

# ACOUSTIC ANALYSIS OF L1 AND L2 SPANISH VOWELS\*

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## 1. Spanish vs. English vowel systems

Spanish contains five vowels in its inventory: /a/ (low, central), /e/ (medium, front, closed), /i/ (high, front, closed), /o/ (medium, back, closed), and /u/ (high, back, closed). English (in comparison) has 12 or more vowels (depending on variety): /æ/ (low, front), /ɑ/ (low, central), /ʌ/ (medium, central), and /ə/ (medium, central); /e/ (medium, front, closed) and /ɛ/ (medium, front, open); /i/ (high, front, closed) and /ɪ/ (high, front, open); /o/ (medium, back, closed) and /ɔ/ (medium, back, open); /u/ (high, back, closed) and /ʊ/ (high, back, open) (Schwegler et al. 2010, Hualde 2014).

## 2. Spanish vs. English vowel duration

Spanish and English vowels vary greatly on the parameter of duration. In Spanish, all vowels are short, and duration is almost identical for both stressed and unstressed vowels. In English, /e/, /i/, /o/, and /u/ are lengthened and realized as diphthongs, while other vowels are short, and stressed vowels are considerably lengthened, while unstressed vowels are considerably reduced, often to a schwa (Schwegler et al. 2010, Hualde 2014).

## 3. F1 and F2

Spanish and English vowels can also be measured based on the first two formants in a spectrogram: F1 and F2. Formants (or formant frequencies) can be defined as acoustic resonances with which a vowel is articulated. They are influenced by the position of the articulators (jaw, lips, and tongue) and are represented in a spectrogram by dark, horizontal bands. F1 indicates the height of a vowel (how low in the mouth it is articulated). F2 indicates the anteriority of a vowel (how front in the mouth it is articulated) (Schwegler et al. 2010, Hualde 2014, Colantoni et al. 2015).

F1 and F2 distribution for Spanish vowels is as follows: /a/: Low, central vowel (high F1, medium F2). /e/: Medium, front vowel (medium F1, high F2). /i/: High, front vowel (low F1, high F2). /o/: Medium, back vowel (medium F1, low F2). /u/: High, back vowel (low F1, low F2). Spanish vowels differ in F1 and F2 from their English counterparts, with Spanish /a/, /o/ and /u/ being higher (lower F1) and more back

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\* This paper was presented at the 2022 annual conference of the Canadian Linguistic Association, held virtually, June 2, 2022, and at the University of Toronto Graduate Language Research Day, November 12, 2021. The presentation was based on a course assignment for my PhD program in Hispanic Linguistics at University of Toronto, submitted April 18, 2016. I would like to thank Laura Colantoni for her help and comments on this paper.

(lower F2) than English /æ/, /o/, and /u/, and Spanish /e/ and /i/ being lower (higher F1) and more back (lower F2) than English /e/.

#### **4. Literature review**

Previous research has found that, in L1 English/L2 Spanish speakers: F1 and F2 of Spanish vowels may progress toward those of native speakers, as L2 proficiency increases. However, effects of stress from L1 English may persist, since F1 and F2 for stressed L2 Spanish vowels may be higher or lower than for unstressed vowels, depending on the vowel (Menke and Face 2010, Cobb and Simonet 2015). In perception, L1 English/L2 Spanish speakers may assimilate Spanish /a/ to English /æ/ + /ʌ/ + /ɒ/ + /ɛ/, Spanish /e/ to English /e/, Spanish /i/ to English /i/, Spanish /o/ to English /o/, and Spanish /u/ to English /ʊ/ + /u/. In production, they may substitute English /æ/, /e/, /i/, /o/, and /u/ for Spanish /a/, /e/, /i/, /o/, and /u/ (Morrison 2003, Menke 2010).

#### **5. Research questions and hypotheses**

##### **5.1 Duration**

For this study, the following questions will be investigated for duration: Are there differences in Spanish vowel duration between L1 English-L2 Spanish and L1 Spanish speakers? If there are, do these differences occur for all vowels or only for some vowels? Do these differences vary as a function of vowel, stress and L2 learner proficiency?

It can be hypothesized that: In L1 English-L2 Spanish speakers with lower proficiency, stressed /e/, /i/, /o/ and /u/ will be realized with a longer duration than in native speakers, while unstressed /a/ will be realized with a shorter duration than in native speakers. However, with increased proficiency, these speakers will move closer to native speaker target values on the parameter of duration.

##### **5.2 F1**

For this study, the following questions will be investigated for F1: Are there differences in Spanish vowel F1 between L1 English-L2 Spanish and L1 Spanish speakers? If there are, do these differences occur for all vowels or only for some vowels? Do these differences vary as a function of vowel, stress and L2 learner proficiency?

It can be hypothesized that: In L1 English-L2 Spanish speakers with lower proficiency, unstressed and stressed /a/, /o/ and /u/ will be realized with a higher F1 than in native speakers, while unstressed and stressed /e/ and /i/ will be realized with a lower F1 than in native speakers. However, with increased proficiency, these speakers will move closer to native speaker target values on the parameter of F1.

##### **5.3 F2**

For this study, the following questions will be investigated for F2: Are there differences in Spanish vowel F2 between L1 English-L2 Spanish and L1 Spanish speakers? If there

are, do these differences occur for all vowels or only for some vowels? Do these differences vary as a function of vowel, stress and L2 learner proficiency?

It can be hypothesized that: In L1 English-L2 Spanish speakers with lower proficiency, all vowels (unstressed and stressed) will be realized with a higher F2 than in native speakers. However, with increased proficiency, these speakers will move closer to native speaker target values on the parameter of F2.

## 6. Methodology

Data for this corpus study were collected from the *University of Toronto Romance Phonetics Database* (Colantoni and Steele 2004), and in particular, from the Romance Language Survey. This database includes data from the main Romance languages: Spanish, Portuguese, French, Italian, and Romanian.

### 6.1 Participants

Colantoni and Steele (2004) collected data from 30 participants, living in Toronto (15 L2 Spanish learners with L1 English, 15 L1 Spanish speakers). Due to time limitations, data for this corpus study were only collected from six of these participants: three L2 Spanish learners with L1 English: SL002, intermediate (female, age 20), SL003, advanced (male, age 29), and SL001, near-native (male, age 18), and three L1 Spanish speakers: SN130 (male, age 19, from Chile), SN131 (female, age 19, from El Salvador), and SN135 (male, age 26, from Colombia).

### 6.2 Tasks

Participants in Colantoni and Steele's study completed the following tasks: (1) Reading individual Spanish words, in the carrier phrase *Digo \_\_\_ otra vez (I say \_\_\_ again)*. (2) Reading the Aesop fable *El viento del norte y el sol* ("The North Wind and the Sun") in Spanish. (3) Retell of the story *Caperucita roja* ("Little Red Riding Hood"), in Spanish, with the help of pictures. (4) Oral description of their favorite meal, in Spanish. Data for this corpus study were only collected from the word reading task.

### 6.3 Stimuli

Corpus data were collected from sound files of 50 words, each spoken by the six participants, in the word reading task (10 word tokens per vowel, five stressed and five unstressed, 300 words in total), from the *University of Toronto Romance Phonetics Database* (Colantoni and Steele 2004). Duration, F1 and F2 for each vowel token were measured using Praat (Boersma and Weenink 1992/2015).

## 7. Data analysis

Duration was measured by selecting the target vowel within the spectrogram for each stimulus. This selection generated a second spectrogram, below which the duration of the

vowel displayed, in seconds. All measurements were multiplied by 1000 to obtain a measure in milliseconds, and rounded up or down to the nearest millisecond.

F1 was measured by selecting the target vowel within the spectrogram for each stimulus, and in turn, selecting the centre of the vowel, to avoid coarticulation effects (Colantoni et al. 2015). F1 measurements were obtained from this point, using Praat (Formant > Get First Formant) and rounded up or down to the nearest Hz.

F2 was measured by selecting the target vowel within the spectrogram for each stimulus, and in turn, selecting the centre of the vowel, to avoid coarticulation effects. F2 measurements were obtained from this point, using Praat (Formant > Get Second Formant) and rounded up or down to the nearest Hz.

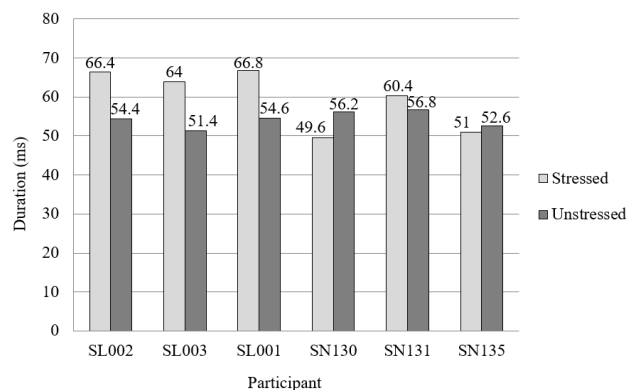
## 8. Results

### 8.1 Duration

Overall, results provide some evidence that duration of L2 Spanish-L1 English vowels may vary from, or be approximately equal to, that of L1 Spanish vowels, depending on vowel, stress, and L2 proficiency.

#### 8.1.1 Vowel /a/

In all three L2 speakers (SL002, SL003, and SL001), stressed /a/ was realized with a mean duration longer (by 12.73, 10.33, and 13.13 ms, respectively) than the native speaker mean of 53.67 ms. In these speakers, unstressed /a/ was realized with a mean duration approximately equal to or slightly shorter than (0.8, 3.8, and 0.6 ms shorter than, respectively) than the native speaker mean of 55.2 ms (Figure 1).

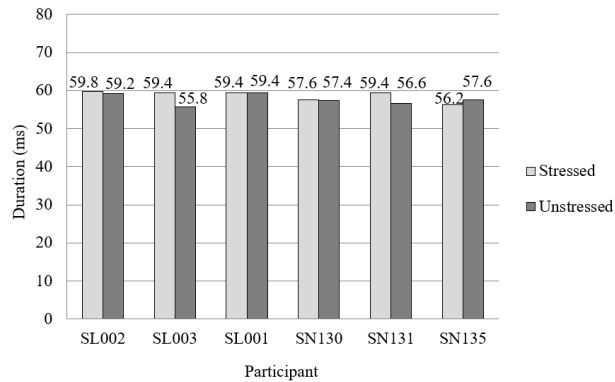


**Figure 1.** Mean duration of vowel /a/, by participant and stress.

#### 8.1.2 Vowel /e/

In all three L2 speakers (SL002, SL003, and SL001), stressed /e/ was realized with a mean duration slightly longer (by 2.07, 1.67, and 1.67 ms, respectively) than the native speaker mean of 57.73 ms. In these speakers, unstressed /e/ was realized with a mean

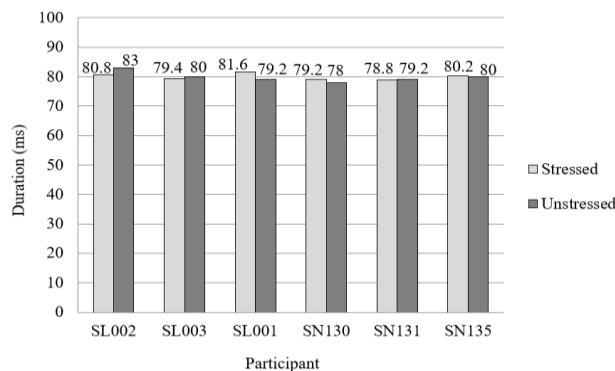
duration approximately equal to (2 ms longer than, 1.4 ms shorter than, and 2.2 ms longer than, respectively) the native speaker mean of 57.2 ms (Figure 2).



**Figure 2.** Mean duration of vowel /e/, by participant and stress.

### 8.1.3 Vowel /i/

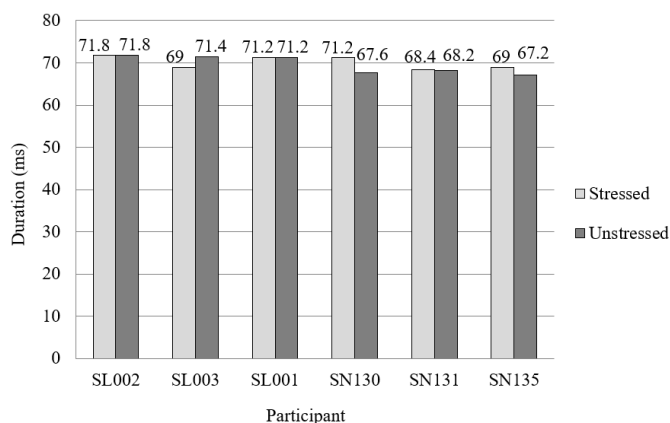
In all three L2 speakers (SL002, SL003, and SL001), stressed /i/ was realized with a mean duration approximately equal to (1.4 ms longer than, equal to, and 2.2 ms longer than, respectively) the native speaker mean of 79.4 ms. In these speakers, unstressed /i/ was realized with a mean duration slightly longer than or approximately equal to (3.93, 0.93, and 0.13 ms longer than, respectively) the native speaker mean of 79.07 ms (Figure 3).



**Figure 3.** Mean duration of vowel /i/, by participant and stress.

### 8.1.4 Vowel /o/

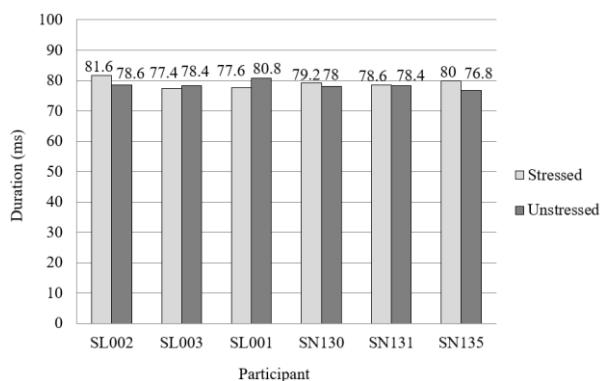
In all three L2 speakers (SL002, SL003, and SL001), stressed /o/ was realized with a mean duration approximately equal to (2.27 ms longer than, 0.53 ms shorter than, and 1.67 ms longer than, respectively) the native speaker mean of 69.53 ms. In these speakers, unstressed /o/ was realized with a mean duration slightly longer (by 4.13, 3.73, and 3.53 ms, respectively) than the native speaker mean of 67.67 ms (Figure 4).



**Figure 4.** Mean duration of vowel /o/, by participant and stress.

### 8.1.5 Vowel /u/

In all three L2 speakers (SL002, SL003, and SL001), stressed /u/ was realized with a mean duration approximately equal to (2.34 ms longer than, 1.86 ms shorter than, and 1.66 ms shorter than, respectively) the native speaker mean of 79.26 ms. In these speakers, unstressed /u/ was realized with a mean duration approximately equal to or slightly longer than (0.87, 0.67, and 3.07 ms longer than, respectively) the native speaker mean of 77.73 ms (Figure 5).



**Figure 5.** Mean duration of vowel /u/, by participant and stress.

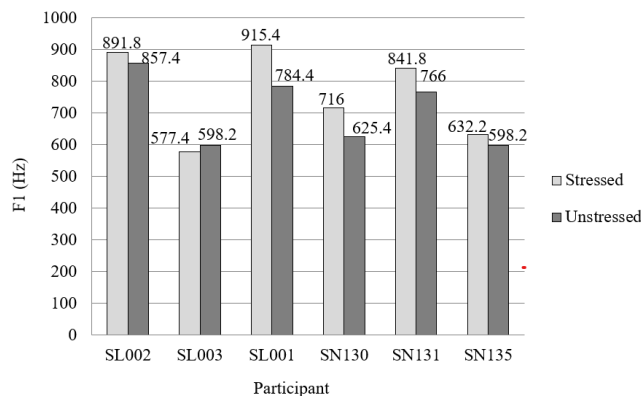
## 8.2 F1

Overall, results provide some evidence that F1 of L2 Spanish-L1 English vowels may vary from L1 Spanish vowels, as a function of vowel, stress, and L2 proficiency.

### 8.2.1 Vowel /a/

In all three L2 speakers (SL002, SL003, and SL001), stressed /a/ was realized with a mean F1 considerably different from (161.8 Hz higher than, 152.6 Hz lower than, and

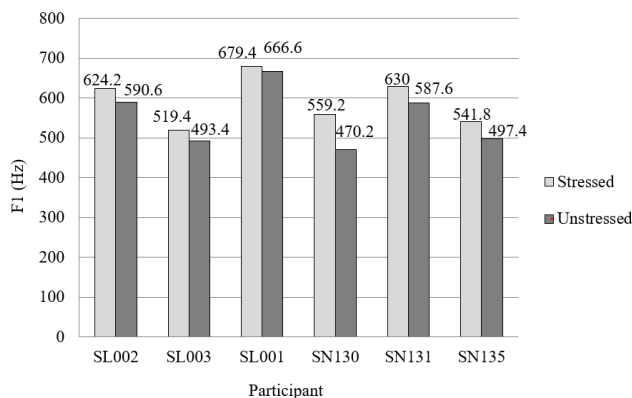
185.4 Hz higher than, respectively) the native speaker mean of 730 Hz. In these speakers, unstressed /a/ was realized with a mean F1 considerably different from (194.2 Hz higher than, 65 Hz lower than, and 121.2 Hz higher than, respectively) the native speaker mean of 663.2 Hz (Figure 6).



**Figure 6.** Mean F1 of vowel /a/, by participant and stress.

### 8.2.2 Vowel /e/

In all three L2 speakers (SL002, SL003, and SL001), stressed /e/ was realized with a mean F1 somewhat or considerably different from (47.2 Hz higher than, 57.6 Hz lower than, and 102.4 Hz higher than, respectively) the native speaker mean of 577 Hz. In these speakers, unstressed /e/ was realized with a mean F1 considerably or somewhat different from (72.2 Hz higher than, 25 Hz lower than, and 148.2 Hz higher than, respectively) the native speaker mean of 518.4 Hz (Figure 7).

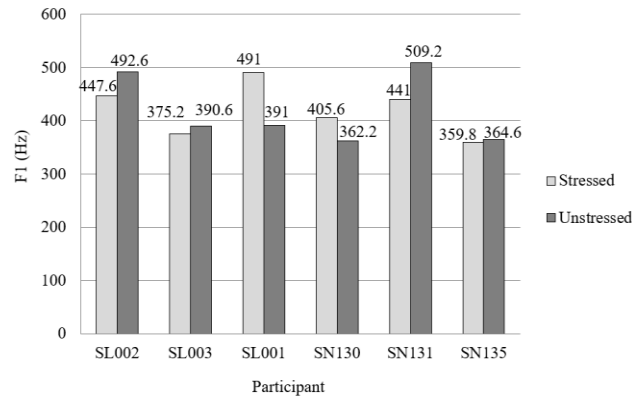


**Figure 7.** Mean F1 of vowel /e/, by participant and stress.

### 8.2.3 Vowel /i/

In all three L2 speakers (SL002, SL003, and SL001), stressed /i/ was realized with a mean F1 somewhat or considerably different from (45.47 Hz higher than, 26.97 Hz lower

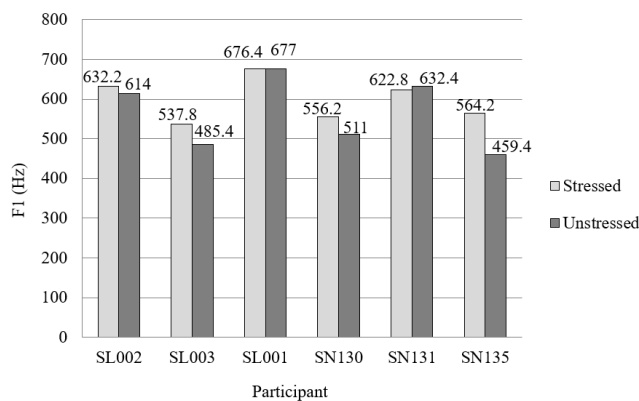
than, and 88.87 Hz higher than, respectively) the native speaker mean of 402.8 Hz. In these speakers, unstressed /i/ was realized with a mean F1 considerably or somewhat different from (80.6 Hz higher than, 21.4 Hz lower than, and 21 Hz lower than, respectively) the native speaker mean of 412 Hz (Figure 8).



**Figure 8.** Mean F1 of vowel /i/, by participant and stress.

#### 8.2.4 Vowel /o/

In all three L2 speakers (SL002, SL003 and SL001), stressed /o/ was realized with a mean F1 considerably or somewhat different from (51.13 Hz higher than, 43.27 Hz lower than, and 95.33 Hz higher than, respectively) the native speaker mean of 581.07 Hz. In these speakers, unstressed /o/ was realized with a mean F1 considerably or somewhat different from (79.73 Hz higher, 48.87 Hz lower, and 142.73 Hz higher than, respectively) the native speaker mean of 534.27 Hz (Figure 9).



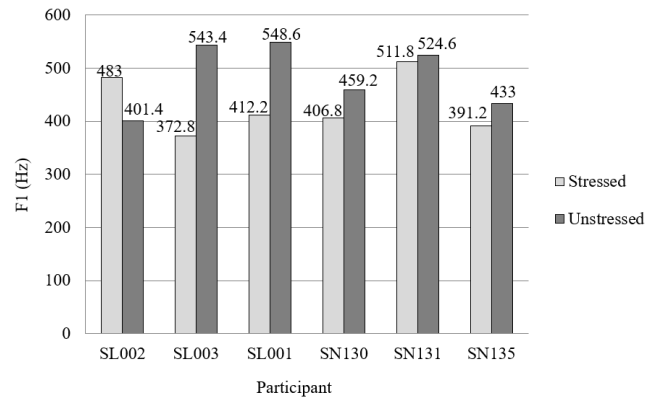
**Figure 9.** Mean F1 of vowel /o/, by participant and stress.

#### 8.2.5 Vowel /u/

In all three L2 speakers (SL002, SL003, and SL001), stressed /u/ was realized with a mean F1 considerably different from (53.6, 163.8, and 124.4 Hz lower than, respectively)



the native speaker mean of 536.6 Hz. In these speakers, unstressed /u/ was realized with a mean F1 considerably different from (70.87 Hz lower than, 71.13 Hz higher than, and 76.33 Hz higher than, respectively) the native speaker mean of 472.27 Hz (Figure 10).



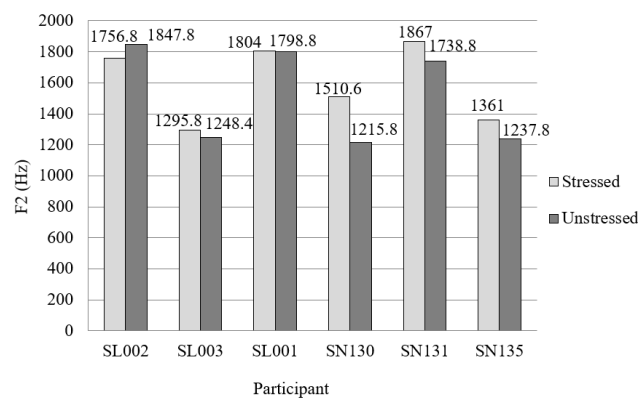
**Figure 10.** Mean F1 of vowel /u/, by participant and stress.

### 8.3 F2

Overall, similarly to F1, results provide evidence that F2 of L2 Spanish-L1 English vowels may vary from L1 Spanish vowels, as a function of vowel, stress, and L2 proficiency.

#### 8.3.1 Vowel /a/

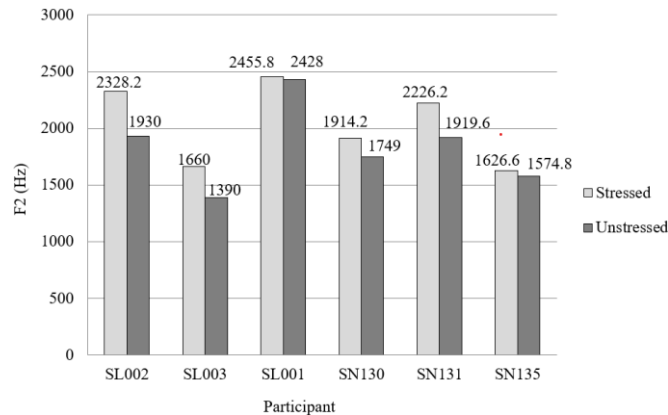
In all three L2 speakers (SL002, SL003, and SL001), stressed /a/ was realized with a mean F2 considerably different from (177.47 Hz higher than, 283.53 Hz lower than, and 224.67 Hz higher than, respectively) the native speaker mean of 1579.33 Hz. In these speakers, unstressed /a/ was realized with a mean F2 considerably different from (450.4 Hz higher than, 149 Hz lower than, and 401.4 Hz higher than, respectively) the native speaker mean of 1397.4 Hz (Figure 11).



**Figure 11.** Mean F2 of vowel /a/, by participant and stress.

### 8.3.2 Vowel /e/

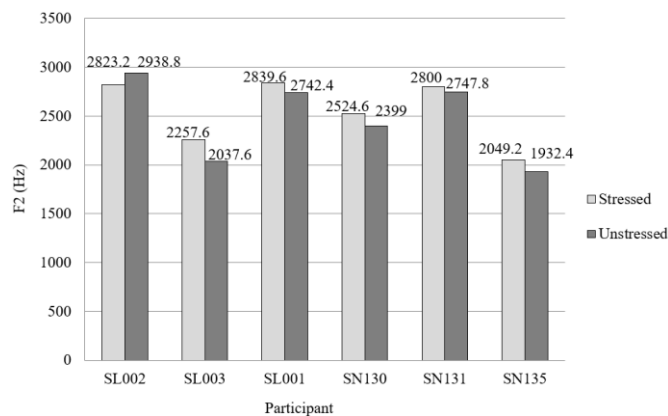
In all three L2 speakers (SL002, SL003, and SL001), stressed /e/ was realized with a mean F2 considerably different from (405.87 Hz higher than, 262.33 Hz lower than, and 533.47 Hz higher than, respectively) the native speaker mean of 1922.33 Hz. In these speakers, unstressed /e/ was realized with a mean F2 considerably different from (182.2 Hz higher than, 357.8 Hz lower than, and 680.2 Hz higher than, respectively) the native speaker mean of 1747.8 Hz (Figure 12).



**Figure 12.** Mean F2 of vowel /e/, by participant and stress.

### 8.3.3 Vowel /i/

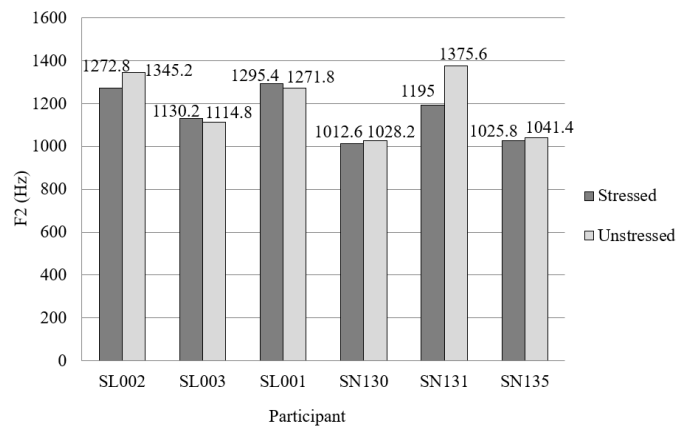
In all three L2 speakers (SL002, SL003, and SL001), stressed /i/ was realized with a mean F2 considerably different from (345.27 Hz higher than, 180.33 Hz lower than, and 381.67 Hz higher than, respectively) the native speaker mean of 2457.93 Hz. In these speakers, unstressed /i/ was realized with a mean F2 considerably different from (579.07 Hz higher than, 322.13 Hz lower than, and 383.33 Hz higher than, respectively) the native speaker mean of 2359.73 Hz (Figure 13).



**Figure 13.** Mean F2 of vowel /i/, by participant and stress.

### 8.3.4 Vowel /o/

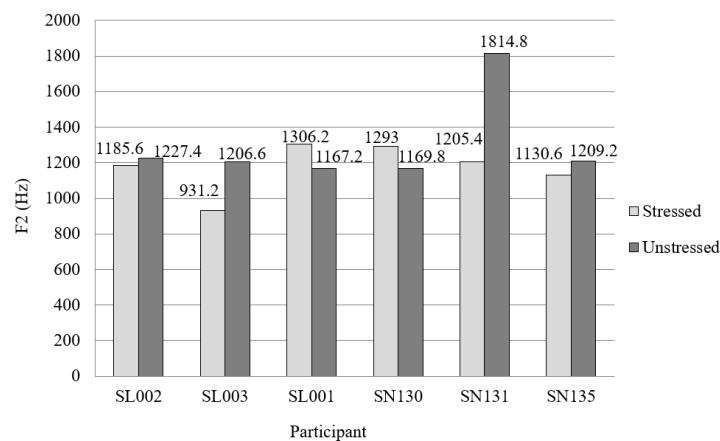
In all three L2 speakers (SL002, SL003, and SL001), stressed /o/ was realized with a mean F2 considerably higher (by 195, 52.4, and 217.6 Hz, respectively) than the native speaker mean of 1077.8 Hz. In these speakers, unstressed /o/ was realized with a mean F2 considerably or somewhat different from (196.8 Hz higher than, 23.6 Hz lower than, and 230.4 Hz higher than, respectively) the native speaker mean of 1148.4 Hz (Figure 14).



**Figure 14.** Mean F2 of vowel /o/, by participant and stress.

### 8.3.5 Vowel /u/

In all three L2 speakers (SL002, SL003, and SL001), stressed /u/ was realized with a mean F2 somewhat or considerably different from (24.07 Hz lower than, 278.47 Hz higher than, and 96.53 Hz higher than, respectively) the native speaker mean of 1209.67 Hz. In these speakers, unstressed /u/ was realized with a mean F2 considerably lower (by 170.27, 191.07, and 230.47 Hz, respectively) than the native speaker mean of 1397.67 Hz (Figure 15).



**Figure 15.** Mean F2 of vowel /u/, by participant and stress.

## 9. Discussion

### 9.1 Summary of results (Duration)

Hypotheses for duration were that for stressed /e/, /i/, /o/, and /u/, mean duration would be longer for L2 Spanish learners with L1 English than for L1 Spanish speakers, and that for unstressed /a/, mean duration would be shorter for L2 Spanish learners with L1 English than for L1 Spanish speakers.

Results provide some evidence that duration of L2 Spanish-L1 English vowels may vary from, or be approximately equal to, that of L1 Spanish vowels, depending on vowel, stress, and L2 proficiency. At the intermediate proficiency level, L2 Spanish mean duration was within (plus or minus) 2.5 seconds of the native speaker mean for unstressed /a/, unstressed and stressed /e/ and /u/, stressed /i/ and stressed /o/. This proximity to target mean values was retained at both the advanced and near-native proficiency levels for all of these vowels and stress types, except for unstressed /a/ (near-native level only) and unstressed /u/ (advanced level only). At the advanced (but not the intermediate) proficiency level, L2 Spanish mean duration was within (plus or minus) 2.5 seconds of the native speaker mean for unstressed /i/. This proximity to target mean values was retained at the near-native proficiency level.

Overall, for L2 Spanish vowels in learners with L1 English, the temporal parameter of duration may be acquired in a near-native-like way for many (but not all) vowels and stress types at the intermediate level of L2 proficiency, with this acquisition improving at the advanced level, and with many improvements being retained at higher proficiency levels. This parameter may be the easiest to acquire within a hierarchy of difficulty of acoustic analysis parameters for L2 Spanish-L1 English vowels (duration being easiest, F1 more difficult and F2 most difficult). Seven of 10 vowel x stress combinations were acquired in a near-native-like way at the intermediate proficiency level (of which five were retained at both the advanced and near-native levels), and one additional vowel x stress combination was acquired in a near-native-like way at the advanced proficiency level (and was retained at the near-native level).

### 9.2 Summary of results (F1)

Hypotheses for F1 were that for stressed and unstressed Spanish /a/, /o/, and /u/, mean F1 would be higher (i.e., vowels would be articulated lower in the mouth) for L2 Spanish learners with L1 English than for L1 Spanish speakers, and that for stressed and unstressed /e/ and /i/, mean F1 would be lower (i.e., vowels would be articulated higher in the mouth) for L2 Spanish learners with L1 English than for L1 Spanish speakers.

Results provide some evidence that there may be differences in Spanish vowel F1 between L1 English-L2 Spanish and L1 Spanish speakers, and that these may vary as a function of vowel, stress, and L2 proficiency. At the intermediate proficiency level, L2 Spanish mean F1 was higher than native speaker mean values (i.e., improving beyond native speaker targets) for unstressed /e/ and unstressed /i/, and lower than native speaker mean values (i.e., improving beyond native speaker targets) for unstressed and stressed

/u/. This proximity to target mean values was retained at both the advanced and near-native proficiency levels, for stressed /u/ only. At the advanced (but not the intermediate) proficiency level, L2 Spanish mean F1 was lower than native speaker mean values (i.e., improving beyond native speaker targets) for unstressed and stressed /a/. However, there was no retention of improvements for any of these latter vowel x stress combinations at the near-native proficiency level.

Overall, for L2 Spanish vowels in learners with L1 English, the spectral parameter of F1 may be more difficult to acquire in a native-like way than the temporal parameter of duration, but easier to acquire in a native-like way than the spectral parameter of F2. Unlike for duration, improvements for F1 overshot native speaker targets, rather than being very close to these targets. Even though more improvements occurred at the intermediate level and fewer at the advanced level for F1 than F2, there was less retention of improvements for F1 than for duration. Although for four of 10 vowel x stress combinations, there was evidence of improvement (although overshooting target values for F1) at the intermediate proficiency level, retention of this improvement at both the advanced and near-native levels was only attested for one of these combinations. Similarly, although for two additional vowel x stress combinations, there was evidence of improvement (although overshooting target values for F1) at the advanced proficiency levels, retention of this improvement at the near-native level was not attested for any of these combinations.

### 9.3 Summary of results (F2)

Hypotheses for F2 were that for all stressed and unstressed Spanish vowels, mean F2 would be higher (i.e., vowels would be articulated farther front in the mouth) for L2 Spanish learners with L1 English than for L1 Spanish speakers.

Results provide some evidence that there may be differences in Spanish vowel F2 between L1 English-L2 Spanish and L1 Spanish speakers, and that these may vary as a function of vowel, stress, and L2 proficiency. At the intermediate proficiency level, L2 Spanish mean F2 was lower than native speaker mean values (i.e., improving beyond native speaker targets) for unstressed /u/. This improvement (for unstressed /u/) was retained at the advanced and near-native proficiency levels. At the advanced proficiency level, L2 Spanish mean F2 was lower than native speaker mean values (i.e., improving beyond native speaker targets) for unstressed and stressed /a/, /e/, and /i/. However, there was no retention of improvements for any of these latter vowel x stress combinations at the near-native proficiency level.

Overall, for L2 Spanish vowels in learners with L1 English, the spectral parameter of F2 may be more difficult to acquire in a native-like way than the temporal parameter of duration or the spectral parameter of F1. Unlike for duration, and similarly to F1, improvements for F2 overshot native speaker targets, rather than being very close to these targets. In addition, there was less retention of improvements for F2 than for duration. Fewer improvements occurred at the intermediate level, and more at the advanced level for F2 than F1. In only one of 10 vowel x stress combinations, evidence of improvement was attested (although overshooting target values for F2) at the

intermediate proficiency level, and retention of improvement at both the advanced and near-native levels was only attested for one of these combinations. And although for six of the remaining nine vowel x stress combinations, there was evidence of improvement (although overshooting target values for F2) at the advanced proficiency levels, retention of this improvement at the near-native level was not attested for any of these combinations.

#### **9.4 Future work**

Further research is needed to expand on the results of this corpus study. First, further experimental research needs to be conducted similar to Colantoni and Steele's study on Spanish vowels in L2 Spanish learners with L1 English, and the results of this research should be compared to those of that previous study and to those of this corpus study. In addition, future research needs to investigate the parameters measured in this study (vowel duration, F1 and F2) for Spanish vowels in L2 learners of Romance languages other than Spanish (ex. Portuguese, Catalan, French, Italian, Romanian). The results of this subsequent research should be compared to those of Colantoni and Steele's study and to those of this corpus study.

#### **10. Conclusions**

This corpus study has provided some evidence that: (1) Overall, duration of L2 Spanish-L1 English vowels may vary from, or be approximately equal to, that of L1 Spanish vowels, depending on vowel, stress, and L2 proficiency. (2) For many L2 Spanish stress x vowel combinations, duration may be acquired in a near-native-like way at the intermediate and advanced L2 proficiency levels. (3) There may be greater retention of improvements for duration than for F1 or F2 of L1 English-L2 Spanish vowels. (4) F1 and F2 of L2 Spanish-L1 English vowels may vary from those of L1 Spanish vowels, depending on vowel, stress, and L2 proficiency. (5) L2 Spanish learners may modify (increase or decrease) their original F1 and F2 values from L1 English beyond those of L1 Spanish speakers. (6) Such modifications for F1 may be more common at the intermediate proficiency level, while for F2, they may be more common at the advanced level. (7) Based on conclusions (1) to (6), there may be a hierarchy of difficulty of acoustic analysis parameters for L2 Spanish vowels in learners with L1 English: duration (easiest), F1 (intermediate), F2 (most difficult). However, further experimentation is needed to provide evidence which confirms the results and conclusions of this corpus study.

#### **References**

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