An Analysis of Vowels across Word Boundaries in Veracruz, Mexican Spanish

Janet M. Smith, Tanya L. Flores, Michael S. Gradoville

Indiana University Bloomington

Abstract

This project examines vowels in hiatus across word boundaries in Spanish. Our findings are based on a corpus of seven female speakers of the Veracruz variety of Mexican Spanish. Previous research on vowel transitions has proposed several possible outcomes for vowel combinations across word boundaries in Spanish: hiatus, diphthong, reduction or deletion of one vowel, or creation of a new vowel. The purpose of this project was to investigate the conditions under which these outcomes actually occur in running speech using spectrographic analysis.

In terms of hiatus, our results support those of a study conducted on the Spanish of northern New Mexico/Southern Colorado by Alba (2006), which concluded that maintaining hiatus was not the preferred outcome. Likewise, in the present study, 94% of our 148 tokens showed non-maintenance of hiatus. Our data did not clearly reveal a single preferred outcome among the non-maintenance tokens, but rather a mixture of tendencies. These varied widely by vowel combination and speaker. Another surprising outcome that deserves attention is centralization. Centralization was present in all four vowel combinations, occurring more frequently than anticipated, given that it is thought not to occur in Spanish.

1. Introduction

Our project[1] examines vowels in hiatus across word boundaries in the Spanish of seven female speakers of the Veracruz variety of Mexican Spanish. Studies that examine this topic are rare, especially within the realm of laboratory phonology using spectrographic analysis. Prior experiments on the topic have utilized aural perceptions to distinguish vowel sequences in hiatus from those that are diphthongs and it is only recently that

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studies are being done that use speech analysis software such as Praat, WaveSurfer and PCquirer to validate the theoretical claims on vowel hiatus and vowel maintenance that have been attested for so many years.

Most of the previous studies on the topic have relied on aural perception; however, aural perception is difficult to replicate because it relies crucially on the perceptions of a limited number of individuals and, furthermore, it does not provide an exceptional level of detail of the acoustics (in this case, the precise movements of F1 and F2) involved. Aural perceptions rely on the perceiver's categorization of a given phenomenon. In order to more objectively identify patterns in the data, we deemed it necessary to investigate the acoustic correlates of vowels across word boundaries. Therefore, the present paper hopes to advance our methods of analysis of vowel sequences utilizing the acoustic analysis software program, Praat.

2. Review of previous literature

When two vowels come into contact, there are three options for the production of the vowels: 1) they can be produced in hiatus, meaning that the two vowels are produced in two separate syllables, 2) they can also be produced as a diphthong (also known as synaeresis, when it occurs within the same word; and synalepha when it occurs across word boundaries), meaning that the two vowels are in the same syllable, (Hualde et al. 2001) or 3) the two vowels can fuse into a single vowel of a quality that differs from that of the original two, otherwise known as coalescence. Perhaps due to the lack of an objective method with which to classify vowel combinations such as this, prior literature has focused on distinguishing diphthongized vowels from vowels in hiatus. One of the earlier studies on the subject that did mention coalescence was that by Stockwell and Bowen (1965). They base their results on their own observations and those of Spanish instructors, and their theories on the generative linguistics of Chomsky. However, they (and others of the same era) were still able to come up with a set of rules to explain what speakers do when two vowels are in contact with each other. In doing so, they distinguish between two categories: geminate pairs and non-geminate pairs. Vowel combinations falling into the first category led to articulatory reduction resulting in a vowel with longer duration than that of the corresponding monophthongal vowel. In the case of non-geminate pairs, one of three outcomes was possible. The first is that the first vowel gets shortened and the second vowel gets lengthened, while still maintaining the quality of each vowel. The second is that one of the vowels converts to a semi-vowel, or a glide, while the other is maintained; and the third is complete deletion of the first vowel. In addition to admitting that the vowel /a/ causes irregularities in Spanish vowel combinations, Stockwell and Bowen also add that if either vowel is stressed, the stressed vowel will not be reduced or affected in any way.

While no acoustic study to date has come close to confirming or rejecting the phonological rules proposed by Stockwell and Bowen (1965), several studies that have focused their analysis on aural perception have tried. One of the more recent experiments to do so is that of Alba (2006). While most other studies on vowels in contact have addressed word internal contexts, Alba focused on vowels across word boundaries. His study is notable in that it is based upon corpus data from actual

language use. Alba made a binary distinction between hiatus resolution and maintenance, coded based on the concurring opinions of two native speakers of Spanish. This classification scheme was dictated both by the binomial logistic regression statistical method employed and the sound quality of the data used. He used 29 hours of sociolinguistic interviews from 38 native Spanish-speakers from the southern Colorado/New Mexico area. He analyzed the /a.V/ vowel combinations of the guided conversation portion of each interview, where /a/ was always the first vowel and "V" represented each of the five vowels in Spanish, /ieaou/. After extracting and analyzing each of the 1,912 vowel combinations, he found that in the majority of the tokens (74%) the speakers reduced the vowels in hiatus instead of maintaining the hiatus. For the 74% of the tokens where reduction occurred, either one of two stress patterns was present: 1) neither vowel was stressed or 2) the first vowel, /a/, was stressed. The vowel reduction for the other two stress patterns (stress on the second vowel or stress on both vowels) was much less. (The stress identified by Alba is not emphatic stress, but rather canonical Spanish stress placement. Therefore, the decision to classify any given syllable as stressed or not was based on Alba's knowledge of the rules of Spanish stress placement.) He also found that when the second vowel was /e/, /a/, or /o/, it was more frequent that the vowel combination be reduced.

Moving from the aural perception side of classifying the hiatus/diphthong contrast to the laboratory acoustic analysis side, duration is one of the most salient features of the contrast and is also one of the easier acoustic correlates to measure. Hualde and Prieto (2002) performed an experiment to determine the relationship between the duration of a vowel sequence and its classification as a hiatus or as a diphthong. In this experiment they were testing the extent to which native speakers of Spanish could use their intuition to syllabify words that contained either a hiatus or a diphthong. The authors asked the participants (native speakers of Madrid Spanish) to syllabify each of the twenty words after having read each word in a carrier phrase. The word list spanned the following three categories: an intervening morphological boundary, the similarity to another word in which the stress falls on one of the two vowels in the sequence, and the preference for hiatus in the stressed position. Then, they compared the duration of each vowel sequence /ia/ with the participants' perception of that sequence as a hiatus or as a diphthong. The purpose of doing so was to try and identify some acoustic correlates of the hiatus-diphthong contrast since the majority of studies to date have been perceptual studies (Hualde and Prieto 2002: 219). They found that, in general, the speakers' intuitions about the syllabification of items on a word list coincided with their productions in that the words they syllabified as hiatus also had the longest duration. The division between the syllable durations that were hiatus and those that were diphthongs was not clear-cut; there was a region of overlapping durations in the area in the middle with some diphthongs produced in the lower range of the hiatus productions and some hiatus produced in the upper range of the diphthong productions. Nonetheless, the results of the experiment seem to corroborate the belief that vowels in hiatus have a longer duration than do vowels in diphthongs.

One of the more recent studies on the subject of the hiatus/diphthong contrast to take into account formant values as well as duration is the sociolinguistic study done by Garrido (2007). In her study she compares the two vowel combinations /ea/ and /io/ in the speech of men and women that spoke two different varieties of Colombian Spanish:

one from the Andes mountains and the other from the coast, using two different tasks. In one task the participants were asked to read the words in the word list in the carrier phrase “Yo digo _____ para ti.” (“I say _____ for you.”) and in the other tasks the participants were asked to narrate a picture story. In order to analyze the data, she measured the duration of each vowel sequence and the first formant value (F1) of the first vowel utilizing Praat. She found a differentiation in length according to task type with the longest vowel sequences being produced when they read the word in the context of the carrier phrase. The stressed syllable of the sequence [jo] was found to be the longest syllable for the speakers from the Andes, but that was not the case for the speakers from the coast. In general she found that the speakers from the Andes produced longer syllables than did the speakers from the coast. Regarding the first formant, she appears to have combined her speakers and only separated them by vowel sequence type and stress type because she only gives one number for all of her subjects regardless of geographical origin. There were seventeen speakers in total with the division being about equal between participants of one area and those of the other. Garrido concluded that in the context of the carrier phrase, the speakers from the coast produced the first vowel of each sequence with a lower F1 value than those same speakers when they were narrating the picture story. Comparing the results of the picture story across the two varieties of Colombian Spanish revealed almost no discernable difference; the differences in vowel height seem to have disappeared when the informants were asked to produce semi-spontaneous speech.

In another recent study, Colantoni and Limanni (2008) compared diphthongs and hiatus in two varieties of Argentinean Spanish. One variety was in contact with Guaraní and the other was not, being characterized as a conservative variety of Spanish. In their study, they focused on word-internal vowel combinations, limiting the combinations in their study to /ia/, /ie/ and /io/. In the acoustic part of their analysis, they measured the duration of each vowel as well as the duration of the transition. They also measured three formant values (F1, F2, and F3) at each of the three quartiles of the vowel sequence, as outlined above. (Their criterion for identifying the transition was a change of 20 Hz in F2.) Using the transition period they had identified, they were able to measure the velocity with which F2 changed. They found that in the variety in contact with Guaraní there is more diphthongization than in the non-contact variety included in the study. (Diphthongs are far from being the norm in Guaraní.) In the contact variety of Spanish, they found that the first vowel and the transition were shorter than they were in the non-contact variety. The contact variety also favored a longer second vowel than the non-contact variety with a more gradual transition between vowels. Non-contact varieties favored a longer transition. As a result of the phoneme and vowel transition durational differences, the authors concluded that the variety in contact used syllable duration as an acoustic cue to distinguish between vowels in hiatus and diphthongs.

As a result of the rather inconclusive literature on this topic and the lack of a fine-grained analysis of the acoustic correlates of tongue movements involved in the production of the vowels and their transition, in this study we hope to better understand the nature of the movements that occur when producing vowels in hiatus. Prior analyses of this phenomenon have classified the following possible outcomes: hiatus, diphthong, deletion of one vowel, and coalescence of the two vowels to form a third, meaning that the characteristics of the two vowels are assimilated to form a third, distinct vowel while

the two monophthongal vowels that gave rise to the third vowel are deleted. Therefore, one goal of this project is to ascertain whether the vowel transitions follow a consistent schema or if they show variable articulations. We also hope to determine the degree to which the duration of the movement corresponds with the length of the trajectory (e.g. do movements that show temporal reduction correspondingly show substantive reduction?).

Although vowel transitions have been plotted on a vowel space in the past, to the best of our knowledge this will be the first time that vowel transitions will be plotted in the vowel space using data from actual speech production of Spanish. Thus we will be able to observe the transitions in each vowel sequence as they occur in the data. It is our hope that the analysis of those transitions will allow us to address with acoustic data an issue that has traditionally been analyzed via aural perception.

3. Methodology

3.1 Corpus/Participants

Our project examined vowels in hiatus across word boundaries in the Spanish of seven female speakers of the Veracruz variety of Mexican Spanish, ranging in age from eighteen to twenty-eight. Each speaker was a student pursuing a university or professional degree. The participants were recorded individually by Dr. Erik Willis with a USB Pre-Microphone Interface for Computer Audio and a Shure WH20 microphone in a quiet environment in Veracruz telling the story by Mercer Mayer (1969), *Frog, Where Are You?.* It is a picture story, allowing for the elicitation of semi-spontaneous narrative speech.

3.2 Analysis technique

We took an initial inventory of all of the vowel combinations found in the informants' speech that spanned two words in order to narrow our focus on specific combinations, leaving aside geminate vowel combinations and vowels in contact with the palatal consonants /ʝ/ and /ɲ/, which have vowel-like characteristics, making them difficult to distinguish in spectrographic analysis. For example, "está en" was analyzed, but "como a la" was excluded. As a result of this analysis, we decided to focus this study on the vowel combinations with the most tokens: /ae/, /ea/, /oa/ and /oe/. These four vowel combinations had 28, 46, 19 and 55 occurrences, respectively, for a total of 148 combinations. These totals reflect the vowel combinations that were analyzed and not the total number of tokens found in their speech. Twenty-seven tokens had to be eliminated, the majority of which were eliminated due to an inability to distinguish vowel boundaries as a result of the vowel combination being in contact with an approximant [ß], [ɣ], [ð] or with a nasal /m/ or /n/, which are heavily vocalic and under certain conditions can be indistinguishable from vowels due to their regular periodicity and occasional lack of visible cues in the spectrogram. When dealing with vowels, one always has to take into account the surrounding phonetic context; therefore, in our analysis, we also considered the effect of the surrounding consonants.

In order to analyze the vowels in hiatus, we used Praat. The first step was to identify the durations of each vowel sequence, which was done by analyzing both the waveform and the spectrogram. With the duration of the vowel sequence selected in Praat, formant measurements (F1 and F2) were taken at the 25%, 50% and 75% marks of the vowel sequence (See Figure 1). If the hiatus has been maintained, then the formants should reflect this. They will then be plotted against each speaker's vowel space for comparison. To construct each speaker's vowel space, we measured formant values of three monophthongal vowels for each of the five vowels found in Spanish, and took their average. We chose monophthongal vowels that were flanked by any combination of plosives and fricatives, since in Spanish there are very few sets of five words with a minimal pair distinction on the basis of a differing vowel. These minimal pairs did not occur in the semi-spontaneous speech of the informants. One exception was the vowel /i/ which was very rare in a monophthongal position. As a result we were forced to accept productions of the word *y* (and) if it was flanked by the above consonants or by pauses.

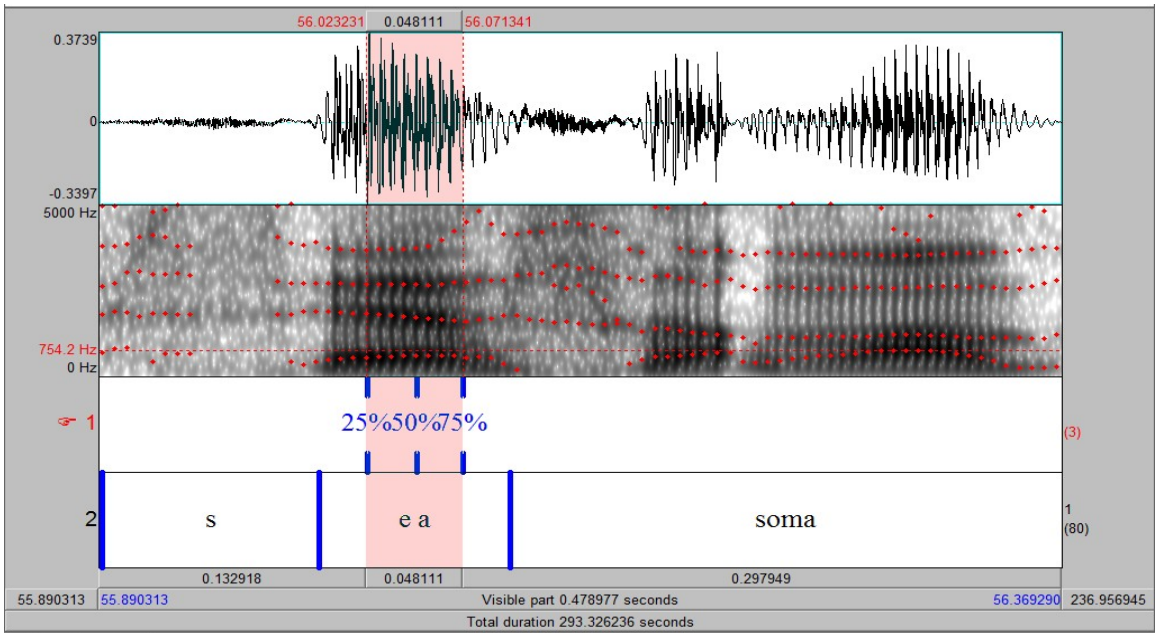

Figure 1: An example utterance of one of our speakers saying "se asoma" (he leans out). The vowel boundaries are marked with the bottom blue borders and the measurement boundaries are marked by the upper set of blue borders. As can be seen from the selection highlighted in pink, the vowel sequence is relatively stable with very little formant frequency change in the middle 50% of the vowel.

Upon completion of our analysis, we hope to have a better understanding of what occurs when the vowels discussed above come into contact at a word boundary in the Spanish of Veracruz, Mexico.

4. Results

In order to facilitate the reader's comprehension and location of the tables and figures referenced below, the following directory is provided.

4.1 Criteria for distinguishing maintenance from non-maintenance

While the criteria are not yet in place to differentiate hiatus from diphthongs using formant measurements alone, the data does hint toward the following initial classifications:

1) If all three points are found tightly plotted together (barring the influence of nasals), it can be classified as either a coalesced vowel or vowel elision.

2) Given the equality of our measurements, if two consecutive points are plotted together and the third is rather far away (see the /o.a/ combination of vf4-ll or the /a.e/ combination of vf2-fr for examples), it is an indication of vowels in hiatus.

3) If neither of the first two conditions are satisfied, it would suggest a diphthong.

4.2 Maintenance vs. non-maintenance

We found that 94% of the tokens (N=148) in this study showed a preference for non-maintenance of the hiatus. These included two cases of maintenance for /a.e/, three cases for /e.a/, and two each for /o.a/ and /o.e/. Maintenance was determined from the vowel charts when the trajectory of the vowels in contact went from the vowel space of the first vowel to the second, as determined by each speaker's monophthongal vowels. For example in Figure 2, /goal/ (in red) would be classified as maintenance, while /soal/ (in blue) would not. Six of the nine productions that were maintained were flanked on

[2] The codes given are identification markers for the purposes of distinguishing each speaker.

both sides by alveolar consonants, one was in the context of an alveolar as the first consonant and a bilabial as the second, another reversed the phonetic context so that the bilabial was the first consonant and the alveolar the second, and the last, depicted in red in the graph below, was in the context of a velar as the first consonant and an alveolar as the following consonant.

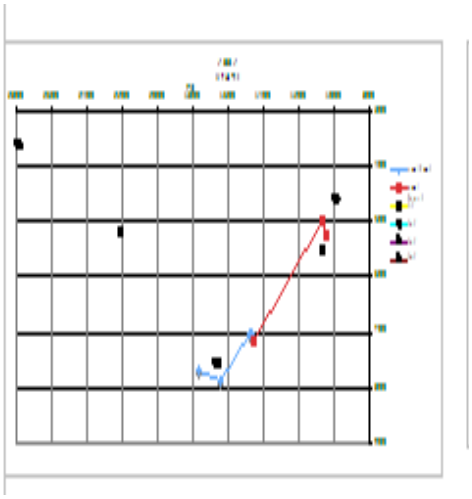

Figure 2. /o.a/ vowels of Vf4-II plotted with her monophthongal vowels.

4.3 Duration

When considering duration, Hualde and Prieto (2002) found that duration is one of the acoustic correlates of hiatus, which was corroborated by our findings in that each of the nine tokens where maintenance was observed were of longer durations. While it was never the case that the vowel combinations with the longest durations fit into our definition of vowel maintenance, it was notable that the vowel combinations where maintenance occurred had durations that were much longer than the non-maintenance vowel combinations.

Also notable were the longest durations of each vowel combination. It is interesting to note that /e.a/ had the shortest duration with a maximum of 193 ms, followed by /a.e/ at 264, /o.e/ at 328 ms and /o.a/ at 449 ms. (Depicted in Appendix H). As can be seen from Appendix I, the /o.e/ and /o.a/ vowel combinations had one outlier apiece, which for both vowel combinations coincided with the vowel combinations with the longest durations. For the /a.e/ vowel combination we can see that the majority of the data is within one standard deviation from the mean (119 ms), with only one token between one and two standard deviations away. The vowel combination /e.a/, with eighteen more tokens than /a.e/, exhibits a bit more variation. This vowel combination had ten tokens between one and two standard deviations away, indicating that the durations of /e.a/ were not as tightly clustered around the mean (98 ms) as the tokens for the /a.e/ combination. /O.e/ shares the same duration distributional pattern as /e.a/, with a very comparable mean of 101 ms, which is not surprising considering those two vowel

combinations were the most numerous. Vowel combination /o.a/, with only nineteen tokens, does not show very much variation and, while significance cannot be calculated with so few tokens, it can be noted that except for the one outlying token, all the durations of the /o.a/ vowel combination are fairly tightly clustered around the mean (143 ms).

4.4 Stress

The prescriptive definition of stress was applied when evaluating the stress patterns of the 148 tokens. For all four vowel combinations, twenty-six contained at least one stressed vowel. Of those twenty-six, fourteen contained stress on the first vowel, eleven on the second, and only one contained stress on both vowels. Slightly more than half (14/26) showed a dominance for the vowel that was accented, while a good portion of them did not, showing instead a preference for the non-accented vowel to be dominant. Six of the twenty-six stressed tokens did include the word "no" (indicated by an "*" on the charts in the appendices). Five of the six maintained a vowel position within the domain of /e/.[3] Other than the pattern identified when the first word was "no", there does not appear to be another identifiable outcome correlate of stress.

4.5 Analysis of vowel combinations

4.5.1 /a.e/

Most of the tokens of this vowel combination showed the expected movement from /a/ to /e/, spanning within the range of the control vowels, with only a few exceptions. Speaker Vf1-am, for example, had three tokens with large trajectories through the vowel space, surpassing the /a/ and /e/ targets.

Contrary to the belief that nasals act as formant suppressants (Sampson 1999), our data revealed that not all nasals brought formants down. In the chart for Vf-frm we can see that one case of "rana escapo" (represented by the dark blue line) approached and actually made it to /e/ territory. Two additional tokens of this type show the same movement from /a/ territory to /e/ territory, though one /naes/ of 163 ms, seems to be a fronted /a/ of some sort, possibly affected by the preceding nasal. The impact is greater when the vowel combination is flanked by nasals on each side, as seen in the /ae/ chart for speaker vf4-ll. Vf5-vo produces an interesting token in /laem/ due to its appearance of being a vertical line of dots in the F1/F2 space. Nasals may again be the culprit suppressing the v-like trajectory common among the vowel sequence tokens.
While the majority of tokens for this category moved naturally between /a/ and /e/, in the following subsections, we will describe three specific tendencies of tokens that showed coalescence, a dominant vowel, or centralization. Only one speaker, Vf2-fr, did not demonstrate any of these tendencies, as both of her tokens for this category maintained hiatus.

[3] For a more detailed discussion on the stress of Spanish, including that of function words, see Hualde (2005).

Coalescence

In the /a.e/ combination, we saw four instances of coalescence from three different speakers. These tokens followed the proper gesture for the combination, but did not travel across the expected locations in the vowel space; rather all three measurements taken at the 25%, 50% and 75% marks of their duration, are gathered in a new location of the vowel space, distinct from the /a/ or /e/ target. For speaker Vf-frm, the token /naes/ of longest duration (163 ms) coalesced in the area of a fronted /a/. Speaker Vf1-am produced three /laen/ tokens, the shortest (61 ms) appears to be coalesced in the region between the /a/ and /e/ targets, while a second /laen/ measuring 86 ms, may be coalesced as a fronted /a/. Speaker Vf4-ll produced one token, /naen/, that coalesced as a fronted hybrid vowel between the targets of the /a/ and /e/ region. While the effects of the nasals on both sides are difficult to determine at this point, it is visible on this chart that they did not lower the formant values for this token.

Dominance

For the vowel combination /a.e/, it seems that /a/ was the dominant vowel in eight of the 28 tokens, while /e/ dominated only three tokens. This dominance was determined by visual inspection of the token plots (see Appendices A through G), where all three plot points occur closely within the same vowel space, /a/ or /e/. Of the tokens where /a/ was the dominant vowel, four of them came from the same speaker, Vf-dr: /rael/ (65 ms), /raes/ (75 ms), /raes/ (103 ms), and /táen/ (131 ms). These were also the shortest tokens for this speaker, who produced only five tokens in this category.

All three tokens produced by Vf5-vo are entirely in the /a/ vowel space. These relatively short tokens are preceded by a bilabial and two different alveolar consonants, but are all followed by nasals: /baen/ (61 ms), /laem/ (62 ms), and /raen/ (87 ms).

Centralization

Considering the vowel combination, the tokens in this category were not expected to cross the schwa territory. However, we found three tokens (belonging to two speakers) that crossed into schwa area during at least one quartile. Speaker Vf3-il produced a /raes/ of 69 ms that begins its trajectory in the proper direction, but for the extent of the third quartile moves upward across the schwa space. While the other /raes/ for this speaker (108 ms) can be considered an /e/-dominant token, it also crosses schwa territory in both measured segments of its trajectory. Speaker Vf4-ll provided the best example of full centralization in the token /baen/ of 73 milliseconds. This token moves across the space as if moving from /o/ to /e/, in a v-like pattern.

4.5.2 /e.a/

Two speakers, Vf1-am and Vf-dr had tokens that headed toward zero, possibly due to the following bilabial consonant. For the first speaker, the token was /seab/ and for the second /deab/. Most of the tokens for this vowel combination plotted between their productions of /e/ and /a/, which is to be expected. Two of the three vowel combinations for Vf3-il appear to have an /a/ significantly lower than what was found in the

monophthongal vowels, but that may just be due to a wider variation in /a/ territory than is found for the other speakers. Most of the tokens for these speakers were in the region between the targets /e/ and /a/, but in the following subsections, we will describe three specific tendencies of tokens that showed coalescence, a dominant vowel, or centralization.

Coalescence

Ten of the forty-six tokens in the /e.a/ combination demonstrated coalescence. Three belong to speaker Vf1-am: /seab/ of 111 ms and both /leab/ tokens (both measure 75 ms); all three of these have coalesced in the space between /e/ and /a/. Speaker Vf4-ll has four tokens that have coalesced, three of them are in the space between /e/ and /a/ and the fourth, /seab/ (82 ms), looks like a fronted /a/. Speaker Vf-frm also has a token /seas/ that seems to have coalesced in the space between /e/ and /a/. Two of speaker Vf5-vo's tokens show coalescence between /e/ and /a/: /seak/ of 51 ms and /keás/ of 90 ms. The former of these is more centralized, but not quite in schwa territory.

Dominance

At least seven of the tokens in this category had /a/ as a dominant vowel, while /e/ dominated three of the total forty-six. Of the two tokens in this combination for speaker Vf2-fr, one shows an /a/ dominance and the other shows an /e/ dominance. The /a/-dominant token /seal/ measures 82 ms and is slightly fronted, while the /e/-dominant token /seat/ is only 47 ms and is a slightly centralized. Speaker Vf4-ll has one token where /e/ is the dominant vowel, /keab/ of 56 ms; it is also the token of shortest duration for this speaker in this category. While the other tokens appear to be coalesced as new distinct vowels, one of the tokens may actually be an /a/ dominant token, /seab/ (82 ms). There are four tokens in Vf-dr that seem to illustrate /a/ dominance, the first three are: /deab/ (76 ms), /deas/ (81 ms), and /deab/ (88 ms). However, the fourth token, /deab/ is unusual due to its longer duration (175 ms) and because it moves in the opposite direction of what is expected for this category. Speaker Vf5-vo has one token with complete /e/-dominance, /seak/ of 64 ms, and one token with /a/ as a dominant vowel, /leag/ of 65 ms.

Centralization

Few tokens in the /e.a/ combination are completely centralized. One of Vf2-fr's tokens appears just inside the /e/ space, approaching schwa territory. Speaker vf-dr has one unusual token, /deab/ of 74 ms, that projects from left to right across schwa space heading towards zero formant values. Speaker Vf5-vo has one clear example of centralization in token /seak/ of 51 ms. While there are no complete centralized tokens for speaker Vf1-am, several tokens seem to be heading toward schwa by the end of the third quartile.

4.5.3 /o.a/

Coalescence

Occurring twice in the nineteen productions, coalescence was not a very popular phenomenon in the realization of the production of the vowel combination /o.a/. In the speech of vf-frm, the longest of all the vowel combinations is a very interesting case. The apparent lack of a transition to another vowel in this case may be due to the fact that the transition to /a/ occurred after the third quartile mark. However, it might also very well be the case that the two monophthongal vowels have merged to form a "hybrid" vowel combining, in this instance, the F1 of the second vowel with the F2 of the first.

Dominance

Of the nineteen productions of the /o.a/ vowel combination, four were /a/ dominant productions and an additional four were /o/ dominant productions. Of the four /a/ dominant productions, it is interesting to note that the consonant on each side of the vowel combination was an alveolar. With the /o/ dominant productions, there existed a bit more variation, even though each of the four tokens was in contact with at least one alveolar consonant. All four vowel combinations contained an alveolar as the preceding consonant. Two of the four that were preceded by an alveolar were also followed by an alveolar, with the remaining two followed by either a velar consonant or a bilabial consonant.

Centralization

Centralization wasn't that common amongst the tokens of the /o.a/ vowel combination. Only three of the six speakers who produced measurable /o.a/ vowel combinations produced tokens that included some form of centralization: vf-frm, vf3-il and vf5-vo. The /noag/ token of speaker vf3-il and the /doal/ and /roal/ tokens of speaker vf-frm show centralization, but only of one vowel. Speaker vf3-il shows slight centralization of the /a/, while vf-frm shows centralization of the /o/. However, the only token we found where all three measured points are close to complete centralization is the /rroas/ token of speaker vf5-vo. Due to an infrequency of centralization within this vowel combination, it can be argued that centralization is not the norm.

4.5.4 /o.e/

Coalescence

With regard to the /o.e/ vowel combination, coalescence was far from common. In fact, of the seven female speakers, only two produced at least one instance of coalescence with a total of three tokens between the two of them. All were preceded and followed by an alveolar consonant. Interestingly, each speaker coalesced in a different area of their vowel space. Speaker vf1-am produced her two tokens (/tóel/ and the shortest token of /toes/) in the vowel space located between her monophthongal /e/ space and the canonical schwa space. Speaker vf5-vo produced her token in the vowel space

between /a/ and /e/, which is not what is expected for the vowel combination /o.e/, but is nonetheless a clear example of vowel coalescence.

Dominance

The dominance of one vowel over the other did not fare much better than coalescence in terms of popularity. Five of the seven speakers were found to produce nine tokens of vowel dominance. Of the nine tokens where one vowel was found to be dominant, six were /e/ dominant and the remaining three /o/ dominant. Each of the /e/ dominant tokens was both preceded and followed by an alveolar consonant. Although each of the three /o/ dominant tokens was preceded by an alveolar, it was followed by one in two of the three tokens. In the third /o/ dominant token, the consonant that followed /o.e/ was a bilabial.

Centralization

Each speaker produced at least one token of centralization, for a total of fifteen productions. Fourteen of the fifteen tokens were flanked by an alveolar consonant on each side with the fifteenth being flanked by the palato-alveolar affricate /tʃ/ and an alveolar. The majority of the productions, nine, including the one preceded by the palato-alveolar affricate, were "vertically centralized", meaning that the tokens were not only in the schwa vowel space, but that they also showed a tendency for moving vertically in the vowel space. The remaining six tokens were either "horizontally" or "diagonally" centralized, with four being in the former category and two in the latter. The four tokens that were "horizontally centralized" were divided amongst three of the speakers: vf2-fr, vf3-il and vf4-ll, while the "diagonally centralized" tokens were produced by a single speaker: vf1-am. Every single token of centralization described above was clearly situated in the schwa area between /o/ and /e/, which is to be expected when combining two mid-vowels.

5. Discussion/conclusion

Upon initial inspection of each speakers' vowel space (seen in the attached appendices), it can be seen that centralization was a lot more common than the other possible outcomes for word-boundary hiatus. Coalescence, by definition, consists of only one vowel with characteristics of each of the two vowels that it came from and should exhibit very minimal movement, which, from looking at each speaker's vowel space, was suggested by very few tokens (comparatively speaking).

In partial concordance with Stockwell & Bowen (1965), each of the four vowel combinations either showed a preference for the dominance of one vowel over the other, or a maintenance of hiatus with the exception of /o.e/. This particular vowel combination showed an extensive amount of centralization, which was not one of the outcomes described by Stockwell & Bowen, nor has it been described anywhere else in the previous literature done on the subject of vowels in contact across word boundaries. It is logical that /o.e/ would be the vowel combination most likely to undergo centralization since both vowels are mid-vowels. Centralization has even been shown to occur in the

other vowel combinations that are of unequal vowel height, although to a lesser extent. Nonetheless, this phenomenon has received little to no attention from the linguistic community due to the fact that centralization is thought not to occur in Spanish.

Although Stockwell & Bowen's first two outcomes for non-maintenance were not able to be corroborated using the current method of analysis, the third outcome, that of V1 deletion (described above as vowel dominance), was found to occur with each vowel combination, though to a lesser extent with /o.e/. Surprisingly enough, the opposite (V2 deletion) was also found to occur, even though Stockwell and Bowen neglect to acknowledge it. The frequency with which the first vowel or the second was deleted varied by vowel combination, but for each combination, it was in a clear minority of the productions.

Coalescence was not mentioned by Stockwell and Bowen (1965), but was also found to occur in each vowel combination. It was found in a handful of tokens for /a.e/, /o.a/ and /o.e/, but was much more prevalent among the /e.a/ vowel combination, occurring in a little less than a quarter of its tokens. This hybrid of two vowels is common enough to be more than just a fluke, therefore deserving more attention in future research.

In accordance with the results of Hualde and Prieto (2002), the tokens with the longer durations were the ones identified as vowels in hiatus, therefore corroborating the belief that duration is an important component of producing vowels as hiatuses instead of as diphthongs. Our narrow definition of hiatus maintenance may very well be too constrictive for what the human ear is able to perceive as a vowel in hiatus; a more open definition may very well allow for stronger support of this belief, but it was deemed that it was best to go with the narrow definition given above so as to best avoid the grey area created by the combination of duration and vowel token shape. Longer durations were typically representative of a longer trajectory due to the time necessary to arrive at the destination, but it wasn't always the case. Shorter durations seemed to correspond with articulatory reduction, which can mean that one vowel was elided or that both vowels were present, but the trajectory of movement was not as long.

Overall, stress (accent) did not seem to affect the outcome of the vowel combination when charted. A pattern was identified as the explanation of the behavior of the tokens that had "no" as the first word, but there does not appear to be another readily identifiable pattern. The token behavior that was noted appears to have occurred at random due to the inability to find a correlation with vowel sequence duration and with preceding and following phoneme type.

The phonetic environment itself sometimes had a very noticeable effect on the production of the vowel combination. The tokens that were in contact with a nasal, especially when there were nasals on each side often affected the formant values by raising the F1 value, lowering the F2 value, or a combination of the two. Rather unexpected was the appearance of the influence of a /b/ that sometimes occurred. It can be seen that the trajectory heads toward zero in the /deab/ (74) token of speaker vf-dr, but the gesture is really exaggerated in the /seab/ (97) token of speaker vf1-am. From this token it is readily noticeable that the /b/ is impacting the production of the vowels as early as the third quartile. Another interesting case is that of /rael/ of speaker

vf3-il. Due to the downward movement of this token, it is hypothesized that this speaker was actually producing something closer to the dark /l/ found in American English, than the typical Spanish light /l/.

6. Future research

Future research must address certain shortcomings in the analysis herein. For example, lip rounding was not accounted for in our formant measurements. In the present study, only three points within the vowel transitions were measured. In tokens of particularly long durations, this may not be an accurate representation of everything that the tongue did during the transition. We hope to develop more complete visual representations in an upcoming study, allowing also for a more accurate method for classifying diphthongs. We also hope to tie in the process used by Colantoni and Limanni (2008) in their study on Argentinean Spanish, using the slope of the transition to assist us in distinguishing hiatuses from diphthongs.

Future studies would also include a schema for quantifying such a study with numbers. For example, the standard deviations of the F1 and F2 values of each token could be calculated. A low standard deviation value would suggest little movement. If the standard deviations of both F1 and F2 were low, it would suggest a stable vowel. Any division between a stable vowel and a dynamic vowel would need to be made on an arbitrary basis or on the basis of a perception study in which correspondences are drawn between what is found in an acoustic analysis and what native speakers of the language perceive.

Future studies could examine the effects of function words, frequency of word strings, and the influence of stress. We were not able to consider the effects of function words versus non-function words, given that the majority of our tokens included at least one function word. A future study could also consider the frequency of word strings as compared to the oral data of Mark Davies' *Corpus del español,* with the idea that words that commonly occur together will be internalized as a string instead of as separate words. These may therefore exhibit different hiatus maintenance/non-maintenance strategies.

We began this study by analyzing a corpus of 12 speakers, five males and seven females. Though we completed all the steps in our analysis technique for all the speakers, including measuring formant values at all three points (25-50-75), we decided to focus our study on the female speakers for this initial work. In the future, we plan to repeat this study with our data from the male speakers, normalizing the data to be able to combine the findings for all twelve.

This study could also be repeated with a more conservative variation of Mexican Spanish to discover which characteristics of these vowel combinations are "universal" and which are attributable to that particular variety. Vowel movement, after all, is more about gesture movement than about hitting a specific target, as is the case with consonants.

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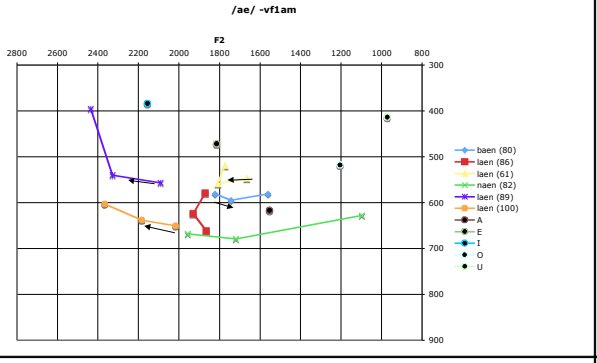
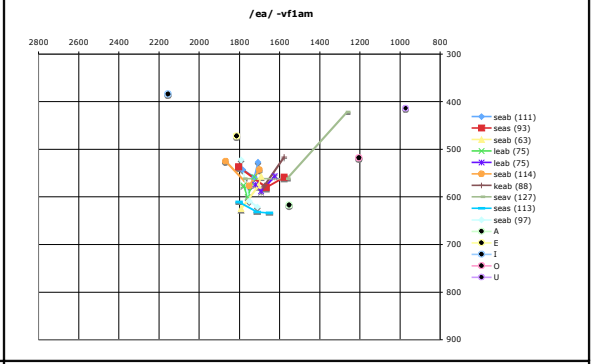
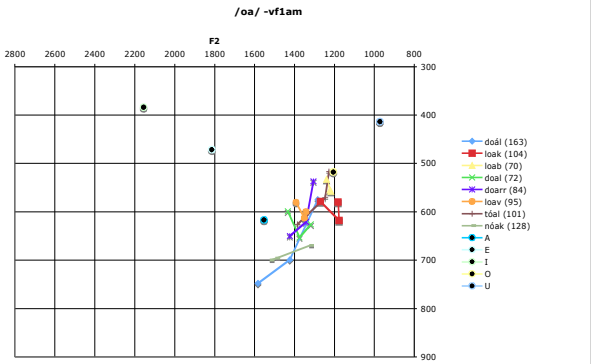
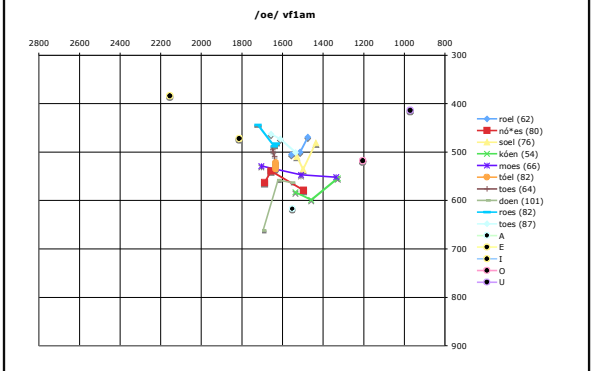
Appendix A: Tokens for Vf1-am

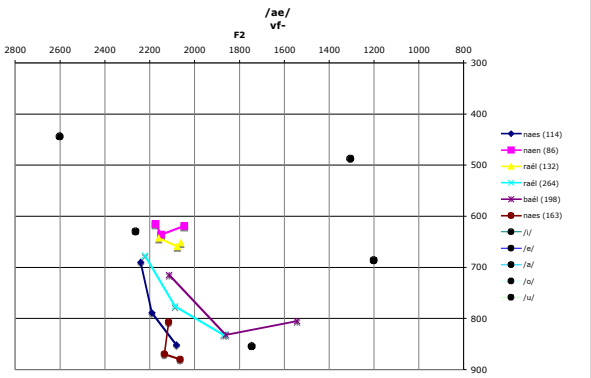


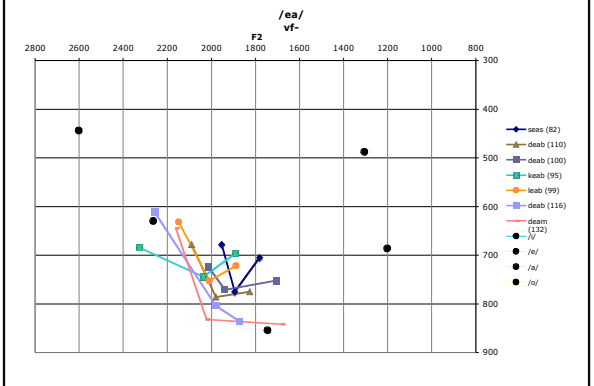


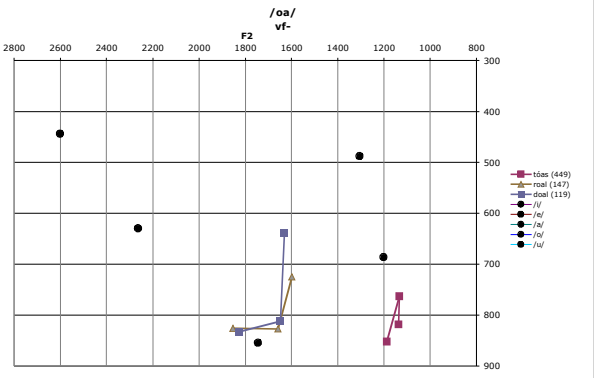


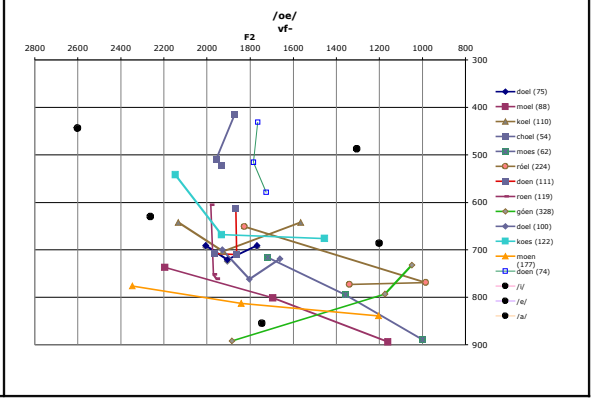


Appendix B: Tokens for Vf-frm

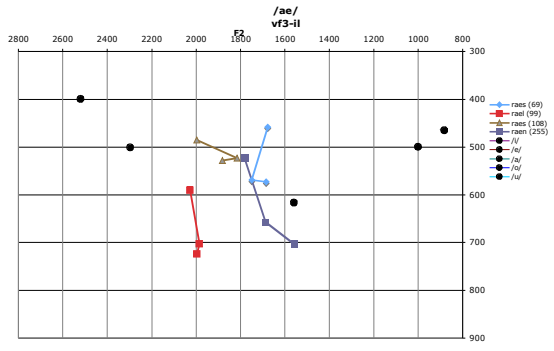


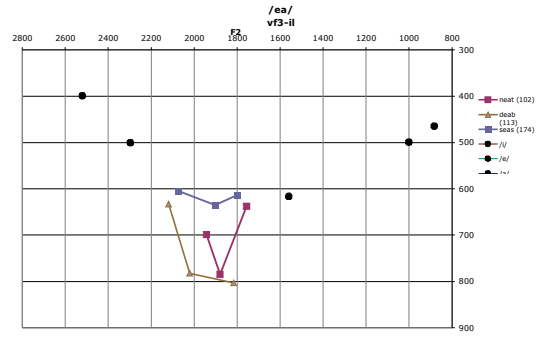


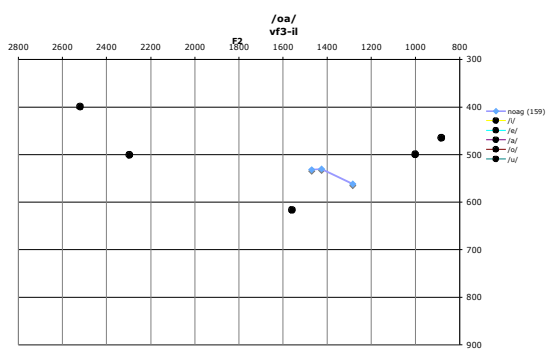


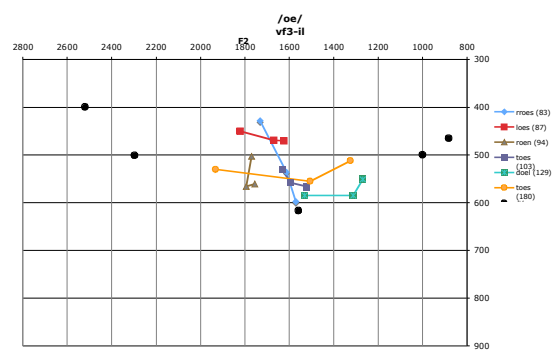


Appendix C: Tokens for Vf3-il









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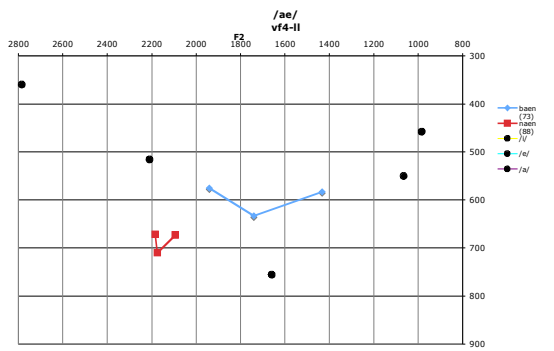
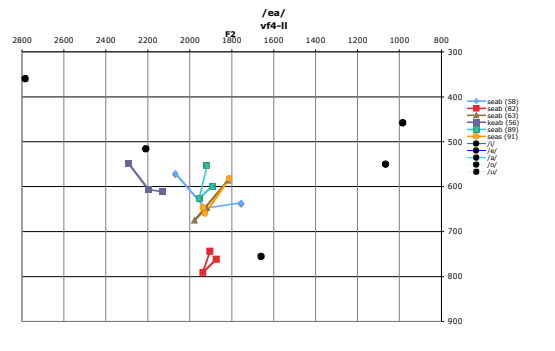
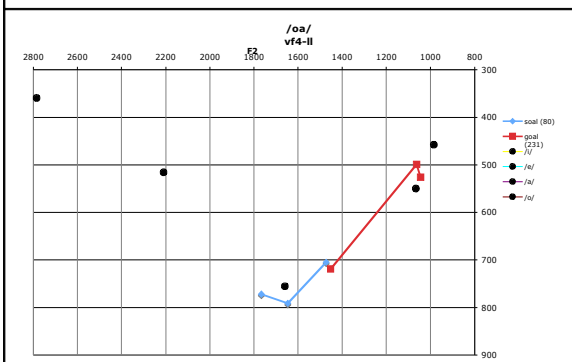
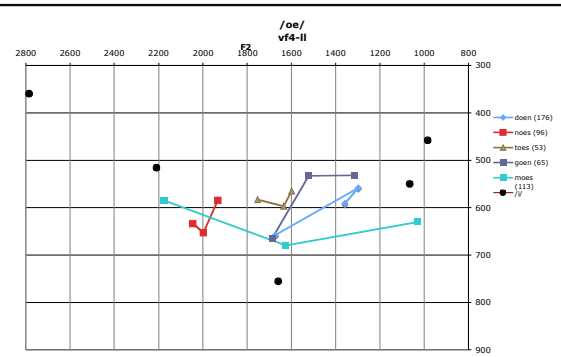
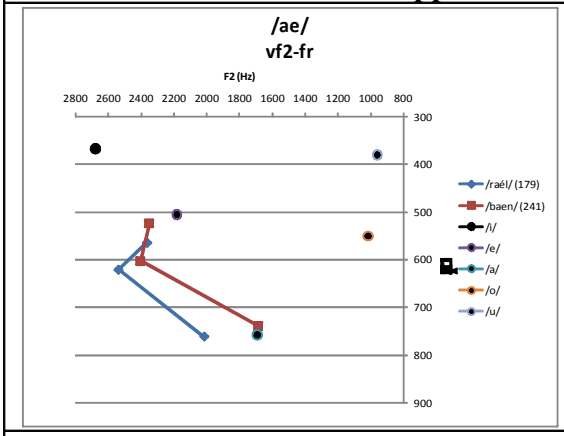


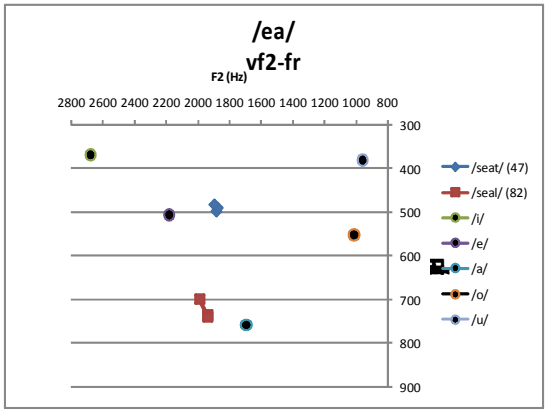




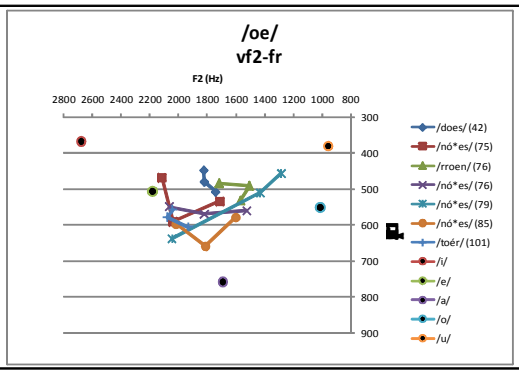


Appendix E: Tokens for Vf2-fr

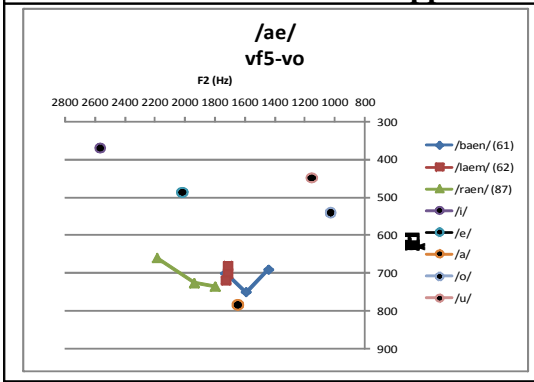


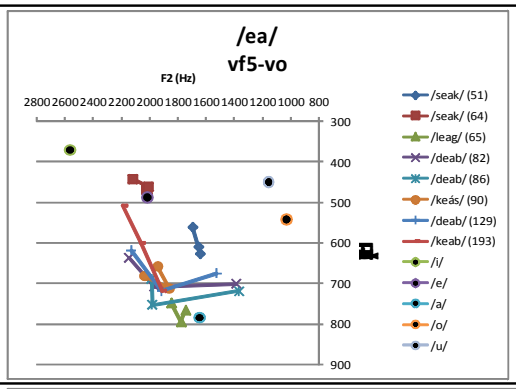


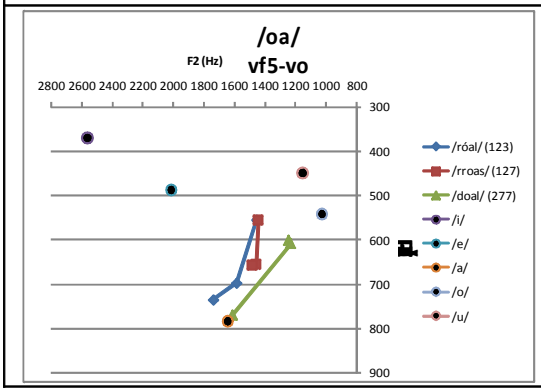
Speaker vf2-fr did not produce a single measurable token of the vowel combination /oa/ across word boundaries.

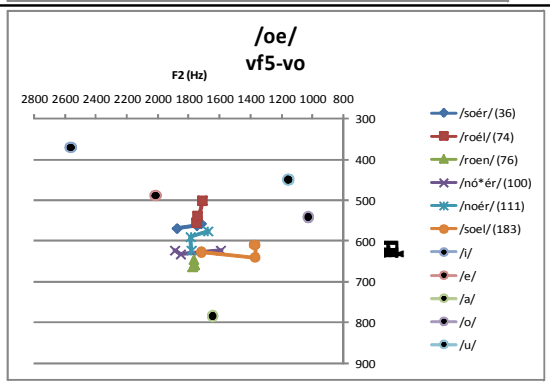


Appendix F: Tokens for Vf5-vo

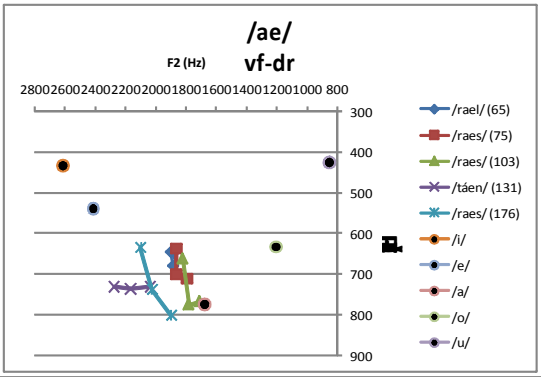


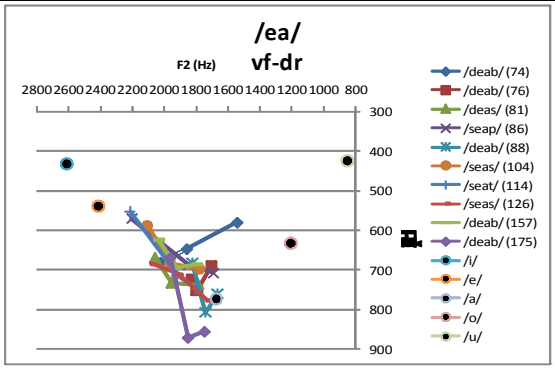


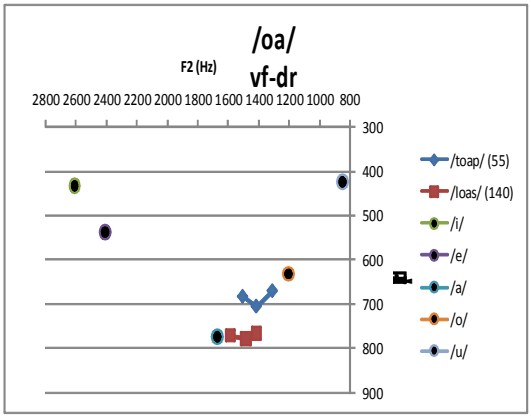


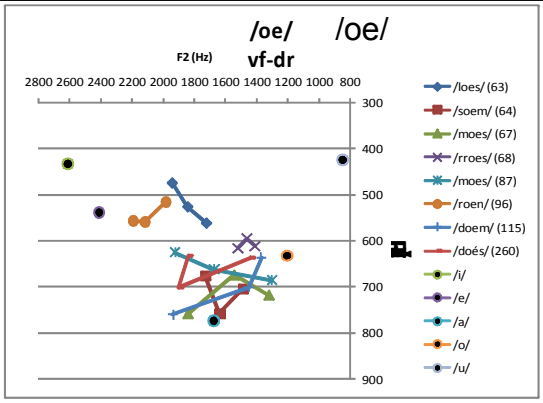


Appendix G: Tokens for Vf-dr

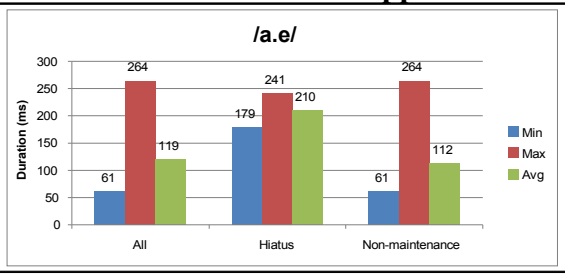


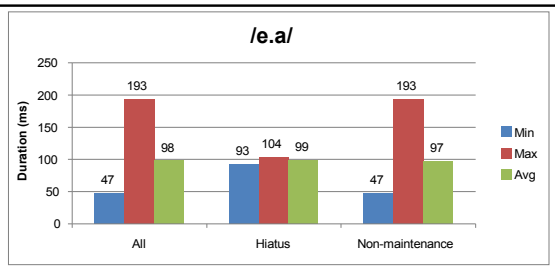


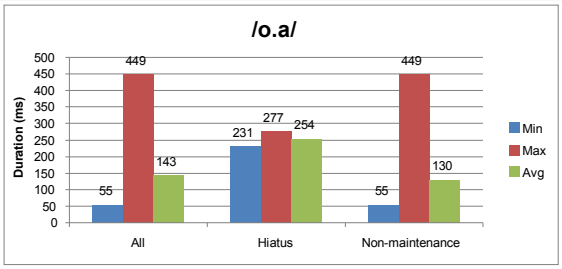


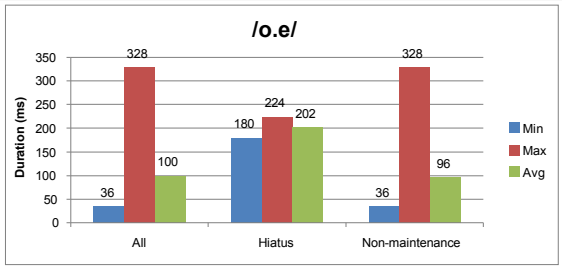


Appendix H: Hiatus Maintenance









Appendix I: Standard Deviations of Vowel Durations