followed [a] it was [l] that seemed to have a fronting effect on the production of [a], relative to the other consonants’ effects. When [t] and [r] followed [a] there was a centralizing force on [a], more so in the fast speech condition than in the slow speech condition. The other following consonants did not enhance the centralizing of [a].

One final series of exploratory analyses were carried out to find out if frequency also impacted how the phonetic environment modulated the production of the vowels. Frequency did affect the modulating influence of the phonetic environment surrounding the VV sequence. In general, it did so by enhancing the centralizing effect brought
about by the fast speech condition. It was the high frequency words in the fast speech condition that showed the highest degree of vowel centralization. Conversely, the production of the vowels of the low frequency words in the slow speech condition was more in the periphery of the vowel space.

It bears mentioning how speech rate affected the resolution of the VV sequences. As seen throughout the results reported in this chapter, there is more variability of the formant values in the slow speech condition when viewed by phonetic context. Formant values in the slow speech condition were not as closely grouped together (i.e., more extreme) as were their fast speech counterparts. It appears as if the fast speech, along with modestly centralizing the production of the VV sequence, is also exerting a leveling effect on the variability of the formant values in the less extreme articulation of the vowels. That is, another effect of fast speech is to cluster the production of the vowels more closely with regard to the formant values.

In the next chapter I will summarize the entirety of the dissertation and discuss the implications of the results.
Chapter 5

Conclusions: Frequency and rate effects on [ea] vowel sequences

5.1 Overview

The research reported in this dissertation contributes to the body of work already carried out on the nature of vowel sequences in hiatus in Spanish. It does so by taking a usage-based approach toward hiatus resolution that makes predictions about the observable variability in the production of certain vowel sequences in a given set of higher and lower-frequency words in Spanish. This dissertation argues that speech rate and stress placement, among others, are not the only factors that modulate the behavior of vowel sequence that are, by prescription, to be produced in separate syllables. It argues that frequency also affects the production of vowel sequences in hiatus.

The chapter is organized as follows. The following sections summarize the results and discuss the implications for better understanding of the way(s) in which frequency can affect the sounds of a language. The subsequent section considers the impact of usage-based research on our understanding of sound change in languages in general. In so doing, the following questions will be addressed:

- How do these results contribute to our knowledge of hiatus resolution in Spanish?
- How do these results support the usage-based model of phonology?
5.2 The present findings

The experiments reported here tested the hypothesis that both speech rate and word frequency would modulate the production of [ea] vowel sequences in Spanish. The effect of frequency was expected based on usage-based theory which posits that words of high frequency are susceptible to phonetic change, in large measure through reduction processes through their increasingly efficient production as a function of great practice on the part of speakers with the articulatory routines associated with their production. Moreover, many investigators have claimed that vowel sequences in hiatus are prone to be resolved as diphthongs in fast speech; therefore, analyses of the vowel sequences also centered around the precise nature of the resolution (i.e., are the vowel sequences becoming more diphthong-like?).

5.2.1 Hiatus resolution and diphthongs

These hypotheses were tested based on observable variation in the production of vowel sequences that are believed to be in separate syllables. When unaccented [i] or [u] is preceded or followed by any other dissimilar vowel ([i, e, a, o, u]) the result is a diphthong. All other combinations of two vowels, including when either [i] or [u] is accented orthographically, are said to be in hiatus. This description, however, is overly simplified since we know that upon production sometimes vowel sequences that are supposed to be in hiatus are not. Under certain conditions, the hiatus between the vowels is changed, modulated, or in some way resolved.

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30 The reader is reminded that there are cases of exceptional hiatus. See section x.x for a brief review.
In reality, there are many ways in which vowels in hiatus (even diphthongs) might be realized. Vowel sequences can be produced as diphthongs, other times as hiatus; sometimes a vowel is deleted, other times not; sometimes hiatus is maintained; sometimes the vowels coalesce, other times not, and so on. In fact, most authors have found that hiatus resolution typically results in the formation of a diphthong, vowel deletion, or in the maintenance of hiatus (Jenkins 1999, Aguilar 2003, Alba 2006, Díaz-Campos et al. 2006).

There are also many factors that have been shown to influence hiatus resolution. These include the specific vowels in the sequence (e.g., hiatus resolution is preferred in vowel sequences that have the potential of becoming rising diphthongs - /ea/ > [ja] - over those that could become falling diphthongs - /ae/ > [aj]). Stress placement is also important, such that vowels that are stressed (lexically or orthographically) resist reduction and, hence, diphthongization (comí otro ‘I ate another’ > [ko.mí.o.tro]) (e.g., Alba 2006).

Other factors have also been claimed to affect hiatus resolution. These include dialectal differences (Espinosa 1930, Lipski 1994, Matluck 1995, Harris 1969, Quilis 1981, Jenkins 1999, Martínez-Gil 2000, Hualde 2005, Alba 2006, Garrido 2007, Smith 2008), socioeconomic level (e.g., Navarro Tomás 1990, Matluck 1995, Diaz-Campos et al. 2006), individual speaker differences (e.g., Navarro-Tomás 1990, Quilis 1981, Hualde et al. 2002), ambiguity (Monroy Casas 1980), and emphatic stress (e.g., Navarro Tomás 1990, D’Introno et al. 1995, Martínez-Gil 2000). These factors were taken into consideration when the experiments were designed and the participants selected for this investigation. Recall that participants were selected from a dialect of
Spanish that is reported to resolve hiatuses as diphthongs, and they were all university students. The experimental design was set up to minimize individual speaker differences (i.e., tasks elicited fast/slow speech), although this is nearly impossible to fully control. The critical items used in the naming tasks were also chosen based on their vowel sequence and based on stress placement. Since the tasks elicited only within-word [ea] sequences (as opposed to between-word sequences), it was easier to control for stress placement and emphatic stress. These factors were important and taken into consideration when designing this investigation. Two other factors said to contribute to the modulation of VV sequences in hiatus in Spanish, however, were the main focus of this investigation. These were speech rate and frequency.

Nearly all accounts of hiatus resolution indicate speech rate and/or carefulness of speech as playing a fundamental role in the resolution of vowels in hiatus (e.g., Navarro-Tomás 1968b, Harris 1969, Jenkins 1999, Techner 2000, Hualde 2005, Alba 2006). Fast speech affects how vowel sequences are produced, and was also an important factor in the modulation of the vowel sequences in this study, as will be discussed below. Few (if any) have made any claims about the resolution of VV sequences in non-fast speech. It was for this reason that the experimental tasks were designed to elicit both fast and slow speech. I reasoned that if frequency affected hiatus resolution, and if it were an effect found in fast speech as well as slow speech forms that it would support the notion that frequency also affects hiatus resolution.

Word and/or word string frequency has also been determined to affect the nature of hiatus resolution. This will be discussed at length below but it bears mentioning that the idea to test for frequency effects was precisely because a few
authors had already begun reporting the possible effect of frequency on the modulation of VV sequences in hiatus. Díaz-Campos et al. (2006), for example, found that not only was /ea/ the most frequent vowel sequence from their data, but it was also the sequence that showed the greatest propensity to diphthongize. Jenkins (1999) also found that the most frequent across-word vowel combination (/ea/) in the New Mexican corpus data also exhibited the most diphthongization; the least-frequent sequence, /eo/, was more likely to maintain hiatus. He also found that pairs of words that had a high frequency of co-occurrence demonstrated a relatively high degree of variability in the resolution of hiatus between them, with a high tendency to be reduced compared to other items that did not occur as often. Alba (2006) also reports that high-frequency items reduced significantly and systematically more than low-frequency items in his analysis of the New Mexican corpus.

These investigations were key to both hypothesizing the role that frequency would play in the resolution of VV sequences in hiatus as well as constructing the experimental tasks that would adequately allow for a proper investigation of the phenomenon. The next section summarizes the results of the tasks already discussed previously in this dissertation.

5.2.2 Effect of Frequency: duration and formant measures

Frequency was found to be a factor in the duration of the vowel sequences in these experiments. Although overall word duration in the high frequency words was found to be significantly shorter than the low frequency words, vowel sequence duration of the high frequency words was found to be significantly longer than those in
the low frequency words. This was not expected. It was believed that the vowel sequences in the high frequency words would also be significantly shorter than their low frequency counterparts. This being the case, it was then determined that the vowel sequences in the high frequency words (in both the fast and slow speech condition) made up a higher percentage of the overall word duration than they did in the low frequency words. It could be hypothesized that for these speakers in these experiments, then, when they were forced to speak more quickly they shortened the words at the expense of the other sounds that surrounded the vowel sequence in order to maintain the integrity (at least durational) of the vowels in hiatus.

Frequency was also found to significantly modulate some of the acoustic properties of the vowels in these experiments. This was determined by measuring the first and second formants of the vowels separately, then by combining the values of F1 and the values of F2-F1 to determine the position of the vowels in the vowel space. The results of frequency on the F1 and F2-F1 of vowels [e] and [a] are summarized here:

- F1 [e] - no main effect for frequency, but descriptively higher F1 value in high frequency words
- F2-F1 [e] - significant main effect for frequency; less difference between F2-F1 in high frequency words than in low frequency words
- F1 [a] - significant main effect for frequency; lower F1 values in high frequency words
- F2-F1 [a] - significant main effect for frequency; less distance between F2-F1 for high frequency words
As hypothesized, frequency was found to significantly modulate the production of the vowels in the sequence in the height and frontness/backness domains for both the [e] and the [a] vowel. This was important because confirmed that frequency can be another factor in determining the nature of hiatus resolution in Spanish. It was also important because it provided the opportunity to determine exactly what the nature of the modulation was. Of all the results obtained from the experiments this was perhaps the most striking. The vowel sequences produced by these subjects in these experiments are, with the exception of a few isolated tokens, not becoming more diphthong-like. Nor do they appear to be robustly maintaining hiatus. Instead, both vowels (although more robustly with regard to [e]) are showing definite signs of coalescence in varying degrees. Broadly, the vowel [e] lowers and becomes more centralized in the high frequency words, while in the low frequency words it remains relatively higher and more forward in the vowel space. Vowel [a], on the other hand, rises slightly and becomes a bit more like the preceding [e] - at least in terms of the height dimension.

The by-item analyses generally confirmed what had been discovered in the by-subject analyses. Although no significant main effect was found for frequency in any of the formant dimensions, descriptively speaking the results confirmed what was found in the by-subject analyses. Namely, that in the high frequency words the [e] vowel in both lowering and centralizing while the [a] vowel is rising slightly. Those results are summarized below:

- F1 [e] - no main effect for frequency, but descriptively larger F1 value in high frequency words
• F2-F1 [e] - nearly significant main effect for frequency; descriptively less difference between F2-F1 in the high frequency words

• F1 [a] - no main effect for frequency, but marginally lower F1 value in high frequency words

• F2-F1 [a] - no main effect for frequency, but descriptively there was less distance between F2-F1 in the high frequency words

Further analyses were performed to explore further why no significant main effect was found for frequency in the by-item analysis. These are discussed further in a following section.

5.2.3 Effect of speech rate

The effect of fast speech on the vowel sequences was robust in all dimensions measured. This was predicted based on the general consensus that fast speech affects the production of vowels in hiatus. It was found to significantly shorten the overall duration of the words as well as the duration of the vowel sequences. This was important in determining that the experimental design was successful at eliciting fast speech from the participants.

Fast speech was also found to significantly affect the F1 and F2-F1 measurements of both the [e] and the [a] vowel. These are summarized below:

• F1 [e] - significant main effect for speech rate; higher F1 values in fast speech

• F2-F1 [e] - significant main effect for speech rate; less distance between F2-F1 in fast speech

• F1 [a] - significant main effect for speech rate; lower F1 values in fast speech

• F2-F1 [a] - significant effect for speech rate; more distance between F2-F1 in fast speech
As predicted, participants’ faster speech manifested itself in the modulation of the formant values of the vowel sequences in the words. Faster speech resulted in higher F1 values of vowel [e], as well as in less distance between F2-F1 of [e]. This finding is noteworthy because it mirrors the effect that frequency had on [e], which is a lowering and centralizing force being exerted on the vowel as a consequence of both high frequency and fast speech. It is important not only because the two factors share a similar patterning of hiatus modulation, but also because of the very nature of the modulation. High frequency words did not result in diphthongization of the vowel sequences; neither did fast speech result in diphthongization. As mentioned, this is notable because it highlights the need for more precise acoustic analysis when performing investigations of hiatus resolution. Fast speech is widely thought to result in the diphthongization of vowels in hiatus. This clearly was not the case with the vowel sequences in these experiments as carried out by these participants; participants from a region of Mexico claimed to diphthongize vowels in hiatus (see, for example, Lipski 1994).

This can be seen in the following figure displaying the average F1 and F2-F1 values paired for both [e] and [a] vowels in both speech conditions in plots representing the vowel space.
Figure 5-1 Vowel plots of [e] and [a] for speech rate and frequency

Subsequent by-item analyses generally confirmed the by-subject analysis; the item analyses were significant for rate, although the same was not the case for frequency. Significant main effects were found for speech rate in all of the formant measures: F1 of [e], F2-F1 of [e], F1 of [a] and F2-F1 of [a]. The effect of frequency was not as robust in the by-item analysis as in the by-subject analysis. In fact, none of the formant measures revealed significant main effects for frequency; although the F2-F1 measure of [e] returned an almost-significant effect for frequency ($p = .065$). There were no interactions reported in the by-item analyses.

5.2.4 Phonetic Environment

Since the experiments were not designed to test hypotheses regarding the possible modulating effect of the phonetic environment surrounding the VV sequences, the analyses that were carried out on phonetic environment were done for exploratory purposes. The exploratory analyses suggest that the consonants that both preceded and
followed the VV sequences significantly modulated the production of the vowel sequences.

I began the chapter by showing a series of graphs of the individual words plotted together for the formant measures and vowels in relation to the consonants that both preceded and followed the VV sequence. This was done in order to provide an overview of how the surrounding consonants affected the formant values of the vowels. In those graphs it could be seen that virtually no immediately visible patterns emerged that would indicate that a particular phonetic environment predictably affected the production of the vowels. For example, the words in which [t] preceded [e] were appeared to be just as dispersed throughout the continuum as the other preceding consonants, and so on.

Nonetheless, several words did share the same pre- or post-VV sequence consonants and I performed a series of additional exploratory analyses to know if, once grouped, a pattern would emerge with regard to the production of the vowels. As expected, the consonants that preceded the VV sequence had more impact on the production of [e] than of [a] (although production of [a] was modulated more by the preceding consonant that might have been expected). Conversely, the consonants that followed the VV sequence impacted the production of [a] more than [e].

Specifically, trilled [ɾ] had the most centralizing effect in the fast speech condition on the production of [e]. Recall that the one word that had a trilled [ɾ] that preceded the [e], real, is also a high frequency word. Therefore we might expect that its centralizing effect is also accentuated by its high frequency. In contrast, consonant [n] caused the vowels to be moderately more fronted in their production. Vowel [e]
was also much lower when preceded by [n] than when it was preceded by any other consonant. On the contrary, when [d] preceded [e] I found the highest fronting and raising effect. This context also exhibited about the greatest difference in [a] between the fast and slow speech samples. This can be seen in the following example spectrograms showing the F1 and F2 of the VV sequence [ea] in the words *real, floreal, beato, ideal,* and *craneal* in the fast speech condition. Each spectrogram is from the same participant.

![Figure 5-2 Example spectrographs showing the effect of the pre-VV consonant on the production of the vowels, fast speech](image)

These example spectrograms provide the opportunity to visually observe and confirm the data reported above. Specifically, in this figure we can see how the consonants that preceded [e] affected the production of [e]; the relative height between the F1 and F2 of [e] is smaller in *real* than it is in *craneal*. There is also a noticeably lower F1 value for [e] in the word *ideal* relative to the F1 of [e] in *craneal*, again supporting the data reported in the sections above which showed a higher, more fronted production of [e] following [d] and a lower, more fronted production of [e] following [n]. The other examples, *floreal* and *real*, show that relative to the other words on the other end of the spectrum the VV sequences in those words was affected less by the preceding consonants. This also accurately represents the results previously reported.
In the analysis of the consonants that followed [a] it was [l] that seemed to have a greater centralizing effect on the production of [a], relative to the other consonants’ effects. When [a] followed [t] and [r] it became more mid than low; more so in the fast speech condition than in the slow speech condition. Overall, however, the effect of the following consonant on the production of [a] was less than that of the preceding consonant effect on [e]. The other following consonants did not enhance the centralizing of [a].

One final series of exploratory analyses were carried out to find out if frequency also impacted how the phonetic environment modulated the production of the vowels. Frequency did, in fact, affect the modulating influence of the phonetic environment surround the VV sequence. In general, it did so by enhancing the centralizing effect brought about by the fast speech condition. It was the high frequency words in the fast speech condition that showed the highest degree of vowel centralization. Conversely, the production of the vowels of the low frequency words in the slow speech condition was more in the periphery of the vowel space. This can be observed in the following example spectrographs of two words; one low frequency (coclear) and the other high frequency (nuclear). Both words were produced by the same participant in the fast speech condition.
These example spectrographs also serve to confirm the data that has been reported. We can see that even though the two words share the same pre-VV consonants, there is visibly less height in the F1 values of the [e] in the high frequency word, *nuclear*. This suggests that even when taking the phonetic environment into consideration, there is still a noticeable frequency effect on the modulation of the vowels in hiatus.

5.2.5 Summary

To answer the first question posed at the beginning of this chapter, the results reported in this study contribute to our knowledge of hiatus resolution in Spanish in two primary ways: first, they suggest that frequency does, indeed, modulate the production of hiatus in Spanish (at least within-word [ea] combinations). This is an important finding given the nature of the experiments which were designed to eliminate as many of the variables that are said to contribute to hiatus resolution. Due to the strict controls used in the design and implementation of the experiments it can be claimed with confidence that frequency affects VV sequences said to be in hiatus. And at least in
this study, VV sequences were slightly more centralized and coalesced in the high
frequency words than in the low frequency words.

Second, these results show us the precise phonetic nature of the modulation; an
important feature that investigations relying on impressionistic coding lack. It would
have been quite difficult to reach the same conclusions about the nature of the
resolutions without performing spectral analyses of the vowel productions, especially
the conclusion that the vowels are centralizing or leveling under the pressure of fast
speech and high frequency. In fact, having read previous research on the nature of
hiatus resolution proved to have incorrectly influenced the expected auditory
impressions of this author, such that the actual spectral analyses were often a surprise -
what sometimes sounded like diphthongization was not. To wit, when [e] followed [n]
it sounded impressionistically as if it was being realized as a glide ([j]). Acoustic
analysis, however, revealed that when [n] preceded [e] the production of [e] was
nothing like the glide [j]. In fact, [n] forced a significantly lower (albeit fronted)
production of [e]. The impact of doing experimentally-based research and
spectrographic analysis will be discussed in more detail below.

5.3 Frequency effects and the Usage-Based Model of phonology

The results reported in this dissertation can be positioned well within the tenets
of the usage-based model of phonology. The usage-based model claims that more
frequent items in a language tend to be affected both on the surface (i.e., a word may
become shorter in duration) and in the mental representation (i.e., words or word strings
of higher frequency have stronger mental representations) (Bybee 2001), and thus the
actual structure of a language. In fact, it is hypothesized that high frequency can even influence the emergence of new categories or structures (e.g., Krug 2001, Bybee 1998a, 1998b). Recall that Bush (2001) found that would you typically palatalizes to [wʊdʒə] in this high frequency string but in the low frequency string good you it does not. This process of palatalization, he found, is more likely to occur between words of high frequency and is a result of a chunking phenomenon, wherein frequently-used strings can become stored as single units (see also Bybee 2002).

Another study of English lends support to the notion that high frequency strings can become single chunks or units. Krug (2001) analyzed going to, have to, got to, and want to in English, concluding that these highly-frequent strings are in the process of becoming modified modals in English. He claims that the radical reduction of those word strings to gonna, hafta, gotta, and wanna, respectively, demonstrates not only the process of chunking, but also that they are in the process of becoming lexically autonomous from their original two-worded string. That is, they have started to behave differently syntactically. This process illustrates the very way in which frequency is claimed to be a function of emergent linguistic structures (also Bybee et al. 2000 and Bybee et al. 2006).

Frequency has also been named as a factor in strengthening the mental representation of syllables, words, and word strings (Meyer et al. 1971, Bybee 2001, Carreiras et al. 1998, 2004, Macizo et al. 2007). Bybee (2001) for example, found that the well-attested phenomenon of French liaison is simply a matter of the high frequency nature of the word strings. In fact, she found that the more frequent the item, the more likely it is to maintain liaison. She claims that such strings are stored in memory and
that because of their high usage the forms get reinforced, causing them to get processed together, thus eroding their connections with other items.

Recall, too, that the usage-based model of phonology hypothesizes that the actual use of a language plays a fundamental role in determining the sounds of a language (Bybee 2001, Krug 2001). Alba (2008) stated, “mounting evidence shows that frequency of use plays a fundamental role in shaping linguistic structure, including phonological structure” (247). High frequency items show a greater degree of sound change, usually in some type of reduction. This can include deletion or reduction of consonants, as in the study of Bybee (2001), which found that word final [t] and [d] are less likely to be pronounced in words that are high-frequency (just, and, and went), as opposed to low-frequency words (i.e., bent, thrust); vowels, such as Bybee and Hooper (2001), Bybee (2001), and Hooper (1976) which report that high-frequency words such as family, memory, and camera tend to reduce the unstressed schwa (famly, memry, camra) to a higher degree than phonetically similar words of lower frequency; and word duration shortening, among others (Myers 2009). Upon usage, words and word strings are susceptible to their articulatory processes becoming more automated (Alba 2008) under the weight of repetition.

Indeed, the reductive force of articulatory automation is precisely the phenomenon found in the data for this dissertation. In the high frequency words there is a type of automation - arguably an efficiency effect - that is happening in the VV sequence of the high frequency items that is not present in the low frequency items. The same process is also occurring as a result of faster speech. In the fast speech condition and in the high frequency words, [e] is both lowering and becoming more
centrally articulated. It is becoming slightly more like the following [a] which can be thought of as an efficiency effect attributable to its relatively high frequency. Alba (2008) claims that such reduction is more likely in high-frequency items because they are subjected more to the reductive processes of articulatory and perceptual processes; processes, he claims, that gradually create gradient phonetic variations. It is precisely the more reduced forms, then, that high-frequency items store mentally as the stronger and more-accessible forms (229). The results in this dissertation are compatible with this view of phonological reduction and mental storage, even though it was not expressly tested in this dissertation.

A recent dissertation by Brown (2009) parallels this current work. He studied the reduction of syllable- and word-final /s/ in Spanish and found that token frequency of the word containing the final /s/ and the frequency of the phonetic environment surrounding the /s/ significantly modulate final /s/ reduction. He also found that high frequency phonetic environments that favor /s/ reduction (i.e., when /s/ follows a voiced consonant) also facilitated /s/ reduction over those that are less frequent. Further, he found differences between different dialects (Colombian, New Mexican, Venezuelan, and Puerto Rican) and concluded that the overall rate of /s/ reduction was influenced by the relative frequency effects found in the respective dialects. Using the usage-based model of phonology he is able to further explain one of the most studied phenomena in Spanish phonology by showing that syllable- and word-final /s/ reduced more often in high frequency words that in those of low frequency. The results heretofore reported arrive at a similar conclusion, thus making an analogous contribution of our understanding of hiatus resolution within words in Spanish.
5.4 Comments on Methodology

An additional component of research on the phonetics of a language is the mechanism through which the data is analyzed, both in terms of the experimental nature of the design as well as the resources used for the data analysis. It seems implausible to derive accurate conclusions about the phonetic properties of speech without a detailed investigation of the acoustic properties themselves, as has been done through impressionistic data analysis\textsuperscript{31}. It was clear from the outset that impressionistic analyses would be insufficient in terms of being able to decipher the actual phonetic effect of frequency and speech rate on these vowel sequences in Spanish. This was reinforced time and time again throughout the analysis when the spectrographic representations of a vowel sequence failed to match up with what was thought to have been heard. In other words, sometimes it sounded like the participant had diphthongized a vowel sequence, but the spectrographic analysis showed otherwise. Although it is difficult to make any claims about the conclusions that other researchers have come to based on their impressionistic analyses of hiatus modulation, the experience of performing actual acoustic analyses on the vowels (and the frequent disaccord between that was thought to have been heard and what was represented spectrographically) casts at least some shadow of doubt on findings based on impressionistic analysis nonetheless.

\textsuperscript{31} Of course, all analyses defined as \textit{phonetic} in nature proceed through quantitative measures of the variables under scrutiny.
This type of experimentally-based data collection was also beneficial for the following reasons: it was easier to maintain control of the objectives of the experiment, it was easier to elicit the desired forms, and it was possible to modulate speech rate and word frequency. Additionally, some of the factors that have been reported to contribute to hiatus resolution were more easily manipulated, such as stress and the exact high and low frequency items that shared VV sequence and phonetic environment; others were more easily controlled, such as exclusion of phrasal intonation via the word list naming experiments.

Of course that is not to say that experimental testing is without challenges or drawbacks. One possible downside to experimentally-based investigations is that participants are still free to behave as they please. Indeed, participants differed as might be expected in their speech rates, and one subjects’ fast speech was not necessarily the same rate as another’s fast speech. Individual differences in the ways in which the subjects actually produced the words also varied to some extent. Nonetheless, there were enough participants that produced a high number of critical items in both speech conditions so as to minimize any extreme effect of individual behaviors.

Recall that hiatus was resolved with relatively few tokens illustrating the diphthongization that was expected when designing the study for this dissertation. As pointed out above, such expectations might have lead to processing the resolution of the VV sequence as a diphthong when, in fact, the spectral properties of the vowel package indicated that what was seen was something that more closely resembled coalescence. That said, it is also possible that the results here (i.e., the surprising lack of
diphthongization) may be at least in part attributable to the experimental versus naturalistic context in which the words were produced. Experiments such as the ones here tend to induce a more formal register. People are more self-conscious, and the speech production being elicited involves single word production via the orthographic presentation of the experimental item. Bearing this in mind, it is also important to note that the concept of fast speech is used throughout the dissertation in a fashion that more or less conflates informal speech with fast speech. This may be too broad of an assumption and thus too blunt of an instrument. Finally, we must also take into consideration that individual speakers have a repertoire available to them, which can be modulated by issues such as rate and degree of formality, as well as any other number of factors.

All told, these results might also be compatible with a view in which the particular pattern of resolution here reflects the effects of rate and frequency, but not informality, since the laboratory context and the single word production would presumably keep the degree of formality relatively high in both rate conditions. This does not undermine the main findings regarding how rate and frequency both play a role in affecting how vowels in hiatus are produced, but it may help us to understand why they were resolved in that way. It also leads to possible additional studies with a similar population which might test for how less formal registers might be predicted to induce more diphthongizing.
5.5 Conclusion and future work

These findings contribute to our knowledge of hiatus resolution in Spanish because they show that frequency clearly modulated the VV sequences of the critical items in the experiments reported here. High frequency items accentuated the effect of the fast speech condition, which was that of a slight vowel leveling. This can be thought of as an articulatory efficiency brought about by the number of repetitions of the high frequency forms. The findings are well-positioned under the umbrella of the usage-based model of phonology, which has shown repeatedly that high frequency items often undergo some sort of articulatory change under the weight of high usage.

Nonetheless, the results discussed here do find a larger magnitude of effects on the VV sequences as a result of the rate manipulation than those found from frequency differences in the items. It is noteworthy that the main effects for frequency were found even in slower, careful speech—a finding that, presently known by this author, has not be documented anywhere else. This is an important contribution. The particular nature of this dissertation of incorporating fast and slow experiments provided the ability to test the effect of frequency in different speech rates.

Phonetic environment, along with speech rate and word frequency also significantly modulated the vowel sequences. Even when preceding and following consonants were found to differentially affect the vowels, however, frequency and speech rate effects were still present. Therefore, it appears as if none of the factors worked in isolation; all three factors contributed to the modulation of the vowel sequences in question.
The data from this dissertation focused solely on the hiatus resolution of within-word [ea] vowel combinations. Recall that there are many other within-word and across-word possible vowel combinations in hiatus in Spanish.

Figure 5-4 Vowel combinations in hiatus in Spanish (shaded)
*This VV combination occurs only between words

From here future research should also study other vowel combinations not included in this dissertation, both within- and across-word VV sequences. It would also be interesting to carry out similar tasks (and spectral analyses) on populations of other dialects or socioeconomic standings, especially on those that are said to diphthongize vowel sequences in hiatus. And, as noted above, it would be especially interesting to see if by teasing apart formal versus informal register from fast versus slow rate we might find different patterns of hiatus resolution.
References


Productivity and the lexicon: Discussion. With comments by Bybee, Dressler, Goad, Janda, Kehayia, Kiparsky, Singh, and Tiffou. 284-94.


Díaz-Campos, Manuel, and Jennifer Brondell. 2006. Phonological variation in vowel sequences: the role of frequency in phonetic reductive processes. NWA 35, Columbus, OH.


Myers, James, and Yingshing Li. 2009. Lexical frequency effects in Taiwan Southern Min syllable contraction. Journal of Phonetics. 37, 2, Apr, 212-230.


Appendix A: Language History Questionnaire

I. Número de participante: Fecha:

II. El propósito de esta encuesta es para tener un mejor conocimiento de su experiencia con los idiomas que habla. Se pide responder lo más acertada y completamente posible a las preguntas siguientes. Tiene el derecho de no contestar ninguna pregunta que no quiera.

III. Sexo: Edad:

IV. ¿Que Usted sepa, tiene algún problema visual o auditivo? Si ha contestado “sí”, explique, por favor:

a. Lengua(s) materna(s):
b. País de nacimiento:
c. Lengua(s) hablada(s) en casa:

V. Indique aquí todos los idiomas que domina por lo menos parcialmente. En cada caso, indique: (1) la edad a la que Usted empezó a aprender dicho idioma, (2) el contexto en que lo aprendió (por ejemplo, en su familia, en la escuela, etc.) y (3) cómo lo usa, si es que lo usa hoy en día. Comience con el idioma que domine mejor.

Idioma 1:

a. Edad de aprendizaje:
b. Contexto de aprendizaje:
c. Uso actual:

Idioma 2:

a. Edad de aprendizaje:
b. Contexto de aprendizaje:
c. Uso actual:

Idioma 3:

a. Edad de aprendizaje:
b. Contexto de aprendizaje:
c. Uso actual:

Idioma 4:

a. Edad de aprendizaje:
b. Contexto de aprendizaje:
c. Uso actual:

VI. Si el español es su lengua materna, indique su habilidad según las categorías indicadas. *Si el español NO es su lengua materna, por favor hable con el experimentador para obtener instrucciones adicionales.

a. Indique su capacidad de leer español: 1=analfabeto, 10=muy proficiente
b. Indique su capacidad de escribir español: 1=analfabeto, 10=muy proficiente
c. Indique su capacidad de hablar español: 1=no fluido, 10=muy fluido
d. Indique su capacidad de comprender español: 1=incapaz de comprender una conversación, 10=muy capaz de comprender cualquier conversación

VII. En la próxima parte se trata de su experiencia con el inglés.

¿Ha estudiado Usted el inglés? Si la respuesta es NO, pase a la última pregunta de esta parte.

VIII. ¿Por cuánto tiempo en años ha estudiado el inglés...
    a. …en su educación secundaria antes de asistir a la universidad:
    b. …en la universidad:

IX. ¿Ha Usted estudiado/vivido en algún país de habla inglesa?
    a. Ciudad y país:
    b. Fechas aproximadas:
    c. Duración aproximada de estancia:
d. Lenguas usadas:

X. En la próxima parte se trata de su competencia en inglés.

Se pide una autoevaluación de su capacidad actual de usar el inglés. NO se trata de las notas que haya recibido en los cursos de inglés.

a. Indique su capacidad de leer inglés: 1=analfabeto, 10=muy proficiente
b. Indique su capacidad de escribir inglés: 1=analfabeto, 10=muy proficiente
c. Indique su capacidad de hablar inglés: 1=no fluido, 10=muy fluido
d. Indique su capacidad de comprender inglés: 1=incapaz de comprender una conversación, 10=muy capaz de comprender cualquier conversación

XI. ¿Hay algún otro aspecto de sus experiencias lingüísticas que Usted quiera indicar aquí?
## Appendix B: Word list used in experimental tasks

<table>
<thead>
<tr>
<th>Spanish word</th>
<th>Word list used in experimental tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>perro</td>
<td>tos, pelear, recurso</td>
</tr>
<tr>
<td>gato</td>
<td>entre, doblaje, golpear</td>
</tr>
<tr>
<td>blanca</td>
<td>craneal, mundial, obra</td>
</tr>
<tr>
<td>plátano</td>
<td>aplicaciones, licor, mantener</td>
</tr>
<tr>
<td>mesa</td>
<td>sablear, piano, usar</td>
</tr>
<tr>
<td>menú</td>
<td>recital, fuerza, coacción</td>
</tr>
<tr>
<td>zapato</td>
<td>indudable, león, proeza</td>
</tr>
<tr>
<td>flaca</td>
<td>radiar, pechos, poema</td>
</tr>
<tr>
<td>pared</td>
<td>isla, momento, ganado</td>
</tr>
<tr>
<td>tuerza</td>
<td>peón, halo, federal</td>
</tr>
<tr>
<td>fibra</td>
<td>nadar, social, objeto</td>
</tr>
<tr>
<td>tercer</td>
<td>matriz, densa, humano</td>
</tr>
<tr>
<td>disgusto</td>
<td>universal, teatro, notable</td>
</tr>
<tr>
<td>rebelión</td>
<td>peano, peor, según</td>
</tr>
<tr>
<td>director</td>
<td>pasear, orgánico, real</td>
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<tr>
<td>afloja</td>
<td>jalar, toaria, prear</td>
</tr>
<tr>
<td>almohada</td>
<td>leal, plantear, verdad</td>
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<tr>
<td>sistema</td>
<td>liar, cuando, jarrón</td>
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<tr>
<td>lámina</td>
<td>beato, acción, noche</td>
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<tr>
<td>danza</td>
<td>nicho, broche, novela</td>
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<tr>
<td>jurado</td>
<td>bracear, flexible, mundo</td>
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<tr>
<td>bufanda</td>
<td>sensorial, unión, vapor</td>
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<tr>
<td>milpear</td>
<td>llamada, padre, junto</td>
</tr>
<tr>
<td>bonito</td>
<td>cubismo, muda, nuclear</td>
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<tr>
<td>coalición</td>
<td>gestual, hechizo, rosado</td>
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<td>gramos</td>
<td>dial, alrededor, floema</td>
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<td>nitrógeno</td>
<td>emplear, quesear, abeja</td>
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<tr>
<td>rato</td>
<td>talión, marrón, técnica</td>
</tr>
<tr>
<td>neón</td>
<td>coclear, bigote, nula</td>
</tr>
<tr>
<td>estudiar</td>
<td>caderas, cohabitan, belén</td>
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<tr>
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<td>jimena, mayordomo, agitar</td>
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<td>floreal, hongo, peal</td>
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<tr>
<td>charco</td>
<td>desear, creado, escuchaba</td>
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<td>puerca, guampa, poeta</td>
</tr>
<tr>
<td>glucosa</td>
<td>crear, guampa, poeta</td>
</tr>
</tbody>
</table>
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