2010

The perception and production of Spanish pure vowels by native English speakers

Lauren Erickson
University of Northern Iowa

THE PERCEPTION AND PRODUCTION OF SPANISH PURE VOWELS BY NATIVE ENGLISH SPEAKERS

A Thesis

Submitted

in Partial Fulfillment

of the Requirements for the Designation

University Honors with Distinction

Lauren Erickson

University of Northern Iowa

May 2010

This Study by: Lauren Erickson

Entitled: The Perception and Production of Spanish Pure Vowels by Native English Speakers

has been approved as meeting the thesis or project requirement for the Designation

University Honors with Distinction

_____

Date, Dr. Juan Carlos Castillo, Department of Modern Languages

_____

Date, Jessica Moon, Director, University Honors Program

Abstract[1]

Quantitatively measuring a person's fluency in a second language (L2) is difficult, but analysis of formant movements during vowel production may provide a more accurate way of measuring the accuracy of acquiring a native-like production of the L2. This study examined the accuracy with which two groups of native English speakers perceived and produced the Spanish vowel /e/ and diphthong /ei/, and compared their results with the results from a group of native Spanish speakers. For the perception portion of the study, participants were asked to correctly identify matching sounds, and the number and percentage of correct responses were compared across groups. For the production portion of the study, participants were recorded while reading a list of Spanish words. The results were analyzed using spectrographic analysis. While the results obtained in this study were statistically significant; due to several recommended changes in the study itself, as well as the delivery of the study, it is recommended that the study be repeated with the recommended changes in order to ensure that these results were not obtained purely by chance.

1. Literature Review

1.1 Introduction

Learning a second language is difficult in itself, but it may be even more difficult to measure a person's progress towards fluency due to the subjective nature of evaluating fluency. We can

[1]Many thanks to Professor Juan Carlos Castillo of the Department of Modern Languages for all of your hard work, guidance, and patience with this project. Without your help it would have been impossible.
Thanks to Todd Bohnenkamp of the Department of Communication Sciences and Disorders for performing the data analysis, as well as his moral support and instruction in using the spectrograph.
Thanks to Xavier Escandell of the Department of Sociology, Anthropology, and Criminology for his guidance in the statistical analysis of the results.
Thanks to Jessica Moon, Director of the University of Northern Iowa Honors Program, for her guidance and friendship throughout this project, as well my time at the University.

measure fluency by the size of a person's vocabulary inventory, or perceived strength of foreign accent; however, these methods are highly subjective and extremely difficult, if not impossible, to measure quantitatively. While it may be difficult to measure these aspects of a language, it is possible to use spectrographic analysis to measure certain qualities of vocal sounds. Each sound has certain values and measurements that are specific to it, and measuring the accuracy with which a non-native speaker pronounces a sound from their second language (L2) may be a more precise way to measure their accuracy of acquiring a native-like pronunciation of the L2.

The objective of this study was to examine the accuracy with which English speaking students percieve and pronounce certain Spanish vowels. This was accomplished by measuring the F1 and F2 values of these Spanish vowels and comparing these results to the values obtained from native Spanish speakers. Measuring and comparing the F1 and F2 values will hopefully provide us with quantitative values that can be compared from person to person as well as more information regarding the acquisition of a second language.

1.2 Describing Vowels

A common characteristic of all languages is the presence of vowels, yet all vowels, or vowel systems, are not the same. Many people are familiar with written vowels such as a, e, i, o, and u; however, they do not know how to describe vowels using phonetic terms. Consonants are described by the manner in which they are articulated in the vocal cavity, but according to Hammond (2001:31), "all vowels are articulated (or produced) by a relatively lesser obstruction of the airstream in the oral cavity than in the articulation of any other speech sound." Since airflow is relatively unobstructed during vowel production, vowels in English and Spanish are described according to three different characteristics: the position of the tongue on a front-back axis, the relative height of the tongue in the mouth, and the amount of lip rounding while producing the vowel sound (Ladefoged 1975).

Sometimes a fourth characteristic, the relative tension of the muscles used to produce the vowels, is also used to describe vowels in English.[2] In this instance we will be looking at the vowel systems of English and Spanish. These two vowel systems differ in many qualities, one of the most obvious being the number of vowel sounds in each language. English contains thirteen vowel sounds (see Figure 1), while Spanish contains only five (see Figure 2) (Bradlow 1994)[3]. Each of the previously mentioned characteristics will be discussed in turn with regards to both English and Spanish. Using Figures 1 and 2 may help provide a visual reference to the positions of the vowels as the characteristics are being discussed. They should be pictured as if they were a map of the oral cavity, with the left side of the figures being where the lips and the teeth are located, and the right sides being where the back of the tongue and the throat are located.

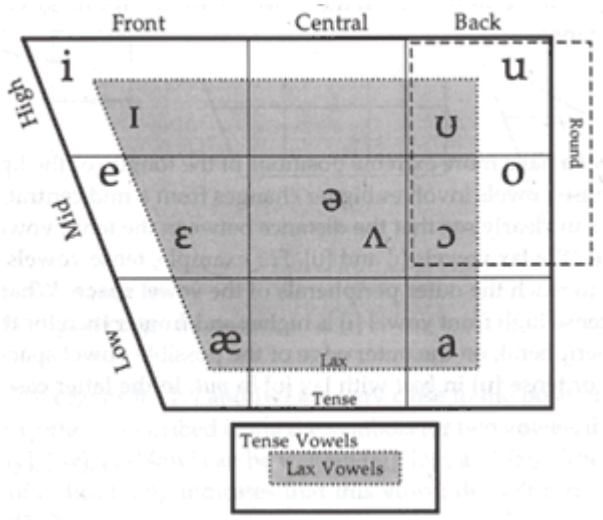

Fig. 1 English Vowel Chart
http://www.ic.arizona.edu/~lsp/IPA/SSAE.html Chart

Figure 1 shows that the oral cavity can be broken into three sections of varying heights: high, middle, and low. These sections allow us to describe the relative height of the tongue when pronouncing vowels. When pronouncing the high vowels, the tongue is positioned relatively close to the hard palate. Moving down towards

[2] In some languages, additional features such as voicing or nasalization are also used to describe vowels. French, for example, has nasalized vowels.

[3] The number of vowels in English is subject to debate. Ladefoged (1975) and Bradlow (1994) say that there are thirteen English vowels; whereas Whitley (2001) states that there are eleven English vowels. Figure 1 only shows twelve English vowels on the chart. The key issue is whether or not certain diphthong sounds are categorized as vowels. For example, the diphthongs /ai/, /oi/, and /aw/ are not included in Figure 1, but are still considered by many linguists to be English vowels.

the intermediate position, or mid level vowels, the tongue relaxes and moves farther away from the hard palate, and a speaker might also notice a slight lowering of the jaw. This lowering of the tongue and relaxation of the jaw is even more pronounced and noticeable when a person moves to the low position. These changes may be felt by saying the words “heed,” “head,” and “had” in sequence (Hammond 2001).

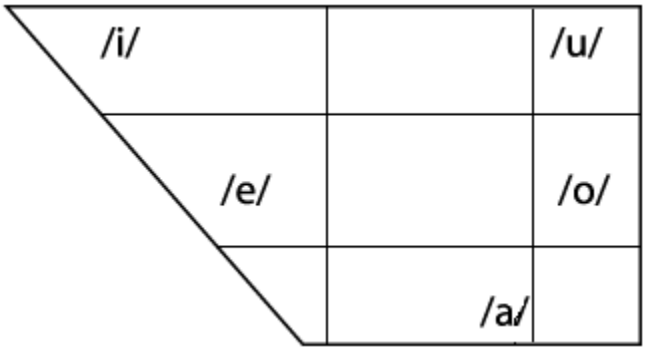

Fig. 2 Spanish Vowel Chart
http://www.indiana.edu/~hlw/PhonUnits/vowels.html

Figure 1 also shows the oral cavity broken into three sections moving from the left side of the figure to the right. These sections are commonly called front, central, and back. Breaking down the oral cavity in this manner allows us to describe the position of the tongue when producing vowels on a front to back plane. The tongue is moved relatively forward and close to the teeth when in the front position, and as it moves through the central and back sections, the tongue retracts until it is positioned closer to the throat. These changes can be felt by saying the words “heed,” “had,” and “hood” in sequence (Ladefoged 1975).These two characteristics combined allow us to map the position of a vowel on a two dimensional plane, which can be accomplished by looking at Figures 1 and 2. For example, in Figure 2, the vowel /i/ would be classified as a high, front vowel, and the vowel /a/ would be classified as a low, central vowel.

The movement of the lips adds another level of complexity to the description of vowels. If a person says the words “see” and “too” that person may feel that the lips are more spread when saying the word “see”, and how they are more rounded when saying the word “too”. In both English and Spanish, all vowels in the front and central sections of the oral cavity are automatically articulated

with unrounded lips, while vowels located in the back section of the oral cavity are automatically articulated with rounded lips (Hammond 2001).

Both the English and Spanish vowel systems contain vowels that are articulated high in the oral cavity, and low in the oral cavity. Both systems also include vowels that are articulated towards the front oral cavity and relatively farther back. Both systems follow similar rules regarding rounding of the lips when articulating vowels; yet, perhaps the most obvious difference between the two systems may be the presence of lax vowels in English, and their absence in Spanish. "Tense" and "lax" are two terms that are used to describe the relative tension of the tongue muscles while producing a vowel (Stockwell & Bowen, 1975). For example, the English word "bait" is pronounced with more tension of the tongue than the English word "bet" (Whitley 2001). Tense/lax vowel pairs such as /i/ and /I/ are typically found when more than one vowel occupy the same section of the oral cavity, which is much more common with the larger vowel inventory, like that of English. A vowel system that has fewer vowels that are more spread out within the vocal cavity would not require this additional characteristic (Hammond 2001). For this reason, the tense/lax contrast exists in English but not in Spanish (Ladefoged 1975; Whitley 2001).

When comparing the English tense vowels /i, e, o,u/ with their Spanish vowel counterparts, one notices that in most cases, the Spanish vowels are comparatively more tense than the corresponding English vowel. This may make it easier for English speakers to distinguish the sounds of Spanish vowels; however, it may also cause miscommunication issues when a native English speaker attempts to speak Spanish. In English, vowels that fall in unstressed syllables tend to be reduced to a more lax vowel, the most notable of which is the schwa or /ə/. This is the most lax of all American English vowels, and a very common error for speakers of English is to reduce the normally tense vowels of Spanish to their lax English counterparts, or even to the very lax /ə/. This is one of the strongest

indicatory of a foreign accent when speaking Spanish, since this sound simply does not exist in Spanish (Hammond, 2001). This may lead to miscommunication issues, which in certain cases may keep a native English speaker from being understood when attempting to speak Spanish.

1.3 Vowels and Diphthongs

These four characteristics (height, position on a front-back axis, lip rounding and tense/lax) are vitally important when discussing the characteristics of vowels in a language, and they do provide us with some basic information regarding the differences between the vowels of Spanish and English. However, we can still look more specifically at these two systems to see how vowels and combinations of vowels, or diphthongs, differ between the two. A diphthong is a sound that is produced when the position of the lips and tongue change throughout the articulation of the sound (Ladefoged 1975). The five Spanish vowels have several characteristics in common: Spanish vowels are always tense and they are never diphthongized, which causes the duration of Spanish vowels vary much less than English vowels (Hammond 2001). On the other hand, English vowels may be tense or lax; and tense vowels are diphthongized, or, the place of articulation of the vowel varies throughout the duration of the vowel (Whitley 2002). This causes the duration of vowels to show a large amount of variance in English.

The Spanish vowels are commonly referred to as pure vowels since all of the Spanish vowels, /a e i o u/, are monophthongs, meaning that the position of the tongue and lips does not change during the articulation of the vowel (Ladefoged 1975). The English equivalent vowels /i e o u/ are diphthongs when located in stressed syllables (Whitley 2001). This is generally represented by adding the /j/ glide to the high, front vowels, and the /w/ glide to the high, back vowels to produce the English sounds /I ei ou u/. For example, the English vowel /e/ generally begins in a similar position as the Spanish /e/. The articulation then tends to slide upward towards the point of articulation for the English vowel /i/,

and the resulting sound combination of the diphthong /ei/ is the common English pronunciation for the vowel /e/ (Ladefoged 1975; Whitley 2001; Hammond 2001). A very common mistake for a native English speaker is to pronounce this Spanish vowel, as well as the other mid and high vowels, with a diphthong. However, diphthongized vowels simply do not exist in Spanish and, to a native Spanish speaker, are another common indicator of a foreign accent (Hammond 2001; Whitley 2001). For example, in the Spanish word *vente* or "come here" the /e/ is pronounced with no diphthongization at all; however, it is common for English speakers to substitute the English diphthongized /e/ in place of the Spanish /e/ which may cause a native Spanish speaker to confuse the word with *veinte* or "twenty."

Diphthongs do exist in Spanish, but they are perceived as completely contrasting sounds to vowels, unlike English where no distinction between the two exists. Therefore, to a native Spanish speaker, the words *reino* "kingdom" and *reno* "reindeer" contain two completely different sounds, /e/ and /ei/, which are never interchangeable without changing the meaning of the word[4]. Therefore, if an English speaker substitutes the diphthongized English /e/ in place of the Spanish /e/, it is quite possible that the pronunciation of the speaker will be misinterpreted as the Spanish diphthong /ei/ (Morrison 2003; Whitley 2001), like in the words *vente* "come here" and *veinte* "twenty". It is likely that the duration of a diphthongized vowel will be longer than that of a monophthong vowel simply because of the additional movements taking place during production; however, this fact has been debated (Ladefoged 1975; Stockwell & Bowen 1975).

[4] It would be interesting to examine the contrast between /o/ and /ou/ to see if a similar situation exists; however, modern Spanish has evolved from Latin in such a way that the /ou/ sound is highly uncommon. Most linguists assume that as the Latin word for gold (*auro*) passed through an intermediate phase (*ouro*) as it evolved into the modern Spanish word (*oro*). This also occurred in the Latin word *audire* as it evolved to *oudire* and then to the modern Spanish word *oir* (to hear). The intermediate phase of these words, as well as several others, all contained the /ou/ diphthong which has since evolved to the vowel /o/ in modern Spanish.

Each characteristic of a vowel contributes in determining that vowel's point of articulation. For vowels, the point of articulation is described as the physical position of the lips and the highest position of the tongues during the pronunciation of a vowel (Ladefoged 1975). English has thirteen vowels and many corresponding points of articulation. Each point covers a specific area in the vocal cavity, and any articulation that falls within this area will most likely be interpreted as the vowel sound corresponding to that area of articulation (Bradlow 1994; Flege, Schirru, and MacKay 2003). Likewise, the five vowel points of articulation in Spanish have a corresponding area of articulation, and any articulation that falls within a given area will be interpreted as the appropriate Spanish vowel.

A common cause of confusion for people trying to learn a second language is the inability to recognize the different articulation boundaries between vowels in the second language (Flege 1995; Morrison 2003). This may mean that English speakers will pronounce Spanish vowels according to the points of articulation of English vowels, which may confuse how a Spanish speaker hears the vowel when it is said by an English speaker (Flege 1995; Stockwell & Bowen, 1975; Whitley 2001). The same confusion may occur when a native Spanish speaker attempts to pronounce an English vowel.

1.4 Spectrograph Analysis

One way of examining a sound is to begin by taking a recording of a sound. This is the only way to produce a permanent record of a sound that can later be analyzed in a variety of ways and can give us more information regarding the sound. One type on analysis that may be performed is spectrographic analysis. A spectrograph does not measure the pitch or intensity (loudness or softness) of a sound, but it allows us to measure the quality of a sound. According to Ladefoged (1975), a vowel sound contains many different pitches resonating simultaneously within it. These pitches are called the overtones, and each vowel sound has its own unique combination of overtones that provide the

vowel with its individual quality. In other words, the quality of a vowel sound is dependent on its overtones.

Each individual pitch provides us with information regarding certain characteristics; however, it is typically difficult to separate the overtones of a vowel out into their individual pitches. This can be achieved though spectrographic analysis. Each characteristic is represented on a spectrogram as vowel formants. There are three main characteristic formants, and they are numbered from one to three: formant 1 (F1) being the lowest, and formant 3 (F3) being the highest.

The formants are recorded by the way that air moves through the vocal tract. The vocal cords are continuously opening and closing, which sends small bursts of air through the vocal tract while the vocal cords are vibrating. These bursts of air are specific to the shape of the vocal tract at that moment in time; therefore since each vowel has a characteristic point of articulation, each vowel will also have a characteristic set of vibrations and formants. The formants are shown as dark horizontal bars going across the spectrograph, and the intensity of each formant is shown by the darkness of its color. The horizontal axis is typically a timescale, and the vertical axis measures the frequency of the vibrations. Each of the formants correlates to one of the previously mentioned vowel characteristics. F1 is inversely related to the height of the vowel, meaning that as a speaker pronounces a high vowel like /i/ and moves toward a lower vowel like /a/, the F1 value will rise, or show a positive change in the F1 value. Likewise, as a speaker moves from a lower vowel toward a higher value, the F1 value will lower, or show a negative change. F2 is somewhat related to the relative front-back position of a vowel in the oral cavity. As a speaker moves from pronouncing a front vowel, such as /e/, to pronouncing a back vowel such as /o/, the F2 value decreases and shows a negative change; and as a speaker moves from a back vowel towards a front vowel, the F2 value increases and shows a positive change. This correlation is not as strong as the correlation between F1 values and the point of

articulation of a vowel in the vertical plane, but it still provides us with a way to measure the relative position of a vowel in the oral cavity.

Figures 3 and 4 show examples of spectrographs and some of the changes previously described in the introduction. Figure 3 shows the Spanish word *reino* or “kingdom”. You can see in the spectrograph that as the speaker pronounces the diphthong /ei/, the F1 drops towards the bottom of the image and the F2 raises toward the top. Accordingly, you can see in Figure 4 (the Spanish word *reno* or “reindeer”) that both the F1 and F2 values remain relatively unchanged throughout the

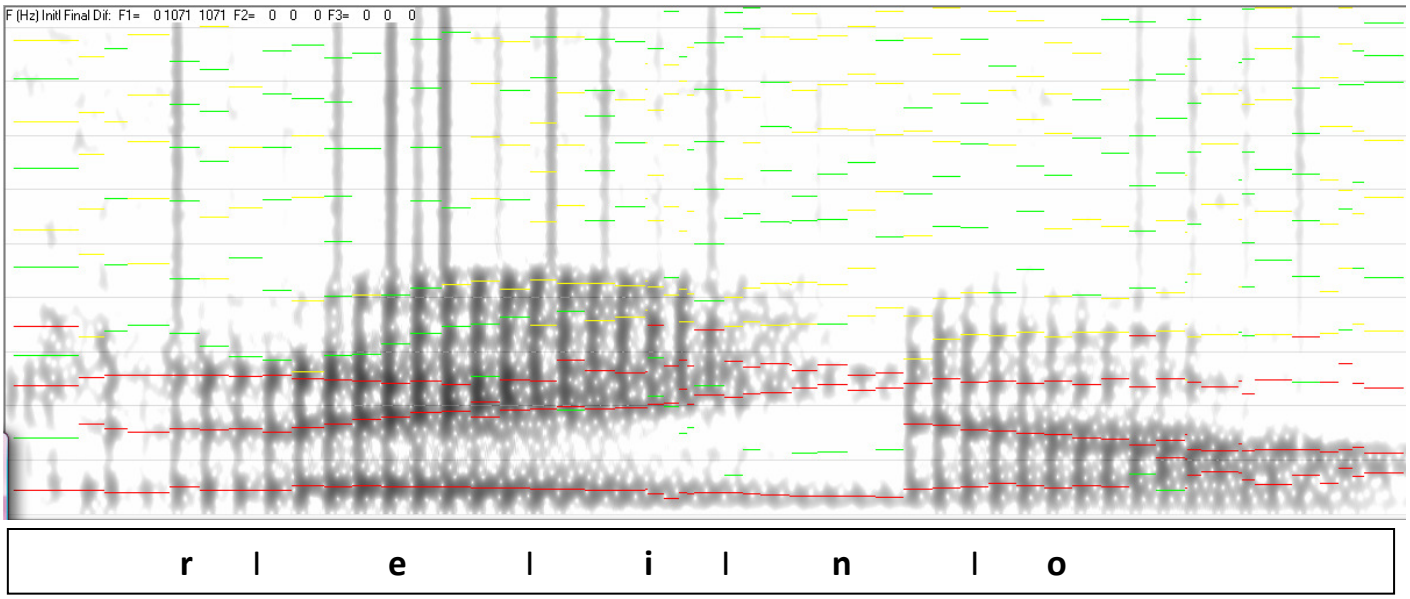

Fig. 3 “reino”

pronunciation of the /e/ vowel.

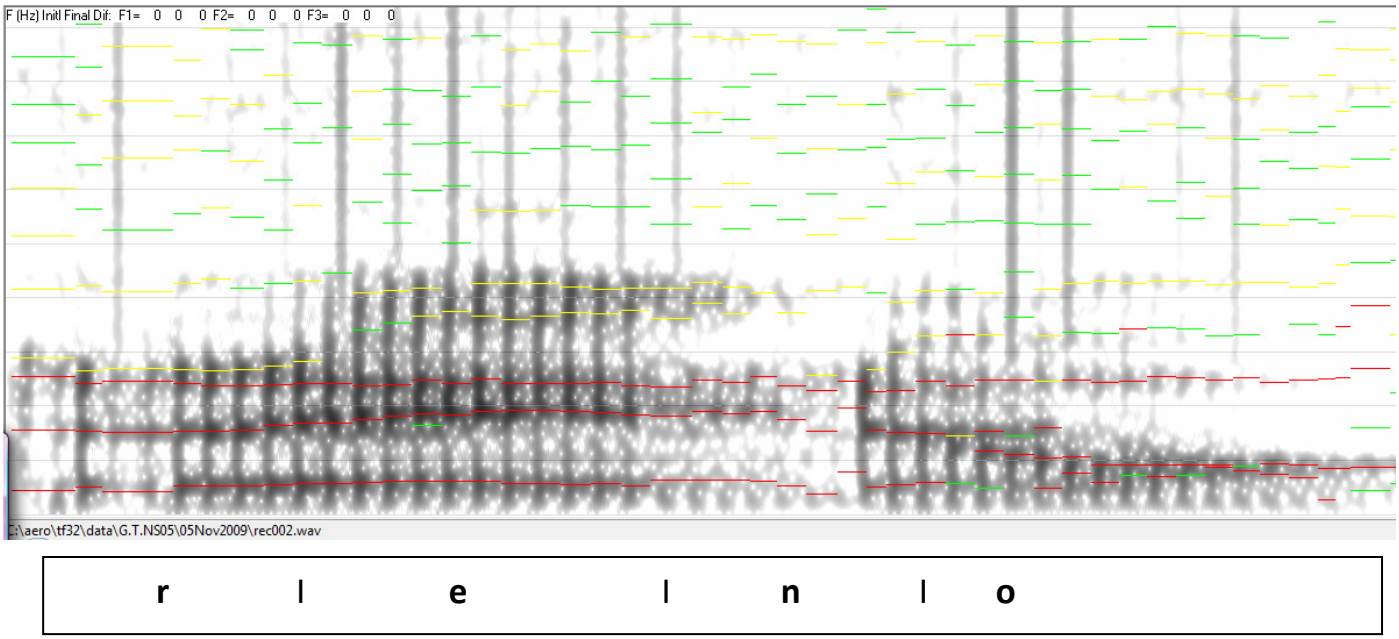

Fig. 4 "Reno"

It is also noted that the amount of roundedness in the lips can also affect the frequencies of the formants, generally causing formants to decrease as the lips become more rounded. This affect is strongest in the third formant (F3) and will not be discussed in this study.

1.5 Previous Studies

The previous discussion of vowels and their descriptive characteristics, combined with spectrographic analysis provide us with the background knowledge to begin to discuss the issues that were examined in this study. Spectrographic analysis provides us with a way of measuring the point where a sound is being articulated in the oral cavity as well as the movements, or lack of movements that occur during the duration of the sound. This was chosen as a way to quantitatively measure the accuracy with which native English speakers perceive and pronounce the Spanish vowel /e/ and the contrasting diphthong /ei/. We have previously mentioned that in Spanish, vowels and diphthongs are not interchangeable; they are two entirely different sounds and are not interchangeable without

changing the meaning of a word. However in English, both mid and high vowels are diphthongized, and some very common mistakes for native English speakers are to diphthongize the Spanish /e/, as if they were pronouncing an English /e/, or to not pronounce the Spanish /ei/ with a strong enough diphthong.

In the same line of thinking, most linguists do not believe that bilingual speakers are able to separate out the phonetic systems of their first language (L1) and L2 (Flege, Schirru & MacKay, 2003). It is well documented that adults have difficulty discriminating and identifying foreign consonant contrasts, and that non-native listeners are less accurate than native speakers in identifying sounds in the native language (Polka, 1994). In the early stages of learning an L2, L2 learners may not be able to accurately produce an L2 sound, and may then substitute similar but slightly different sounds from their L1 in place of the L2 sound. This is more likely to occur when the L2 sound is perceived as being very similar to an L1 sound (Morrison, 2003). Some linguists believe that increased learning and exposure to an L2 will also increases a person's awareness of the phonetic difference between and L1 and L2. Assuming that L2 speakers' perception of an L2 and the accuracy with which they produce L2 sounds are connected, this means that over time as they become more perceptually aware of phonetic differences, they may be able to establish new phonetic categories and more accurately produce these sounds (Flege 1991). The sounds may be accented at first, but as learners gain experience in an L2, their production of L2 sounds may come to more closely resemble the production of native speakers even though exposure to an L2 is not always a direct link to proficiency in speaking or understanding (Fox, Flege & Munro, 1992; Morrison, 2003).

Catherine Best (1994) has proposed a model in which she outlines a method by which learners of an L2 may familiarize themselves with the sounds in an L2, and thereby more accurately perceive the differences between L2 sounds and L1 sounds. Best states that adults are likely to assimilate L2

sounds into the categories of their L1 perceptual space whenever possible. She further states that the ability to distinguish the L2 sounds from one another is excellent when the separate L2 sounds have been assimilated into separate L1 categories and more difficult when the separate L2 sounds are assimilated into the same L1 category. She also states that it is possible for two L2 sounds to be assimilated into the same L1 category, yet differ in their accuracy of fit to that category (Polka, 1994). For example, in the case of English speakers learning Spanish, it may be difficult for English speakers to perceive a difference between the Spanish vowel /e/ and the diphthong /ei/. It is possible that an English speaker would identify these two sounds with the English /e/ which may lead to difficulty distinguishing between the two. According to James Flege (1991), errors in perception may be inferred by how learners pronounce the L2 sounds. Accordingly, he has proposed his own model, the Speech Learning Model (SLM) to account for limits on the ability to produce L2 consonants and vowels in a native like manner.

To begin, Flege (1995: 239) states that "the phonetic systems used in the perception and production of vowels remains adaptive over the life span." He hypothesizes that L2 learners are more likely to establish a new production category for L2 sounds if they are very different from L1 sounds, and that when this does not happen, it limits the accuracy of production of the new sound. He proposes that L2 learners begin by producing L2 words with sounds from their L1, but as they gain more experience in the L2, they may be better able to approximate the differences between the two languages. Flege states that L2 sounds may be assimilated into the same category as an L1 sound through the process of *category assimilation*. He proposes that a new L2 category will not form if the L2 sound continues to be identified as an L1 sound; the production of the L2 sound will be less native-like and the L2 sound will therefore be produced very similarly to the L1 sound to which the L2 sound has been assimilated. On the other hand, an L2 learner may indeed be able to identify and establish a new category for an L2 sound. In this case the L2 sound will be pronounced with much more native-

like accuracy. Flege also states that since L1 and L2 sounds exist in the same space, and if the L1 and L2 sounds are relatively similar, they may shift away from each other in the phonetic space as a means of preserving the phonetic differences between the two. He calls this *category dissimilation*; and further states that this category dissimilation may in some cases, cause further distortion of the production of an L2 sound.

Linda Polka (1994)performed a study to test the ability of English speaking adults in discriminating between two German vowel contrasts, the tense pair/U/-/Y/and the lax pair /u/-/y/ at the same proficiency level as native German speakers. She found that English speakers correctly identified the tense vowel pair /U/-/Y/ with more accuracy than the lax vowel pair /u/-/y/; however, both were identified correctly at lower rates than native German speakers. She also found that the English speakers perceived the back, high, rounded vowels /u/ and /U/ as more similar to English vowels than their front, high, rounded counterparts /y/ and /Y/. From these results, she concludes that the linguistic experience of the English speakers shapes their ability to discriminate between consonants and vowels in a similar manner, and that this provides positive evidence supporting Best's model of perception since native English speakers were better able to assimilate the more familiar /u/ and /U/ vowels into their perceptual space.

James Flege (1991) also performed a study in which he tested the ability of two groups of native Spanish speakers to identify English vowels. A group of Spanish speakers with little experience in English, and a group of Spanish speakers with a greater amount of experience in English were given the task of identifying English vowels with the Spanish vowel it most resembled. Spanish speakers were also given the option to choose "none" if they felt that the sound they heard did not have a corresponding vowel in Spanish. Flege demonstrated that Spanish speakers with more experience in English selected the response "none" when asked to identify the English vowels /æ/ and /I/, more

often than Spanish speakers with little experience (42% vs. 18%). These two vowels are present in English, but not Spanish which may suggest that some participants were able to identify these vowels as non-existent in Spanish[5].

Flege, Schirru, and MacKay (2003) performed a study in which they examined four groups of Italian subjects and whether or not their productions of the English /e/ showed evidence of category dissimilation from the Italian /e/, which is pronounced as a monophthong, much like the Spanish /e/. Native Italian speakers were divided into four groups based on two factors: their age of arrival to Canada (early in life vs. late in life) and the degree of which they continued to use Italian in their daily life after arrival (high use of Italian vs. low use of Italian). The data showed that all four groups of bilinguals produced the English /e/ with less diphthongization than the control group of English speakers, which demonstrates that the English /e/ had been perceptually assimilated with the Italian /e/. The data further demonstrated that the early arrival, low Italian use group produced the English /e/ with more movement than the late arrival, high Italian use group, as well as the native English speakers. The early arrival, low Italian group produced more "overshoot" values, or values that showed more movements in F1 and F2 than what would be expected from a native English speaker. The study attributes this fact to category dissimilation; that the early arrival, low Italian use group was in fact exaggerating the pronunciation of the English /e/ in order to maintain its phonetic difference from the Italian /e/.

A study performed by Morrison (2003) examined the abilities of native Spanish speakers and native English speakers to identify the five Spanish vowels with their respective L1 vowels. The results showed that native English speakers more often perceived the Spanish /i/ and /e/ by assimilating

[5] Flege only states that these results may suggest that some participants were able to identify the vowels as non-existent in Spanish because the percentages were so low. The data was not significant enough to say that many L2 learners of Spanish are able to identify these vowels as non-existent in Spanish, only that some participants demonstrated this tendancy.

them to the English /i/ and /e/ (respectively). This supports Best's model by showing that L2 learners tend to assimilate the new L2 sounds into their L1 categories. The study also shows that when speaking Spanish, English speakers were more likely to substitute the English /i/ and /e/ in place of their corresponding Spanish vowels. This provides evidence that the perception and production of vowels may be connected to a certain extent, and also provides further evidence in support of Best's model of perception as well as Flege's SLM model.

This brings us to the questions presented in the current study. We aimed to see if native English speakers were able to perceive Spanish vowels with similar accuracy as native Spanish speaker, and if English speakers were able to produce Spanish vowels with similar accuracy as a native Spanish speaker. We decided to further examine whether or not English speakers with more exposure to Spanish were more accurate in their perception and production of Spanish vowels than native English speakers with less exposure to Spanish. This was achieved first by seeing if participants were able to match the /e/ and /ei/ sounds, and then looking at the differences in pronunciation of /e/ and /ei/ across groups of participants. We then looked at the data more in depth to determine whether or not the phonological environment of the /e/ or /ei/ made a difference in the pronunciation. We assumed that both groups of native English speakers would show perception and production results that were not as accurate as native Spanish speakers. We also assumed that native English speakers with more exposure to Spanish would show more native-like perception and production of Spanish vowels than would native English speakers with less exposure to Spanish.

2. Methods

2.1 Participant Demographics

Subjects for this study were recruited by in class visits to Spanish classes at the University of Northern Iowa (UNI) during the Fall 2009 semester. Students were asked to provide contact

information if they were interested in participating, and were later contacted by email in order to make an appointment to participate in the study. Before participating in the study, subjects were asked to complete a short questionnaire in order to assess their level of exposure to the Spanish language, as well as their proficiency in Spanish, and were grouped according to the following criteria:

Native Speaker (NS): Born in a Spanish speaking country, lived there for twelve years or more, currently enrolled at UNI

Upper level native English speakers (UL): Born in a non-Spanish speaking country, speak English as a primary language, currently enrolled at UNI, studying in Spanish, more than three years of college-level language experience.

Lower level native English speakers (LL): Born in a non-Spanish speaking country, speak English as a primary language, currently enrolled at UNI, studying in Spanish, less than two years of college-level language experience.

Native Spanish speakers in the experiment were 4 men, 1 each from Chile, Mexico, Puerto Rico, and Southern Texas, and 3 women, 1 each from Chile, Spain, and Argentina, for a total of seven speakers ranging in age from 19 to 74. A total of 15 students were placed in the UL category, 4 men and 11 women, ranging in age from 19 to 23. A total of 13 students were placed in the LL category, 1 man and 12 women, ranging in age from 18 to 24, for a total of 35 participants in the study.

All of the subjects in the UL groups studied Spanish for at least 1 year in high school, the majority (11 of 15) studied Spanish for all 4 years of high school with an average of 3.53 years

studied. All have at least also traveled to a Spanish speaking country, while 10 of the 15 subjects have studied in a Spanish-speaking country for at least 4 weeks. Four subjects have not studied abroad at all, and 1 has studied in Austria. As for the LL group, all of the subjects except for 1 have studied Spanish for at least 2 years in high school; about half (6 out of 13) studied Spanish all 4 years, with an average of 3.23 years. As for having a native Spanish speaker for a teacher, only 6 out of 13 LL subjects report having a native Spanish speaker as a teacher, compared with all 15 of the UL subjects. Only 6 of the 13 LL subjects have traveled to a Spanish-speaking country, while only 1 LL subject has studied abroad. This demographic information is summarized in Table 1.

Group	Average years of Spanish in High School	% who Studied Spanish for 4 years in High School	Studied Abroad	Traveled to a Spanish speaking country
NS	4	100	100	100
UL	3.53	73	67	100
LL	3.23	46	8	46

Table 1: Demographic Information

2.2 Methods for the Perception Portion of the Study

Participants were asked to complete a matching exercise using Microsoft PowerPoint. A male, native Spanish speaker of Castilian Spanish was recorded saying all five Spanish vowels and all fourteen Spanish diphthongs. This recording was then spliced into individual recordings of each sound. Twenty data sets were assembled, each one composed of a combination of five individual vowel or diphthong sounds. Of these five sounds, two were identical and the other three sounds were selected as distracters. Ten of the assembled data sets were selected as controls in which the two identical sounds were neither /e/ nor /ei/. In addition, five of the data

sets had /e/ as the two identical sounds and five other data sets had /ei/ as the two identical sounds.

The data sets were organized in a random order to keep the participants from indentifying pattern in the delivery, but each participant listened to the same order of data sets. Each data set was delivered with a one second pause between each sound. After hearing each data set for the first time, subjects were given the option of listening to each data set a second time. Subjects were allowed to listen to each data set a maximum of two times. The subjects were asked to identify the two identical sounds from each data set. Each sound was assigned a corresponding number (ie. 1, 2, etc.) and subjects identified which two sounds they believed to be the same by circling the two corresponding numbers in each data set on a separate answer sheet.

2.3 Methods for the Production Portion of the Study

Participants were recorded reading a list of Spanish words. The list consisted of 110 words. It was originally planned that 36 words would be used as key words in the study; however this list was later narrowed down to 14. The remaining 96 words were therefore used as control words. Seven of the key words contained the /ei/ diphthong while 7 others contained the /e/ vowel sound.

Prior to their scheduled appointment time, subjects were emailed a vocabulary list of the words used in the study in order to provide each speaker with exposure to each word. This list contained all one hundred ten Spanish words and their corresponding English translations.

Each word was also used in an example sentence, and the English equivalent sentence was also provided.

Each speaker was recorded reading this list of words using TF32 time-frequency analysis software program. The data was then analyzed using the same software. The amount of change in the F1 and F2 values were examined for the /e/ or /ei/ vowel in each key word. This was accomplished by recording the starting value, final value, and change for both F1 and F2 from each speaker.

3. Perception Findings and Discussion

3.1 Perception Results

The data sheets for the perception portion of the study were collected and corrected, and both the control results and the key results were recorded in a Microsoft Excel spreadsheet (see Appendix D). An "X" marks a correct match, and if an incorrect answer was recorded, the two vowels or diphthongs that were incorrectly chosen were recorded in the answer space.

Following the hypothesis proposed in this study, it was expected that NS participants would have a higher percentage of correct answers than both UL and LL participants. We also assumed that UL participants would have a higher percentage of correct answers than LL participants, although still a lower percentage than the NS participants. A basic analysis of the perception data was done by first separating the data sets into a key results category and a control results category. The results of each individual were totaled and these totals were used to calculate the average number correct for each group of participants. The results are summarized in Table 2, and explained in detail below.

Group	Avg. number of correctly matched controls	Avg. number of correctly matched key sets	Avg. number of correctly matched /e/-/e/ pairs	Avg. number of correctly matched /ei/-/ei/ pairs
NS	8.3	7.7	27/35 (77.1%)	23/35 (65.7%)
UL	9.4	8.7	65/75 (86.7%)	63/75 (82.7%)
LL	9.3	8.8	52/65 (80.0%)	54/65 (83.1%)

Table 2: Perception Results

The NS group averaged 8.3 out of 10 correctly answered control data sets, and 7.7 out of 10 correctly answered key sets. Of the key sets, the NS speakers correctly paired 27 out of 35 /e/-/e/ pairs (77.1% correct) for an average of 3.9 correct matches per each participant. NS speakers correctly matched 23 out of 35 /ei/-/ei/ pairs (65.7% correct) for an average of 3.3 correct matches per each participant.

The UL group averaged 9.4 out of 10 correctly answered control data sets, and 8.7 out of 10 correctly answered key sets. Of the key sets, the UL speakers correctly paired 65 out of 75 /e/-/e/ pairs (86.7% correct) for an average of 4.3 correct matches per each participant. UL speakers correctly matched 63 out of 75 /ei/-/ei/ pairs (82.7% correct) for an average of 4.2 correct matches per each participant.

The LL group averaged 9.3 out of 10 correctly answered control data sets, and 8.8 out of 10 correctly answered key sets. Of the key sets, the LL speakers correctly paired 52 out of 65 /e/-/e/ pairs (80.0% correct) for an average of 4.0 correct matches per each participant. LL speakers correctly matched 54 out of 65 /ei/-/ei/ pairs (83.1% correct) for an average of 4.2 correct matches per each participant.

3.2 Discussion of Perception Results

It was expected that the NS group would have the highest percentage of correct answers, followed by the UL group and then by the LL group. However, the results obtained from this portion of the study were not as anticipated. Overall, the UL group had the highest percentage of total correct pairs (84.7%), followed by the LL group (81.5%) and then the NS group (71.4%). The NS and the UL group correctly identified more /e/-/e/ pairings than /ei/-/ei/ pairings, while the LL group correctly identified more /ei/-/ei/ pairings than /e/-/e/ pairings. It is possible that the NS group had the lowest percentage of correct pairs due to the fact that the NS group had the smallest number of participants, therefore any errors would be more greatly reflected in the final results. There may also have been an issue as to whether or not all of the participants fully understood the task at hand. There may have been some confusion as to exactly what they were asked to identify or they may have been confused in regards to the manner in which they were supposed to mark their answers. All of these factors may have influenced the results, but it is difficult to say whether or not they are the only reason for the unexpected results.

The data collected in the perception portion of this study does not support the perception model proposed by Catherine Best. Our results show that both groups of non-native Spanish speakers were more accurately able to identify the /e/-/e/ and /ei/-/ei/ pairs than native Spanish speakers, and that the LL group was more accurate than the UL group.

3.3 Recommendations for Future Research

Participants trained for the perception task by only one example slide; therefore it is quite possible that the subject's poor performance may be due to misunderstanding the directions for the task at hand. For example, the directions presented at the beginning of the

perception portion of the study may have been unclear, and therefore misunderstood or misinterpreted by the participants which may have led to a poor performance for that individual. It is also imperative that each subject understand not only the directions, but also the purpose that they serve in the study and why their participation is important. This may help to motivate the participants to give the maximum effort and attention to the tasks at hand.

4. Production Findings and Discussion According to Group

4.1 Analysis of Production Results According to Group

Readings for the initial value, final value, and the amount of change in F1 and F2 for either /e/ or /ei/ sound of each key word were entered into a Microsoft Excel spreadsheet. In some cases, values were eliminated due to mispronunciation of the word or due to poor quality of the recording and the inability to read the spectrogram. The number of deleted values is shown in Table 3. Using the remaining values, the mean and standard deviation for each initial value, final value and change were calculated for both F1 and F2.

	/ei/	**/e/**
NS	1/35	1/35
UL	18/105	7/105
LL	20/91	13/91

Table 3: Number of deleted data points

The actual data that was examined was the amount of change for both F1 and F2. To begin the data was divided into two categories: words containing /e/ and words containing the

/ei/ diphthong. Two separate ANOVAs were conducted using SPSS to determine if there was a significant difference in the amount of change of F1 for each group, and a significant difference in the amount of change of F2 for each group. Results show that the group had a significant effect on the amount of change in both F1 and F2 [F(4,20)=5.012, p=.002]. The results for F1 are shown graphically in Figure 5 and the results for F2 are shown in Figure 6.

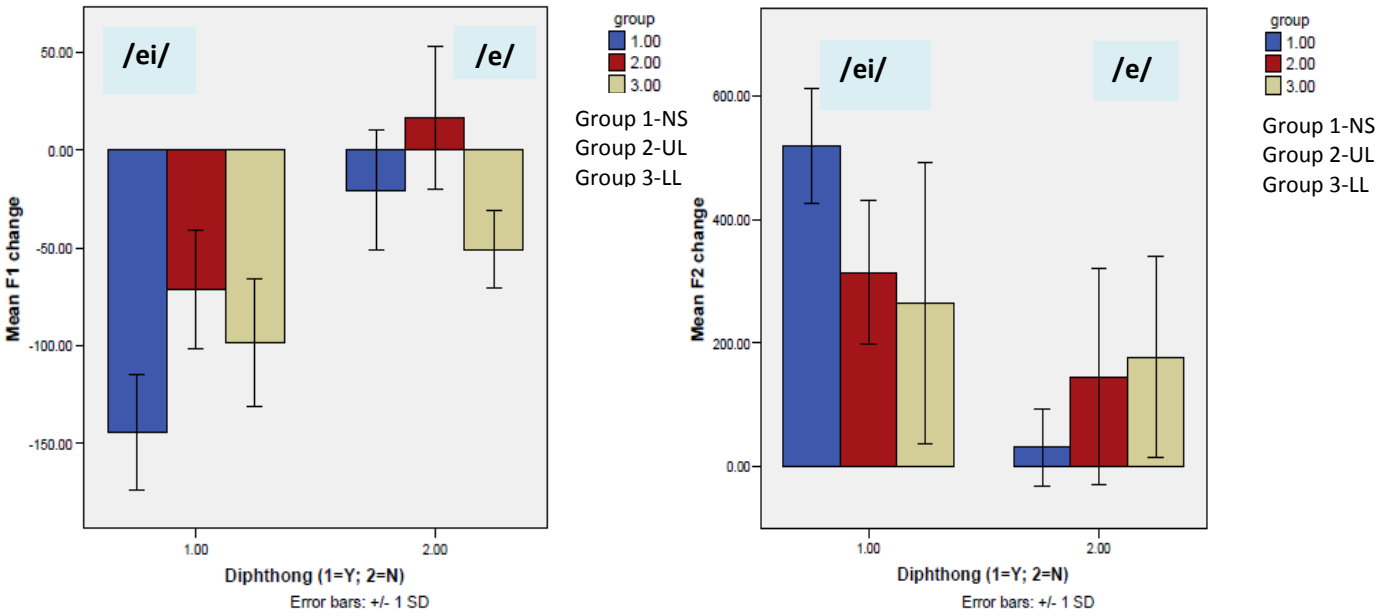

Fig 5: F1 results-group

Fig 6: F2 results-group

For words with /ei/, the F1 values show that NS speakers show a greater negative change, or lowering of the formant, than LL speakers, and that LL speakers show a greater negative change than UL speakers, which does not support the assumed hypothesis. The F2 values for words containing /ei/ do show the expected pattern, where NS exhibits more positive change than UL speaker, and UL speakers show more positive change than LL speakers. The difference between the amount of change for the NS group and the two groups of non-native speakers is much greater (about 200 cps) than the difference in the amount of change between the UL group and the LL group (about 50 cps). This does little to support the

assumption that as non-native speakers gain exposure to an L2, the production becomes significantly more native-like.

The results for F1 and F2 results for words containing /e/ prove to be more interesting. For both F1 and F2 we see that the NS group showed much less change than both the UL and LL groups, which was expected. For F2, the UL group shows slightly less positive change than the LL group; however, the most interesting UL data with respect to the NS group is the F1 data. The LL group exhibits a greater negative change than the NS group, and the UL group also exhibits a greater change than the NS group; however, the direction of the change is *positive*.

4.2 Discussion of Production Results by Group

If a greater amount of exposure to an L2 did cause non-native speakers to have significantly more native-like production, we would have expected to see greater difference in the amount of F2 change for words containing /ei/ between the UL group and the LL group. Alternatively, the small difference may be attributed to the deletion of many more LL data points. We were unsure if the results for the words containing /ei/ would support our assumptions that the UL would show more movement than the LL group, and it is important to note that a greater percentage of words containing /ei/ were deleted for LL speakers due to mispronunciations. This might have affected final results by eliminating the values which showed more variance, leaving only the most accurate data for the LL group and not including the values that may have been less accurate, thereby skewing the data towards a value that is more similar to the native speakers.

The F1 and F2 data for words containing /e/ may provide evidence in support of Flege's SLM theory of category dissimilation when two sounds in a L2 are very similar. It may be possible that the subjects in the UL group were perceptionaly aware of the /e/-/ei/ contrast in Spanish, but these sounds have been further deflected away from one another in the perceptual space. The positive change in F2 (meaning that the position of the tongue moves farther back in the oral cavity during production) during /e/ production may demonstrate that, in an attempt to avoid producing the /ei/ diphthong, the UL subjects actually show movement in the exact opposite direction of the /ei/ diphthong.

5. Production Findings and Discussion According to Phonologic Environment (Category)

5.1 Analysis of Production Results According to Category

Another question examined in this study was whether or not the accuracy with which native English speakers pronounced Spanish vowels varied with the phonologic environment around the vowel. The same production data was used in the analysis by phonologic environment as was used in the analysis by group. Fourteen possible environments were identified, and 7 different environments were examined in this study[6]. The environments were all based on the structure of the syllable which contained the /e/ or /ei/. We examined a combination of both stressed and unstressed syllables, as well as open and closed syllables. An open syllable is one that ends in a vowel, and a closed syllable is one that ends in either a voiced or voiceless consonant. A consonant is voiced if the vocal cords vibrate throughout the

[6] Fourteen categories were originally identified, but they were narrowed down to eight categories due to the sheer volume of data. Of these eight categories, only seven were examined, and the category containing words with /ei/ in an unstressed syllable followed by a voiceless consonant was eliminated. Words containing syllables with these characteristics are mainly found in the vosotros form of Castillian Spanish and are not used in many other dialects of Spanish. Because of this, some of the native Spanish speakers had difficulty pronouncing the words, and several of the native English speakers were unfamiliar with, and mispronounced these words as well.

pronunciation of the sound and voiceless if the vocal cords do not vibrate. Appendix B shows a complete listing of all phonologic environments identified, and Table 4 shows a list of the categories examined. Two separate ANOVAs were conducted using SPSS to determine if the phonologic category had a significant effect in the amount of change in F1 and F2.

Category	Category Description
1	Stressed, open syllable, /ei/
2	Stressed, closed syllable closed by a voiced consonant, /ei/
3	Unstressed, open syllable, /ei/
4	Stressed, open syllable, /e/
5	Unstressed, open syllable, /e/
6	Stressed, closed syllable closed by a voiceless consonant, /e/
7	Stressed, closed syllable closed by a voiced consonant, /e/

Table 4: Phonologic categories examined in the study

Results show that the amount of change in both F1 and F2 is significant when looking at phonologic categories [$F(12,42)=16.885$, $p<.001$]. When these statistics are combined with the in the amount of change for both F1 and F2 [$F(24,42)=2.067$, $p=.019$]. The results for F1 are shown graphically in Figure 7 and the results for F2 are shown in Figure 8.

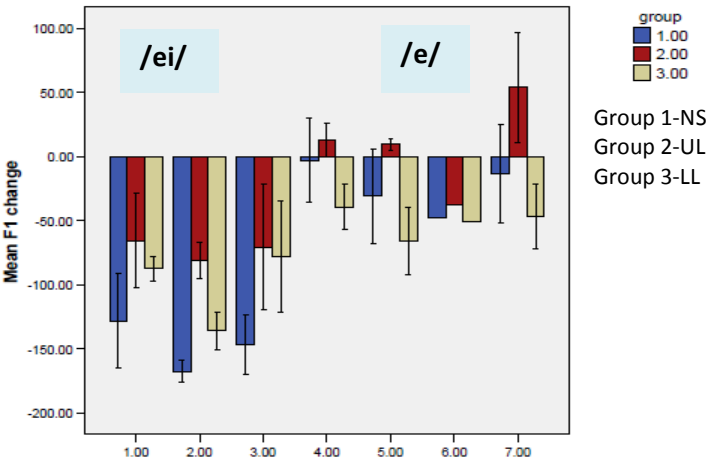

Fig 7: F1 results-category

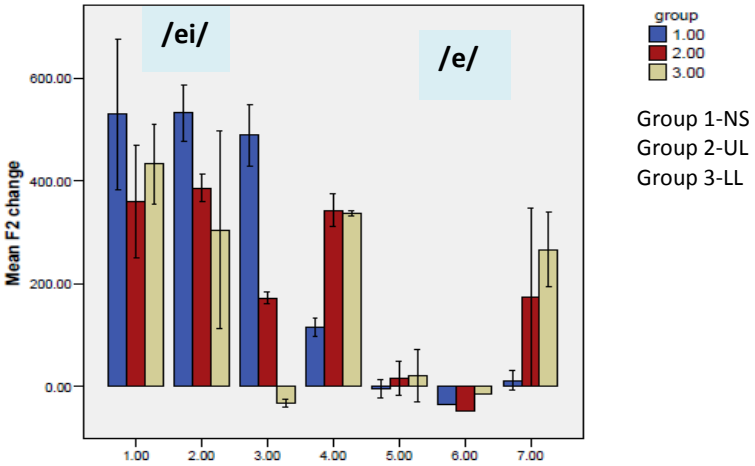

Fig 8: F2 results-category

5.2 Discussion of Production Results by Category

For words containing the /ei/ diphthong, the F1 values for all three categories showed that the NS group produced the greatest amount of negative change and that the LL group produced more negative change than the UL group; however, still less change than the NS group. All three categories of words show the same pattern, which shows that at least for F1, there does not appear to be a phonologic environment in which non-native Spanish speakers are significantly more or less able to accurately produce the /ei/. However for the F2 values for words containing the /ei/ diphthong show a different story. In categories 1, 2 and 3 the NS group produced the greatest amount of movement in the positive direction. In category 1 the UL group produced more positive movement than the LL group, but both groups did exhibit movement in the positive direction. In category 2 the LL group produced more positive movement than the UL group and again, both groups exhibited movement in the positive direction. Category 3 shows that the UL group produced more positive movement than the LL group, and that the LL group produced a slight movement in the negative direction. The

magnitude of the movement is very slight, but it may demonstrate that LL speakers have a more difficult time producing a diphthong in an unstressed open syllable. One more thing to keep in mind is that for the LL group, 9 of the possible 26 vowel readings from category 3 were deleted, so this also may have affected the data.

For words containing the /e/ vowel, the F1 values for all 4 categories show that the NS group shows the least amount of negative change of any group, and the LL group showed the greatest amount of negative change. For categories 4, 5, and 7, the UL group exhibited a positive change in the F1 value, and for category 6, the UL group showed a greater negative change than the NS group but less negative change than the LL group. The positive F1 values for the UL group in categories 4, 5, 7 may show evidence in support of category dissimilation as outlined in Flege's SLM. It may be possible that the UL group is able to perceive a difference between the English /e/ and the Spanish sounds /e/ and /ei/. These sounds all share very similar points of articulation in the oral cavity and it may be that in an attempt to distinguish between them, the UL group has inadvertently dissimilated the categories in an attempt to preserve the differences in the sounds. This may have caused the categories to spread out, which may be why we see the positive F1 change where we assumed that we would see a negative F1 change.

The F2 values for the 4 categories that contain the /e/ vowel were much more unpredictable. For category 4, the NS group showed the least amount of positive change and the LL group showed slightly less positive change than the UL group, although there was hardly any difference between the two groups of non-native speakers. Categories 5 and 7 showed that the NS group produced the least amount of positive change, while the UL group produced

slightly less change than the LL group. It is important to note that the magnitude of change in category 5 is much less than the magnitude of change of category 7. For category 6, the LL group showed the least amount of negative change, and the NS group showed slightly more negative change than the UL group.

Categories 4 and 5 compare the difference between stressed and unstressed /e/ vowels in an open syllable (respectively) and there is a large difference in the results for these data. One possible explanation is that in English, it is restricted against producing a lax vowel in an open syllable if it is the last syllable in a word (Morrison, 2003). The word "le" was used in category 4 which is a prime example of a lax vowel in an open syllable in the last syllable of a word. It is possible that, for this word, the native English speakers produced much more movement due to the influence of their L1. This most likely caused the average change in F2 for category 4 to increase. The /e/ vowel in category 5 appears in a phonological context that is more familiar to native English speakers, and therefore, it may not have been as difficult for them to produce the Spanish /e/ which is similar to the English lax /ɛ/.

Category 6 showed movement in the negative direction for F2; and of a much smaller magnitude whereas category 7 showed a large amount of movement in the positive direction. Both categories compared the difference between stressed, closed /e/ vowels, the only difference was that category 6 was closed by a voiceless consonant and category 7 was closed by a voiced consonant. It is important to note that category 6 only contained the word *este*, whereas category 7 was made up of two words. The smaller amount of data for category 6 may not have been sufficient enough to provide enough data to accurately examine this category.

5.3 Recommendations for Future Research

As far as the production portion of the study, there are several changes in organization of the word list itself that would most likely improve the accuracy and quality of the data obtained. Key word placement within the list of words itself is important. In this study, the word “treinta” was the final word in the list of words that each participant read. In some instances, the participants would either cut the word short, or shorten the duration of the word. This may have inadvertently affected the F1 and F2 values of the /ei/ dipthong in the word. Also, the first four words recorded by each person tended to have a metallic, distorted sound to them. This may be due to the quality of the microphone or the quality of the recording program used in this study. This metallic quality made it difficult to read the spectrogram for the words “tren” and “peinó” which were among the first four words of the list. It may be more beneficial to have the participants read more control words at the beginning and end of the word list to avoid any complications with the recording equipment or with the subjects.

If the subjects were unfamiliar with the words, this may have worsened their performance on the production portion of the study simply due to unfamiliarity of the words. In an attempt to expose each speaker with each word in the study, the vocabulary list was sent out in order to familiarize each participant, especially the UL and LL subjects. Although each of the subjects was provided with a vocabulary list prior to the beginning of their session, there was no guarantee that the subjects studied or reviewed the list prior to their session. It is recommended that subjects in a future study undergo more intense preparation in order to further ensure that each person has exposure to the words. This may include some type of training session to teach proper pronunciation before the actual data collecting session.

Additional training may further eliminate any chance that a poor production performance is due to lack of exposure to certain words.

There are also several ways in which the selection of key words used in the study could be improved. It is shown that the linguistic environment of a vowel may affect the pronunciation of a vowel and make the vowel more difficult to hear clearly. It is recommended that when selecting future key words caution is taken to avoid words where the /e/ vowel is followed by a nasal (/n/, /ñ/). Hammond (2001) states that a vowel is normally nasalized when it is immediately followed by a nasal consonant in the same syllable. This occurs in both English and Spanish; however, the extent of nasalization is highly individualized in both languages. It was seen that some of the participants in this study produced highly nasalized /e/ vowels which, in some instances, caused interference in reading of the F1 values and also in the F2 values. The values were split due to the nasalization of the vowel, which resulted in inaccurate readings and the inability to use the data for that word.

It was often difficult to obtain a reading from words containing /r/ immediately preceding or following the vowel or diphthong in question. The /r/ sound tended to overlap the vowel or diphthong in question, which in some cases made it difficult to obtain readings. This is a phenomenon called r-coloring, which is an additional auditory property of a vowel (Ladefoged, 1975) that was not addressed in this study, nor was its influence anticipated in the results. Upon reviewing the words that were to be used in the final assessment, words in which an /r/ immediately followed a vowel were disregarded due to the additional complications presented by this auditory property.

It is also recommended that care is taken when looking to find data for the /e/ vowel in order to avoid selecting words in which the /e/ is part of another diphthong (/ie/, /ue/). The words muerto, dueño and siesta were to be used in this study, but upon analysis of the data it was seen that the presence of the first vowel in the diphthong greatly affected the F1 and F2 values of the /e/ and most likely resulted in inaccurate readings.

6. Summary

The results from the production portion of this study provide evidence in support of Flege's SLM model in two ways. The results show that in certain phonologic categories non-native Spanish speakers do not produce words containing the /ei/ diphthong with as much diphthongization as native Spanish speakers. Non-native Spanish speakers also tend to produce the /e/ vowel with more diphthongization than native Spanish speakers, suggesting that their L1 exhibits an influence over their L2 production. It is interesting to note that UL speakers demonstrated category dissimilation in three of four categories of words containing the /e/ vowel. While these data show support of the theories mentioned in the introduction to this study, it does not appear to support the idea that increased experience in an L2 will lead to a more native like perception and production of the L2. The results for the production portion of the study show that for production, there is not much difference between the UL group and the LL group; but there is a greater difference in between the NS group and the two groups of non-native speakers. It is also important to note that it is difficult to have confidence in these results due to the vast numbers of changes that would produce more accurate data. The results for the production portion of the study were statistically significant, but it is highly recommended that

the study be repeated with the suggested changes in order to assure that the results obtained were not obtained purely by chance.

Bibliography

Beddor, Patrice S., and Terry L. Gottfried. “Methodological issues in Cross-Language Speech Perception Research with Adults.” *Speech Perception & Linguistic Experience*, edited by Winifred Strange. New Jersey: York Press, 1995. 207-232.

Bradlow, Ann R. “A Comparative Study of English and Spanish Vowels.” *Journal of the Acoustical Society of America* 97 (1994): 1916-1924

Best, Catherine T. “A Direct Realist View of Cross-Language Speech Perception.” *Speech Perception & Linguistic Experience*, edited by Winifred Strange. New Jersey: York Press, 1995. 171-204.

Flege, James E. “The Interlingual Identification of Spanish and English Vowels: Orthographic Evidence.” *The Quarterly Journal of Experimental Psychology* 43 (1991): 3701-3731

Flege, James E. “Second Language Speech Learning Theory, Findings, and Problems.” *Speech Perception & Linguistic Experience*, edited by Winifred Strange. New Jersey: York Press, 1995. 233-277. Print.

Flege, James E., Murray J. Munro, and Ian R. A. MacKay. "Factors Affecting Strength of Perceived Foreign Accent in a Second Language.” *Journal of the Acoustical Society of America* 97 (1995): 3125-3134

Flege, James E., Carlo Schirru, and Ian R. A. MacKay. "Interaction Between the Native and Second Language Phonetic Subsystems.” *Speech Communication* 40 (2003): 467-491

Fox, Robert A., James E. Flege, and Murray J. Munro. “The Perception of English and Spanish Vowels by Native English and Spanish Listeners: A Multidimensional Scaling Analysis.” *Journal of the Acoustical Society of America* 94 (1992): 2540-2551

Hacquard, Valentine, Mary Ann Walter, and Alec Marantz. “The Effects of Inventory on Vowel perception in French and Spanish: An MEG Study.” *Brain and Language* 100 (2007): 295-300

Hammond, Robert M. *The Sounds of Spanish: Analysis and Application*. Somerville: Cascadilla, 2001.

Ladefoged, Peter. *A Course in Phonetics*. San Francisco: Harcourt Brace Jovanovich, Inc., 1975.

Morrison, Geoffrey S. “Perception and Production of Spanish Vowels by English Speakers.” *Procedings of the 15th International Congress of Phonetic Sciences: Barcelona 2003,* edited by M. J. Solé and J. Romero. Adelaide: Causal Productions 2003. 1533-1536.

Morrison, Geoffrey S*. L1 &L2 Production and Perception of English and Spanish Vowels: A Statistical Modeling Approach.* Ph.D. diss., University of Alberta, Alberta, Canada 2006.

Nearey, Terrance M. “Speech Perception as Pattern Recognition.” *Journal of the Acoustical Society of America* 101 (1996): 3241-3254

Polk, Linda. “Linguistic Influences in Adult Perception of Non-Native Vowel Contrasts.” *Journal of the Acoustical Society of America* 97(1995): 1286-1296

Quilis, Antonio. *Fonética Acústica de la Lengua Española*. Madrid, Spain: Editorial Gredos, S. A., 1988.

Schwegler, Armin, and Juergen Kempff. *Fonética y Fonología Españolas*. New Jersey: Wiley, 2007.

Stockwell, Robert P., and J. Donald Bowen. *The Sounds of English and Spanish*. Chicago: The University of Chicago Press, 1965.

Strange, Winifred. *Speech Perception & Linguistic Experience*. Maryland: York Press, 1995.

Whitley, M. Stanley. *Spanish/English Contrasts: A Course in Spanish Linguistics.* Washington D. C.: Georgetown University Press, 2002.

Wilkinson, Kelley. *Similarities and Differences in Perception and Production of Diphthong Sounds Among Native Speakers of Spanish and English*. Undergraduate Honors Thesis, University of Northern Iowa, Iowa, United States. 2004.

APPENDIX A: WORD CATEGORIES

Category	Word	e/ei	Stressed syllable or Unstressed syllable	Syllable ends in consonant or vowel	Followed by voiced consonant, voiceless consonant, or vowel	Contrasting Word
1	Ley	Ei	Stressed	Vowel		Le
1	Reino	Ei	Stressed	Vowel	Voiced	Reno
1	Aceite	Ei	Stressed	Vowel	Voiceless	
2	Veinte	Ei	Stressed	Consonant	Voiced	Vente
2	Treinta	Ei	Stressed	Consonant	Voiced	Tren
3	Peinó	Ei	Unstressed	Vowel		Penó
3	Peinaba	Ei	Unstressed	Vowel		Penaba
4	Dueño	E	Stressed	Vowel	Voiced	
4	Reno	E	Stressed	Vowel	Voiced	Reino
4	Le	E	Stressed	Vowel		Ley
5	Tigre	E	Unstressed	Vowel		
5	Penó	E	Unstressed	Vowel		Peinó
5	Penaba	E	Unstressed	Vowel		Peinaba
5	Terapia	E	Unstressed	Vowel	Voiced	
6	Este	E	Stressed	Consonant	Voiceless	
6	Siesta	E	Stressed	Consonant	Voiceless	
7	Tren	E	Stressed	Consonant	Voiced	Treinta
7	Alergia	E	Stressed	Consonant	Voiced	
7	V**e**nte	E	Stressed	Consonant	Voiced	Veinte
7	Muerto	E	Stressed	Consonant	Voiced	
8	Leyes	E	Unstressed	Vowel	Voiced	
8	Seleccion	E	Unstressed	Consonant	Voiceless	
9	Imagen	E	Unstreessed	Consonant	Voiced	
9	Suéter	E	Unstressed	Vowel	Voiceless	
9	Ejercicio	E	Unstressed	Consonant	Voiced	
10	Lees	E	Stressed	Consonant	Voiceless	
10	Vea	E	Stressed	Vowel	Vowel	
10	Lea	E	Stressed	Vowel	Vowel	
11	Leí	E	Stressed	Vowel	Vowel	
11	Creó	E	Stressed	Vowel	Vowel	
12	Corrieseis	Ei	Unstressed	Consonant	Voiceless	
12	Cantaseis	Ei	Unstressed	Consonant	Voiceless	
13	Bella	Ei	Stressed	Vowel	Voiced	
13	Creyó	Ei	Unstressed	Vowel	Voiced	
13	L**e**yes	Ei	Stressed	Vowel	Voiced	

Words highlighted in yellow were used in the final data analysis.

APPENDIX B: LIST OF WORDS USED IN THE PRODUCTION PORTION OF THE STUDY

You will be recorded as you read this list of words. Read each word and pause for 1-2 seconds before moving onto the next.

Pato
Cien
Peinó
Tren
Acción
Tablera
Acabé
Cuota
Robe
Creyó
Lees
Escribir
Obvio
Buzón
Ley
Corrieseis
Taco
Ciudad
Imagen
Lee
Reí
Idea
Tomé
Cine
Europa
Claro
Deuda
Suave
Esté
Hable
Cuidado
Muerto
Paula
Bombero
Guardar
Armario
Este

Autor
Cantases
Hablé
Tome
Le
Creo
Que
Tomé
Bello
Tigre
Pasto
Diego
Veinte
Acabe
Corrieses
Suéter
Robé
Automático
Guisado
Mega
Peinaba
Inyección
Aire
Fue
Juan
Alergia
Ejercicio
Estoico
Reino
Penó
Velocidad
Cuando
Murciélago
Bella
Reno
Aumentar
Agua

Quiero
Tradición
Piel
Terapia
Vea
Pulmón
Guerra
Puedo
Vente
Cantaseis
Bueno
Auténtica
Guión
Selección
Pingüino
Pierdo
De
Leí
Superficie
Sueño
Meiga
Penaba
Diario
Aceite
Creó
Leyes
Veo
Oscuro
Tema
Siesta
Oigo
Farmacia
Icónico
Caigo
Dueño
Treinta

Participant	M/F	Age	Classification in College	Spanish classes in high school?	Had a native Spanish speaker as a teacher?	Studied Abroad?	Traveled to Spanish speaking country?	Lived in Spanish speaking country?	Hours using Spanish outside of class each week	Other exposure to Spanish
NS01	M	19	Sophomore	4 years	Yes	Yes (USA-2 years)	Yes	Yes	All the time	None
NS02	M	74	Graduate Student	No	Yes	No	Yes	Yes	8 hours	Has taught Spanish classes at the high school and college level
NS03	F	47	Graduate Student	4 years	Yes	Yes (Argentina-5 years)	Yes	Yes	50% of the time	Teaching Spanish
NS04	F	21	Sophomore	4 years	Yes	Yes (USA-2 years)	Yes	Yes	6 hours	Talking with roommate from South America
NS05	M	25	Senior	4 years	Yes	Yes (USA-5 years)	Yes	Yes	8 hours	
NS06	M	24	Senior	4 years	yes	Yes (USA-4 years)	Yes	Yes	80 hours	Speaking with his family
NS07	F	34	Senior	4 years	Yes	Yes (France-1 month)	Yes	Yes	All the time	None
UL01	F	21	Junior	4 years	Yes	Yes (Nicaragua-4 weeks)	Yes	No	0 hours	None
UL02	M	22	Senior	4 years	Yes	Yes (Austria-1 academic year)	Yes	No	5 hours	Listen to the radio and news in Spanish
UL03	F	22	Senior	3 years	Yes	Yes (Spain-1 semester)	Yes	Yes	2 hours	None
UL04	F	21	Senior	3 years	Yes	Yes (Chile- 2x 2 months)	Yes	Yes	5 hours	Uses Skype with exchange students at UNI
UL05	M	20	Junior	4 years	Yes	Yes (Spain-1 semester)	Yes	Yes	2 hours	Working with a fill company translating from Spanish to English and vice versa. Also interviews with latino persons.
UL06	F	20	Sophomore	4 years	Yes	No	Yes	No	5 hours	Read books in Spanish, listen to music in Spanish. Stayed with a host family.
UL07	F	20	Junior	4 years	Yes	no	Yes	No	2-3 hours	Music, journaling. Spanish conversation group and chat online.
UL08	M	22	Senior	4 years	Yes	No	Yes	No	0 hours	None
UL09	M	20	Senior	4 years	Yes	Yes (Spain-6 weeks)	Yes	No	7 hours	Interpret with the Waterloo Community Schools. Done some translating with Dr. Olivares.
UL10	F	19	Sophomore	4 years	Yes	Yes (Italy-9.5 months, Chile-2 months)	Yes	No	Hardly Ever	None
UL11	F	23	Senior	1 year	Yes	Yes (Spain-1 semester)	yes	Yes	1 hour	Cousins from Spain.

UL12	F	21	Senior	4 years	Yes	No	Yes	No	1 hour	Limited volunteer work. Spanish movies and music. Trying to teach mom Spanish.
UL13	F	22	Senior	4 years	Yes	Yes (Spain-1 semester)	Yes	Yes	2-3 hours	Had Spanish exchange students live with family when was 2 years old and again during the summers from ages 14 to 17.
UL14	F	21	Senior	4 years	Yes	Yes (Peru-2 months)	Yes	Yes	0 hours	None
UL15	F	22	Senior	2 Years	Yes	Yes (Spain-1 semester)	Yes	Yes	5-7 hours	Mission trip to Mexico in January 2008 for one week.
LL02	F	19	Sophomore	3 years	Yes	No	No	No	0 hours	Student helper one semester in high school ESL classes.
LL03	F	18	Freshman	4 years	Yes	No	Yes	No	1 hour	Occasionally speaks Spanish with roommate. Instant messages host sister from Costa Rica.
LL04	F	18	Freshman	4 years	No	No	No	No	1-2 hours	None
LL05	F	18	Freshman	4 years	No	No	No	No	1 hour	None
LL06	F	21	Junior	2 Years	Yes	No	No	No	1 hour	None
LL07	M	24	Graduate Student	2 Years	Yes	Yes (Costa Rica-4 months)	Yes	Yes	.5 hours	None
LL08	F	18	Freshman	4 years	No	No	Yes	No	0 hours	Very little
LL09	F	18	Freshman	4 years	No	no	Yes	No	1-2 hours	None
LL10	F	20	Junior	No	No	No	Yes	No	0 hours	Little additional exposure.
LL11	F	22	Senior	3 years	Yes	No	Yes	No	1 hour	Sisters who speak Spanish.
LL12	F	18	Freshman	4 years	Yes	No	No	No	0 hours	None
LL13	F	18	Freshman	5 years	No	No	No	No	0-1 hours	None
LL14	F	21	Junior	3 years	No	No	No	No	less than 1	Listening to some Spanish music.

	e,e	a,a	**ei,ei**	**e,e**	o,o	oi,oi	**ei,ei**	ia,ia	I,i	**e,e**	**ei,ei**	u,u	**ei,ei**	a,a	**e,e**	I,i	**ei,ei**	ai,ai	**e,e**	u,u	TEST	GROUP	CONTROLS	GROUP
NS01	**X**	X	**X**	**X**	X	X	**EI,E**	X	X	**X**	**ei,e**	X	**X**	X	**X**	X	**X**	X	**X**	X	8		10	
NS02	**X**	X	**X**	**X**	X	X	**X**	X	X	**X**	**ei,e**	X	**X**	X	**X**	X	**Ei,ai**	X	**X**	X	8		10	
NS03	**a,e**	X	**X**	**e,ei**	X	X	**X**	X	X	**e,ei**	**ei,e**	X	**X**	X	**X**	ia,ai	**X**	X	**X**	iu,u	6		8	
NS04	**X**	X	**X**	**X**	X	X	**X**	X	X	**X**	**X**	X	**X**	X	**X**	X	**X**	X	**X**	X	10		10	
NS05	**X**	X	**X**	**X**	X	X	**X**	X	X	**X**	**ai,ei**	X	**X**	X	**X**	X	**I,ei**	X	**X**	X	8		10	
NS06	**X**	X	**X**	**X**	X	X	**X**	a,ia	X	**X**	**X**	X	**X**	X	**X**	ia,i	**X**	X	**X**	X	10		8	
NS07	**a,e**		**I,ei**	**a,e**	**uo,o**	**X**	**X**	**X**	**X**	**X**	**ei,e**	X	**X**	**X**	**X**	**X**	**X**	I,ai	**X**	**X**	4	54	2	58
																					avg	7.714286		8.285714
UL01	**X**	X	**X**	**X**	X	X	**X**	X	X	**ei,e**	**ei,e**	X	**X**	a,au	**X**	X	**X**	ai,ia	**X**	X	8		8	
UL02	**X**	X	**X**	**X**	X	X	**X**	io,ia	ei,e	**X**	**X**	X	**X**	X	**ei,e**	X	**X**	X	**X**	X	8		9	
UL03	**X**	X	**X**	**X**	X	X	**I,e**	X	I,e	**X**	**X**	X	**X**	X	**X**	Ia, ie	**X**	X	**X**	X	9		8	
UL04	**X**	X	**X**	**X**	uo,o	X	**X**	X	X	**X**	**X**	X	**X**	X	**X**	X	**X**	X	**X**	X	10		9	
UL05	**X**	X	**X**	**X**	X	X	**X**	X	X	**X**	**ei,e**	X	**X**	X	**X**	X	**X**	X	**X**	X	9		10	
UL06	**e,ei**	X	**X**	**X**	X	X	**X**	X	X	**X**	**X**	X	**X**	X	**X**	I,ai	**X**	X	**X**	X	9		9	
UL07	**ei,e**	X	**X**	**X**	X	X	**X**	X	X	**X**	**X**	X	**X**	X	**ei,e**	X	**X**	X	**X**	X	8		10	
UL08	**X**	X	**X**	**X**	X	X	**X**	X	X	**X**	**X**	X	**X**	X	**X**	X	**X**	X	**X**	X	10		10	
UL09	**X**	X	**X**	**X**	X	X	**X**	X	X	**X**	**ei,e**	X	**X**	X	**X**	X	**X**	X	**X**	X	9		10	
UL10	**e,ei**	X	**e,ei**	**ei,e**	X	X	**X**	X	X	**X**	**ei,e**	X	**X**	X	**ai,a**	ia,i	**X**	X	**X**	X	6		8	
UL11	**X**	X	**X**	**X**	X	X	**X**	X	X	**X**	**X**	X	**X**	X	**X**	X	**X**	X	**X**	X	10		10	
UL12	**X**	X	**X**	**X**	X	X	**ei,e**	X	X	**X**	**X**	X	**X**	X	**X**	X	**X**	X	**X**	X	9		10	
UL13	**X**	X	**X**	**X**	X	X	**X**	X	X	**X**	**ei,e**	X	**X**	X	**X**	X	**X**	X	**X**	X	9		10	
UL14	**a,ei**	X	**e,ei**	**X**	X	X	**X**	X	X	**ei,e**	**ei,e**	X	**X**	X	**X**	X	**X**	X	**X**	X	6		10	
UL15	**X**	X	**X**	**X**	X	X	**X**	X	X	**X**	**X**	X	**X**	X	**X**	X	**X**	X	**X**	X	10	130	10	141
																					avg	8.666667	avg	9.4
LL01	**X**	X	**I,ei**	**X**	X	X	**X**	X	X	**X**	**X**	ou,u	**X**	eu,a	**ei,e**	X	**X**	I,ai	**X**	X	8		7	
LL02	**X**	X	**X**	**X**	X	X	**X**	X	X	**X**	**X**	X	**X**	X	**X**	X	**X**	X	**X**	X	10		10	
LL03	**X**	X	**X**	**ei,e**	X	X	**X**	X	X	**X**	**X**	X	**X**	X	**X**	X	**a,ei**	X	**X**	X	8		10	
LL04	**e,ei**	X	**X**	**X**	X	X	**X**	X	X	**X**	**X**	X	**X**	X	**X**	X	**X**	X	**X**	X	9		10	
LL05	**X**	X	**e,ei**	**X**	X	X	**X**	X	I,ei	**X**	**X**	X	**X**	X	**X**	X	**X**	X	**X**	X	9		9	
LL06	**e,ei**	X	**X**	**X**	uo,o	X	**X**	ei,e	ei,e	**X**	**X**	X	**X**	X	**X**	X	**X**	X	**X**	X	9		7	
LL07	**X**	X	**X**	**a,ai**	X	X	**X**	X	X	**ei,e**	**ei,e**	X	**ei,e**	eu,au	**X**	I,ie	**a,ei**	X	**X**	X	5		8	
LL08	**X**	X	**X**	**X**	X	X	**X**	X	X	**X**	**X**	X	**X**	X	**X**	X	**X**	X	**X**	X	10		10	
LL09	**e,ei**	X	**X**	**X**	X	X	**X**	X	X	**X**	**X**	X	**X**	X	**X**	X	**X**	X	**X**	X	9		10	
LL10	**X**	X	**X**	**X**	X	X	**X**	X	X	**X**	**X**	X	**X**	X	**X**	X	**X**	X	**X**	X	10		10	
LL11	**ei,e**	X	**X**	**X**	X	X	**X**	X	X	**X**	**X**	X	**X**	X	**X**	X	**X**	X	**X**	X	9		10	
LL12	**X**	X	**X**	**X**	X	X	**X**	X	X	**X**	**X**	X	**X**	X	**X**	X	**X**	X	**X**	X	10		10	
LL13	**X**	X	**X**	**X**	X	X	**X**	X	X	**ei,e**	**X**	X	**X**	X	**X**	X	**X**	X	**X**	X	9		10	
LL14	**X**	X	**X**	**X**	X	X	**X**	X	X	**X**	**X**	X	**X**	X	**X**	X	**X**	X	**X**	X	10		10	
																					avg	8.833333		9.25
																					median	9		10
NS	**5**	6	**6**	**5**	**6**	**6**	**5**	**5**	**6**	**5**	**2**	**6**	**6**	**6**	**6**	**4**	**4**	**6**	**6**	**5**	SD	1.328057		1.150728
UL	**11**	15	**13**	**14**	**14**	**15**	**13**	**13**	**14**	**13**	**9**	**15**	**15**	**14**	**12**	**12**	**12**	**14**	**15**	**15**				
LL	**8**	12	**10**	**10**	**11**	**12**	**12**	**11**	**10**	**11**	**11**	**11**	**11**	**10**	**11**	**11**	**10**	**11**	**12**	**12**				
	% Correct																							
NS	**0.714286**	**0.857143**	**0.857143**	**0.714286**	**0.857143**	**0.857143**	**0.714286**	**0.714286**	**0.857143**	**0.714286**	**0.285714**	**0.857143**	**0.857143**	**0.857143**	**0.857143**	**0.571429**	**0.571429**	**0.857143**	**0.857143**	**0.714286**				
UL	**0.733333**	**1**	**0.866667**	**0.933333**	**0.933333**	**1**	**0.866667**	**0.866667**	**0.933333**	**0.866667**	**0.6**	**1**	**1**	**0.933333**	**0.8**	**0.8**	**0.8**	**0.933333**	**1**	**1**				
LL	**0.615385**	**0.923077**	**0.769231**	**0.769231**	**0.846154**	**0.923077**	**0.923077**	**0.846154**	**0.769231**	**0.846154**	**0.846154**	**0.846154**	**0.846154**	**0.769231**	**0.846154**	**0.846154**	**0.769231**	**0.846154**	**0.923077**	**0.923077**				
	ee	%				ei				total														
NS	**27**	77.14286	**27/35**			23	65.71429	**23/35**		71.42857														
UL	**65**	86.66667	**65/75**			62	82.66667	**62/75**		84.66667														
LL	**52**	80	**52/65**			54	83.07692	**54/65**		81.53846														

	Ley s	f	change	Reino s	f	change	Aceite s	f	change		Veinte s	f	change	Treinta s	f	change		Peinó s	f	change	Peinaba s	f	change
NS01	455	389	-66	498	305	-193	434	321	-113		424	290	-134	485	242	-243		536	443	-93	398	292	-106
NS02	515	390	-125	581	333	-248	465	336	-129		527	179	-348	581	410	-171		558	386	-172	576	233	-343
NS03	457	396	-61	540	393	-147	569	384	-185		569	359	-210	530	332	-198		Unreadable			593	324	-269
NS04	536	323	-213	590	441	-149	602	394	-208		543	436	-107	492	408	-84		503	465	-38	498	415	-83
NS05	423	389	-34	508	348	-160	485	395	-90		495	420	-75	547	375	-172		517	339	-178	484	386	-98
NS06	481	386	-95	419	372	-47	466	359	-107		456	378	-78	495	365	-130		496	406	-90	452	392	-60
NS07	469	465	-4	457	367	-90	555	327	-228		530	353	-177	489	431	-58		630	422	-208	531	348	-183
UL01	574	636	62	601	451	-150	Mispronounced				466	355	-111	680	348	-332		Mispronounced			588	396	-192
UL02	467	413	-54	456	340	-116	398	357	-41		437	351	-86	371	404	33		365	428	63	420	460	40
UL03	510	500	-10	453	577	124	473	355	-118		448	453	5	433	395	-38		560	578	18	425	340	-85
UL04	595	565	-30	514	475	-39	533	494	-39		484	521	37	499	617	118		375	380	5	Mispronounced		
UL05	563	463	-100	541	308	-233	438	473	35		499	574	75	517	409	-108		534	452	-82	Mispronounced		
UL06	592	604	12	574	359	-215	460	411	-49		527	406	-121	658	445	-213		580	530	-50	562	382	-180
UL07	504	487	-17	543	374	-169	477	365	-112		559	454	-105	519	414	-105		463	404	-59	541	499	-42
UL08	508	452	-56	549	447	-102	475	310	-165		524	431	-93	Unreadable				643	495	-148	564	276	-288
UL09	462	461	-1	482	360	-122	418	407	-11		463	314	-149	490	454	-36		648	467	-181	438	394	-44
UL10	486	549	63	541	523	-18	Mispronounced				Mispronounced			495	375	-120		Mispronounced			Mispronounced		
UL11	566	524	-42	591	467	-124	441	510	69		571	606	35	676	620	-56		415	501	86	607	527	-80
UL12	579	493	-86	524	569	45			0				0	553	471	-82		378	366	-12	536	442	-94
UL13	565	550	-15	573	412	-161	433	430	-3		526	264	-262	576	266	-310		Unreadable			607	519	-88
UL14	577	543	-34	492	421	-71	581	291	-290		Mispronounced			538	539	1		Unreadable			Mispronounced		
UL15	675	571	-104	568	395	-173	537	452	-85		Mispronounced			746	727	-19		Mispronounced			Mispronounced		
LL02	511	400	-111	442	452	10	499	318	-181		567	377	-190	488	400	-88		Unreadable			501	476	-25
LL03	599	565	-34	Mispronounced			489	444	-45		605	595	-10	626	417	-209		550	582	32	Mispronounced		
LL04	602	528	-74	482	399	-83	419	417	-2		493	407	-86	558	454	-104		447	407	-40	533	421	-112
LL05	652	535	-117	554	530	-24	463	440	-23		605	463	-142	617	415	-202		501	449	-52	593	455	-138
LL06	556	506	-50	Unreadable			574	470	-104		539	344	-195	628	575	-53		Unreadable			Unreadable		
LL07	531	493	-38	510	500	-10	Mispronounced				528	330	-198	598	459	-139		Mispronounced			480	453	-27
LL08	674	579	-95	541	489	-52	524	556	32		562	465	-97	749	323	-426		Unreadable			572	399	-173
LL09	686	376	-310	565	370	-195	509	256	-253		584	319	-265	687	425	-262		638	526	-112	Unreadable		
LL10	677	507	-170	Mispronounced			Mispronounced				Mispronounced			618	493	-125		Mispronounced			696	366	-330
LL11	521	507	-14	625	566	-59	Mispronounced				596	569	-27	Mispronounced				660	555	-105	Mispronounced		
LL12	639	465	-174	519	513	-6	511	415	-96		Mispronounced			602	488	-114		599	602	3	501	418	-83
LL13	607	514	-93	613	429	-184	Mispronounced				556	504	-52	580	504	-76		742	626	-116	560	412	-148
LL14	544	539	-5	495	301	-194	Mispronounced				511	392	-119	559	601	42		624	716	92	528	585	57
						0																	
Mean	Ley s	f	change	Reino s	f	change	Aceite s	f	change		Veinte s	f	change	Treinta s	f	change		Peinó s	f	change	Peinaba s	f	change
NS	476.5714	391.1429	-85.4286	513.2857	365.5714	-147.714	510.8571	359.4286	-151.429		506.2857	345	-161.286	517	366.1429	-150.857		540	410.1667	-111.286	504.5714	341.4286	-163.143
UL	548.2	520.7333	-27.4667	533.4667	431.8667	-101.6	472	404.5833	-62.2308		500.3636	429.9091	-64.5833	553.6429	463.1429	-90.5		496.1	460.1	-36	528.8	423.5	-105.3
LL	599.9231	501.0769	-98.8462	534.6	454.9	-79.7	498.5	414.5	-84		558.7273	433.1818	-125.545	609.1667	462.8333	-146.333		595.125	557.875	-37.25	551.5556	442.7778	-108.778
Standard Deviation																							
NS	38.30517	41.14782	68.53432	62.58784	43.82487	65.49228	63.67477	31.99405	54.64692		51.15243	87.40328	96.22493	36.7015	63.95162	64.66949		49.54594	44.47659	77.49562	68.56592	63.90581	106.8635
UL	57.55147	61.20045	50.24208	46.3124	80.77382	96.72996	53.96632	70.62508	94.15958		44.67275	107.0294	96.79825	103.962	123.2589	124.6822		110.8978	67.69121	85.80857	73.887	81.16136	92.39535
LL	62.63314	58.4244	83.03598	57.17264	81.13973	81.5694	45.17901	91.85703	95.57047		37.85258	94.19323	80.5225	65.527	76.46964	118.5115		93.58333	98.42682	75.33307	65.38561	62.68129	110.2948
Category Mean	Category 1	2	3	4	5	6	7																
NS	-128.19	-156.071	-137.214	-2.9881	-30.9286	-47.7143	-21.7857																

	Reno s	f	change	Le s	f	change		Penó s	f	change	Penaba s	f	change		Este s	f	change		Tren s	f	change	Vente s	f	change
	488	596	108	427	423	-4		458	404	-54	541	556	15		472	496	24		485	359	-126	451	422	-29
	579	593	14	441	393	-48		518	473	-45	494	475	-19		555	528	-27		461	429	-32	573	533	-40
	unreadable			468	461	-7		602	361	-241	387	341	-46		487	430	-57		448	481	33	544	459	-85
	553	606	53	517	451	-66		487	408	-79	500	524	24		551	404	-147		503	542	39	484	457	-27
	563	628	65	487	473	-14		511	545	34	558	583	25		508	482	-26		869	565	-304	498	547	49
	500	527	27	486	445	-41		484	463	-21	471	465	-6		503	467	-36		451	399	-52	480	581	101
	473	327	-146	426	423	-3		496	505	9	471	442	-29		538	473	-65		517	675	158	591	601	10
	Mispronounced			593	639	46		556	447	-109	unreadable				655	644	-11		520	478	-42	509	379	-130
	448	422	-26	419	478	59		410	342	-68	468	489	21		492	467	-25		384	363	-21	448	498	50
	505	486	-19	535	558	23		505	511	6	572	598	26		724	637	-87		441	620	179	520	606	86
	583	533	-50	570	600	30		421	471	50	461	455	-6		498	465	-33		659	605	-54	553	642	89
	519	508	-11	517	531	14		479	505	26	544	514	-30		mispronounced				605	511	-94	493	479	-14
	439	578	139	563	611	48		524	449	-75	545	484	-61		594	545	-49		672	572	-100	mispronounced		
	496	486	-10	530	548	18		498	593	95	452	477	25		498	551	53		558	714	156	444	644	200
	511	539	28	531	551	20		545	510	-35	533	557	24		528	450	-78		541	626	85	509	589	80
	481	445	-36	459	490	31		476	463	-13	443	360	-83		464	584	120		410	456	46	427	392	-35
	498	427	-71	577	585	8		mispronounced			633	731	98		506	597	91		523	528	5	468	528	60
	549	615	66	540	600	60		638	705	67	652	655	3		586	491	-95		645	608	-37	582	773	191
	525	621	96	601	488	-113		643	675	32	613	628	15		719	515	-204		533	567	34	504	635	131
	554	692	138	547	576	29		538	614	76	621	731	110		622	621	-1		716	761	45	504	649	145
	589	528	-61	631	588	-43		555	524	-31	624	711	87		mispronounced				unreadable			598	717	119
	515	667	152	640	470	-170		687	759	72	764	713	-51		650	476	-174		551	684	133	508	720	212
	471	459	-12	501	527	26		436	380	-56	unreadable				485	499	14		unreadable			538	450	-88
	561	503	-58	561	584	23		mispronounced			671	365	-306		696	625	-71		591	645	54	538	402	-136
	486	432	-54	572	512	-60		519	393	-126	580	578	-2		500	458	-42		442	452	10	473	416	-57
	584	505	-79	656	642	-14		632	494	-138	854	721	-133		778	747	-31		709	593	-116	575	730	155
	unreadable			778	788	10		unreadable			unreadable				701	534	-167		637	686	49	588	599	11
	513	542	29	582	527	-55		mispronounced			456	330	-126		471	412	-59		unreadable			459	558	99
	699	570	-129	668	709	41		649	573	-76	626	485	-141		629	597	-32		unreadable			540	571	31
	631	496	-135	717	608	-109		711	706	-5	767	765	-2		809	775	-34		584	409	-175	550	396	-154
	571	455	-116	664	603	-61		mispronounced			mispronounced				658	600	-58		582	281	-301	500	444	-56
	654	568	-86	683	618	-65		720	648	-72	692	613	-79		765	720	-45		611	531	-80	582	575	-7
	625	658	33	665	627	-38		501	523	22	unreadable				Unreadable				622	542	-80	646	651	5
	514	591	77	629	606	-23		533	511	-22	558	554	-4		588	502	-86		691	691	0	544	496	-48
	609	516	-93	631	613	-18		464	509	45	667	617	-50		719	724	5		636	628	-8	469	339	-130
	Reno s	f	change	Le s	f	change		Penó s	f	change	Penaba s	f	change		Este s	f	change		Tren s	f	change	Vente s	f	change
	526	546.1667	20.16667	464.5714	438.4286	-26.1429		508	451.2857	-56.7143	488.8571	483.7143	-5.14286		516.2857	468.5714	-47.7143		533.4286	492.8571	-40.5714	517.2857	514.2857	-3
	515.1429	539.0714	23.92857	550.2	554.2	4		533.9286	540.5714	6.642857	566.0714	578.7857	12.71429		579.6923	541.7692	-37.9231		554.1429	578.0714	23.92857	504.7857	589.3571	84.57143
	576.5	524.5833	-51.9167	639	612.6154	-26.3846		573.8889	526.3333	-47.5556	652.3333	558.6667	-93.6667		649.9167	599.4167	-50.5		610.5	545.8	-64.7	538.6154	509.7692	-28.8462
	44.35313	112.5654	87.74831	34.58736	27.22044	25.25489		45.83667	63.94976	89.83821	55.77164	80.86968	27.67326		32.24755	41.11714	52.31862		150.2707	109.3472	146.1003	52.46495	68.61174	61.95966
	43.92276	85.76306	79.23914	58.57498	52.9018	64.91423		80.35447	114.9372	63.59561	92.19166	119.5184	57.98465		89.165	69.67323	93.80873		98.92955	106.4002	89.40957	49.39352	119.6949	95.98775
	70.69589	64.60855	69.11579	72.34293	74.67099	43.66642		106.2149	106.0919	62.92875	116.9006	146.1583	98.03443		116.9627	121.4716	46.43568		72.99505	132.258	111.1066	53.47825	114.5063	91.15449

	Ley s	f	change	Reino s	f	change	Aceite s	f	change		Veinte s	f	change	Treinta s	f	change		Peinó s	f	change	Peinaba s	f	change
NS01	1956	2219	263	1656	2372	716	1758	2220	462		1748	2176	428	1814	2250	436		1565	2185	620	2077	2306	229
NS02	1928	2394	466	1804	2431	627	1800	2420	620		1918	2536	618	1798	2455	657		1754	2133	379	1983	2613	630
NS03	2272	2779	507	1772	2649	877	1959	2600	641		2296	2724	428	1887	2880	993		unreadable			2147	2826	679
NS04	2183	2507	324	2009	2623	614	2139	2806	667		2299	2604	305	2201	2653	452		2308	2723	415	2043	2697	654
NS05	1723	2237	514	1737	2246	509	1908	2192	284		1823	2413	590	1810	2413	603		1938	2237	299	1864	2346	482
NS06	1588	2049	461	1296	2026	730	1532	1932	400		1620	2027	407	1377	1736	359		1385	2080	695	1479	1964	485
NS07	2176	2321	145	1776	2441	665	2016	2661	645		2053	2736	683	1949	2475	526		2336	2615	279	2063	2626	563
UL01	1864	2391	527	2147	2718	571	Mispronounced				2161	2690	529	2030	2570	540		Mispronounced			2566	2818	252
UL02	1674	1994	320	1642	1937	295	1589	2236	647		1785	2467	682	1449	1911	462		1872	1942	70	1698	1854	156
UL03	1783	2289	506	1836	2194	358	2126	2325	199		2131	2304	173	2044	2069	25		2214	2298	84	2402	2353	-49
UL04	1940	2421	481	2000	2424	424	2132	2081	-51		2014	2552	538	1972	2129	157		2292	2434	142	Mispronounced		
UL05	1693	2014	321	1916	2358	442	1761	1821	60		1857	2236	379	1811	2279	468		1924	1882	-42	Mispronounced		
UL06	1982	2289	307	1943	2551	608	1948	2457	509		1994	2359	365	1854	2507	653		2272	2658	386	2076	2808	732
UL07	2096	2377	281	2047	2896	849	2081	2595	514		2314	2528	214	1880	2575	695		2274	2446	172	2600	2608	8
UL08	1727	2070	343	1859	2014	155	1785	1989	204		1845	2403	558	Unreadable				1818	2260	442	1680	2229	549
UL09	1849	1856	7	1494	2062	568	1836	1850	14		1887	2136	249	1656	1964	308		1729	2222	493	1934	2044	110
UL10	2050	2323	273	2012	2359	347	Mispronounced				Mispronounced			1943	2614	671		Mispronounced			Mispronounced		
UL11	2054	2385	331	1864	2117	253	2279	2263	-16		2199	2308	109	1988	2086	98		2249	2193	-56	2279	2249	-30
UL12	1887	2653	766	2085	2424	339			0				0	2155	2428	273		2518	2637	119	2582	2543	-39
UL13	2236	2488	252	1931	2478	547	2286	2353	67		2240	2491	251	2199	2449	250		unreadable			2283	2247	-36
UL14	1991	2359	368	2375	2954	579	2561	2946	385		Mispronounced			1859	2762	903		unreadable			Mispronounced		
UL15	1980	2377	397	2076	2753	677	2120	2580	460		Mispronounced			2135	2316	181		Mispronounced			Mispronounced		
LL02	1845	2283	438	1613	2233	620	1954	2639	685		2206	2282	76	2017	2561	544		unreadable			2347	2108	-239
LL03	2057	2539	482	Mispronounced			2125	2288	163		2406	2427	21	2023	2445	422		2451	2459	8	Mispronounced		
LL04	2048	2395	347	2288	2826	538	2287	2746	459		2233	2610	377	1968	2595	627		2623	2578	-45	2527	2607	80
LL05	1820	2460	640	1823	2583	760	2349	2561	212		2194	2331	137	2036	2741	705		2601	2696	95	2597	2629	32
LL06	1780	2421	641	Unreadable			1988	2189	201		2009	2188	179	1894	1773	-121		unreadable			Unreadable		
LL07	1401	2007	606	2848	2003	-845			0		1869	2170	301	1629	2447	818		Mispronounced			2211	1827	-384
LL08	1863	2447	584	2125	2274	149	2123	2523	400		2174	2417	243	1764	2302	538		unreadable			2402	2549	147
LL09	1971	2609	638	2115	2290	175	1936	2678	742		2404	2474	70	2171	2512	341		2566	2525	-41	Unreadable		
LL10	1750	2135	385	Mispronounced			Mispronounced				Mispronounced			1553	1868	315		Mispronounced			2318	2373	55
LL11	2230	2567	337	1902	2588	686	Mispronounced				2271	2423	152	Mispronounced				2557	2463	-94	Mispronounced		
LL12	2144	2547	403	2122	2758	636	2266	2670	404		Mispronounced			2134	2238	104		2618	2856	238	2388	2591	203
LL13	1734	2501	767	1792	2531	739	Mispronounced				2227	2301	74	1855	2312	457		2156	2155	-1	2276	2230	-46
LL14	2107	2532	425	2125	2389	264	Mispronounced				2202	2431	229	2056	2602	546		2693	2362	-331	2406	2222	-184
Mean	Ley s	f	change	Reino s	f	change	Aceite s	f	change		Veinte s	f	change	Treinta s	f	change		Peinó s	f	change	Peinaba s	f	change
NS	1975.143	2358	382.8571	1721.429	2398.286	676.8571	1873.143	2404.429	531.2857		1965.286	2459.429	494.1429	1833.714	2408.857	575.1429		1881	2328.833	447.8333	1950.857	2482.571	531.7143
UL	1920.4	2285.733	365.3333	1948.467	2415.933	467.4667	2042	2291.333	230.1538		2038.818	2406.727	337.25	1926.786	2332.786	406		2116.2	2297.2	181	2210	2375.3	165.3
LL	1903.846	2418.692	514.8462	2075.3	2447.5	372.2	2128.5	2536.75	362.8889		2199.545	2368.545	169	1925	2366.333	441.3333		2533.125	2511.75	-21.375	2385.778	2348.444	-37.3333
Standard Deviation																							
NS	254.2036	235.0709	141.4419	216.242	215.5332	114.8672	197.7628	307.6545	149.6905		263.7383	271.6418	136.8179	245.5753	357.3222	210.4514		388.4853	270.7947	171.5837	226.0814	294.4633	154.6908
UL	159.4409	211.9004	166.2252	207.4147	317.1832	182.7812	271.2459	329.1878	242.4613		180.5557	158.6891	206.7929	201.3559	266.0628	261.7956		259.0893	258.8332	194.5262	349.8174	316.4582	272.8667
LL	221.1594	178.003	137.7333	339.7175	255.3139	485.7841	160.3291	198.3977	245.0523		154.1761	129.4337	109.798	193.3856	292.9401	258.2051		167.3605	211.0773	162.2088	119.3375	274.9901	194.0593
Category Mean	Category 1	2	3	4	5	6	7																
NS	530.3333	534.6429	489.7738	115.5357	-3.5	-35.4286	19.35714																
UL	354.3179	371.625	173.15	354.5238	15.71429	-44.6923	174.3214																
LL	416.645	305.1667	-29.3542	336.9006	20.72222	-13.0833	266.6154																

	Reno s	f	change	Le s	f	change		Penó s	f	change	Penaba s	f	change		Este s	f	change		Tren s	f	change	Vente s	f	change
	1619	1626	7	1910	1962	52		1781	1700	-81	1896	1836	-60		1869	1886	17		1751	1868	117	1736	1875	139
	1741	1895	154	1910	2000	90		2044	2022	-22	1881	1900	19		2068	2078	10		1257	1300	43	1901	1954	53
	unreadable			2430	2628	198		2493	2428	-65	2373	2238	-135		2560	2480	-80		2197	2167	-30	2140	2208	68
	2058	2152	94	2181	2265	84		2174	2149	-25	2307	2227	-80		2307	2189	-118		2291	2174	-117	2136	2263	127
	1672	1887	215	1813	1723	-90		1871	1874	3	1969	2051	82		2044	1999	-45		1777	1892	115	1907	1844	-63
	1605	1713	108	1615	1906	291		1595	1622	27	1465	1687	222		1706	1628	-78		1274	1204	-70	1657	1637	-20
	2147	2190	43	2237	2505	268		2264	2317	53	2415	2428	13		2297	2343	46		2159	2093	-66	2016	1991	-25
	Mispronounced			2058	2394	336		2449	2412	-37	unreadable				2278	2304	26		2028	2526	498	2171	2498	327
	1296	1773	477	1569	1858	289		1653	1856	203	1887	1944	57		1886	1792	-94		1783	1995	212	1528	1599	71
	2147	2091	-56	1879	2356	477		2147	2099	-48	1982	2031	49		1925	1875	-50		1923	2116	193	1979	2064	85
	1871	2503	632	1770	2550	780		2043	2611	568	880	914	34		2409	2542	133		1976	2273	297	2013	2105	92
	1646	1725	79	1778	1816	38		1633	1565	-68	1964	1985	21		mispronounced				1535	1716	181	1812	1801	-11
	1919	1989	70	2011	2117	106		2047	2077	30	2110	2040	-70		2202	2202	0		1915	2072	157	mispronounced		
	1862	2185	323	1961	2266	305		2244	2228	-16	2315	2350	35		2269	2098	-171		1994	2329	335	2186	2196	10
	1541	1747	206	1566	1755	189		1880	1741	-139	1999	1913	-86		1885	1807	-78		1506	1854	348	1930	1962	32
	1543	1837	294	1671	1888	217		1819	1932	113	1948	1942	-6		1942	1888	-54		1544	1624	80	1802	1815	13
	1863	2264	401	2029	2385	356		mispronounced			2218	2192	-26		2205	2083	-122		2148	2121	-27	2229	2125	-104
	1827	2052	225	2055	2316	261		2235	2102	-133	2118	2044	-74		2183	2136	-47		2012	2338	326	1994	2115	121
	1996	2283	287	1846	2630	784		2283	2291	8	2221	2249	28		2063	2045	-18		1835	2680	845	2003	2203	200
	1847	1954	107	2156	2328	172		2222	2387	165	2077	2080	3		2312	2086	-226		1972	1972	0	2058	2097	39
	1687	2638	951	1943	2512	569		2668	2532	-136	2518	2343	-175		mispronounced				unreadable			2229	2024	-205
	2020	2836	816	1933	2534	601		2366	2404	38	2114	2216	102		2315	2435	120		2081	2790	709	2087	2144	57
	1794	2185	391	1811	2123	312		2312	2266	-46	unreadable				2163	2063	-100		unreadable			2148	2349	201
	2216	2231	15	1943	2364	421		mispronounced			2258	2288	30		2111	2143	32		2116	2555	439	2084	2837	753
	2011	2379	368	1810	2223	413		2354	2485	131	2261	2308	47		2499	2413	-86		1900	2339	439	2032	2248	216
	2033	2407	374	1938	2363	425		2586	2624	38	2074	2018	-56		2019	2057	38		2065	2357	292	2085	2093	8
	unreadable			1960	2160	200		unreadable			unreadable				2051	2011	-40		1944	1982	38	1963	2048	85
	1699	1896	197	1547	1830	283		mispronounced			1693	1727	34		2028	1993	-35		unreadable			1914	2157	243
	2061	2237	176	1855	2088	233		2273	2256	-17	2344	2302	-42		2283	2313	30		unreadable			2204	2262	58
	1976	2598	622	1736	2425	689		2035	2038	3	1982	1974	-8		1864	1855	-9		2067	2614	547	2451	2613	162
	1813	2118	305	1785	2083	298		mispronounced			mispronounced				1951	1970	19		1934	2419	485	1997	2345	348
	2000	2415	415	2056	2489	433		2341	2565	224	2226	2142	-84		2086	2073	-13		2087	2253	166	2397	2556	159
	2197	2526	329	2186	2430	244		2405	2416	11	unreadable				Unreadable				1960	2412	452	2039	2084	45
	2041	2208	167	1825	2089	264		2130	2320	190	2190	2171	-19		2161	2148	-13		1957	1972	15	1993	2268	275
	1972	2614	642	2139	2349	210		2514	2501	-13	2483	2433	-50		2114	2134	20		2298	2605	307	2346	2591	245
	Reno s	f	change	Le s	f	change		Penó s	f	change	Penaba s	f	change		Este s	f	change		Tren s	f	change	Vente s	f	change
	1807	1910.5	103.5	2013.714	2141.286	127.5714		2031.714	2016	-15.7143	2043.714	2052.429	8.714286		2121.571	2086.143	-35.4286		1815.143	1814	-1.14286	1927.571	1967.429	39.85714
	1790.357	2134.071	343.7143	1881.667	2247	365.3333		2120.643	2159.786	39.14286	2025.071	2017.357	-7.71429		2144.154	2099.462	-44.6923		1875.143	2171.857	296.7143	2001.5	2053.429	51.92857
	1984.417	2317.833	333.4167	1891.615	2232	340.3846		2327.778	2385.667	57.88889	2167.889	2151.444	-16.4444		2110.833	2097.75	-13.0833		2032.8	2350.8	318	2127.154	2342.385	215.2308
	235.5122	226.7957	74.92062	280.4483	333.3945	134.0073		307.2847	303.6791	47.80765	342.6343	261.2731	118.4845		289.4701	285.5669	60.76144		428.2563	403.5976	93.62946	185.9327	215.613	78.26968
	225.2362	342.1944	290.3551	180.0403	290.3491	230.3558		297.4346	307.1079	185.8129	369.1526	349.2893	72.29473		182.311	231.0659	102.0085		209.0645	342.4055	249.1068	192.655	214.5527	125.1377
	153.3057	211.5599	182.0637	172.6347	189.9368	134.8768		171.853	183.4973	98.37739	229.0892	216.511	45.70588		162.7959	150.402	45.44219		119.5945	229.3061	189.0555	173.1352	240.8764	189.7051