“In soes en sieze zit de a”

An acoustical description of Dutch vowels by Spanish learners of Dutch

MA thesis

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1. Introduction

Speech, a defining feature of humanity, is one of the most important means of successful communication. However, when learning a second language (L2), especially at a later age, it is difficult to become as fluent as a native speaker. Minimizing ones foreign accent is an important factor in order to be successful in a second language. So, language training programs could benefit from knowledge about foreign accents. Further, automated speech recognition programs could incorporate knowledge about foreign accents, making it easier for L2-learners to be understood when using such a computer program.

Foreign accent depends on a number of factors, among them the speaker's first language (L1). This study investigates the case of L1-Spanish speakers learning Dutch as a second language.

Both Spanish and Dutch vowel systems have been analysed thoroughly before (e.g. Pols, Tromp & Plomp 1973, Van Nierop, Pols & Plomp 1973, Adank, Van Hout & Smits 2004 and Adank, Van Hout & Van de Velde 2007 for Dutch, and Morrison & Escudero 2007 and Chladkova, Escudero & Boersma 2008 for Spanish). In this thesis I will present an acoustic analysis (duration, fundamental frequency and formants) of Dutch vowels as spoken by L1-Spanish learners of L2-(or L3-)Dutch. The formant analysis will be compared with a formant analysis of Dutch vowels by Dutch speakers (Bank 2009), to provide a means of comparison with the target language.

The main goal of this study is to provide a quantitative description of the vowel system of L2-Dutch as spoken by L1-Spanish learners. Further, a better understanding of speaker difficulties in L2-learning can be gained, particularly if the L2 vowel system has a larger inventory than the L1 vowel system. Finally, the possible influence of orthography in L2-learning will be discussed, especially in distinguishing between L2-vowels that are allophones in the L1.

2. Background

The Dutch vowel system has been described extensively. The Dutch vowel system has twelve monophthongal vowels: /i ɪ y ʏ e ɛ ø a ɑ o ɔ u/. Three of these, /e ø o/, are commonly referred to as long vowels, and are often slightly diphthongized. Pols *et al.* (1973) made a frequency analysis of the Dutch monophthongal vowels for 50 male speakers, and Van Nierop *et al.* (1973) did the same for 25 female speakers. Adank *et al.* (2004) and Adank *et al.* (2007), in a recent acoustic analysis of Standard Dutch vowels, contrasted the two main speech communities of Dutch: the Netherlands and Flanders. They analysed 15 vowels (the twelve monophthongal vowels, plus three diphthongal vowels /ɛɪ ɔu œy/), spoken in a neutral context (i.e., /sVs/, where V is replaced by one of the vowels/diphthongs). All vowels were analysed on three characteristics: vowel length, fundamental frequency and formant frequencies. Gussenhoven (1999) describes the Dutch vowel system in IPA symbols. He makes a distinction in tense and lax vowels (where /i y e ø a o u/ are tense, and /ɪ ʏ ɛ ɑ ɔ/ are lax). These terms originate in Jakobson and Halle's distinctive feature theory of phonology: lax vowels require less muscular effort and movement than their tense counterparts, or so it is claimed. Further, they are more central in the vowel space (Jakobson, Fant & Halle 1953). Describing phonemes in terms of lax and tense features (or [+/- Advanced Tongue Root]) can be problematic (see Durand (2005) for a discussion). However, since this distinction provides a convenient means of distinguishing between, for instance, /i/ and /ɪ/, I will use this terminology in this thesis for the sake of simplicity.

Spanish has an inventory of five vowels (see for example Maddieson 1984:267 and Martínez-Celdrán *et al.* 2003): /i e a o u/. There is no tense/lax distinction for vowels in Spanish. Morrison & Escudero (2007) and Chladkova *et al.* (2008) have made a study comparable to Adank *et al.* (2004), contrasting Peruvian and European Spanish dialects. Like Adank *et al.*, they conducted a formant analysis and reported on fundamental frequency and vowel length. All vowels were analysed in different consonantal contexts (i.e., /sVs/, /pVp/, /tVt/, /kVk/, /fVf/, where V is one of the five vowels). Morrison & Escudero (2007) conclude that the dialects do not differ in formant values, so speakers of Spanish from different dialects can be taken together when studying L2 vowel perception and production for L1-Spanish speakers. However, they observe a substantial difference in vowel length between Peruvian and European Spanish dialects. If this difference is intrinsic to the dialect and not an effect of speaking rate, it could have an effect on L2 speech studies that take vowel duration into account. This may be relevant for the current study.

There is an extensive body of work concerning second language learning. Of interest here are the studies that examine vowel production in a second language. Several factors play a role in second language acquisition (SLA). Among them are starting age of SLA (which usually will be the age of arrival in the L2-speaking country), length of residence in the L2-country, motivation and talent for learning. These different factors all have influence on the intelligibility of the L2-learner, in for example vocabulary and foreign accent. Piske, MacKay & Flege (2001), in an overview of studies that examine foreign accent in L2, conclude that starting age of SLA is the most important predictor of degree of foreign accent. Other factors were uncertain for prediction (but this does not mean that those other factors don't play a role). It is generally believed that there is a critical period for SLA, after which acquiring a foreign accent becomes almost inevitable.

Most studies that examined the production of L2-vowels take English as the second language, for a variety of L1-speakers (for instance Flege, MacKay & Meador (1999) and Piske, Flege, MacKay & Meador (2001) for Italian learners; Tsukada *et al.* (2005) for Korean learners; Ingram & Park (1997) for Japanese and Korean learners, Munro (1993) for Arabic learners, and there are many more (see Piske, MacKay & Flege (2001:192/193) for an extensive list)). Few studies examine the *production* of L2-Dutch vowels. Among them are Snow &

Hoefnagel-Höhle (1977) and Flege (1992) for English learners, Bongaerts, Mennen & Van der Slik (2000), for various L1-speakers (the biggest group being German) and Van Wijngaarden (2001) for American learners. Of these, Snow & Hoefnagel-Höhle (1977) and Bongaerts *et al.* (2000) only tested L2-language "goodness" (focussing on foreign accent), as rated by native speakers. Van Wijngaarden (2001) specifically studied intelligibility of L2-speech with added noise: for L2-speech to be still intelligible, less noise could be added than with L1-speech, indicating that L2-speech is generally harder to understand. Flege (1992) is the only one to include acoustic measurements, apart from intelligibility ratings. To my knowledge, L2-Dutch production of L1-Spanish learners has not been described before.

Ingram & Park (1997) studied perception and production of L2-Australian English vowels by Japanese and Korean learners. They suggest that a learner's L2-production capabilities are closely related to her L2-perception: the Japanese ability to produce acoustically separate /e/ and /æ/ tokens (where Korean speakers do not) is interpreted as the result of perceiving this distinction. However, it is unclear where this difference in perception comes from. It must be noted, however, that in Ingram & Park's production task, the same English words (with the target vowels in "hVd"-context) were used as in the preceding perception task. Subjects could therefore in production possibly rely on exemplar tokens stored in memory, and on phonological information in their mental lexicon. This is different from the situation in the current study, where nonsense words are used, and speakers had to rely on their orthographic knowledge. Yet another method was used by Tsukada *et al.* (2005), in their study of L2-English by child and adult Korean learners. Here, a picture-naming task was used: twenty-one words were elicited three times. The first 21 elicitations were prompted by a (digitized) token of the target word, spoken by a native English speaker; subsequent elicitations were only prompted if the subject failed to say a target word. However, Tsukada *et al.* decided to analyse only the prompted elicitations, transforming the task essentially to a word repetition task. Tsukada *et al.* find that adult Korean learners of English produce much smaller /e/-/æ/ distinctions (and /ɑ/-/ʌ/ distinctions) than native speakers of English, whereas North Korean children produce vowel distinctions that are comparable with native speakers of English. It is difficult to compare these findings with Ingram & Park (1997), because different groups of speakers are evaluated (Japanese vs. Korean in Tsukada *et al.*, and Korean vs. native English in Ingram & Park).

From the comparison between the Dutch and Spanish vowel inventories, it follows that one of the problems that Spanish learners of Dutch will encounter will be the adaptation of a larger vowel inventory. Flege & Hillenbrand (1984), in a comparison of native speakers of French with the L2-French of American English speakers, suggest that 'new' vowels (L2-vowels that have no equivalent in L1) are learned better than L2-vowels that do have an equivalent in L1. In the present study, this would especially apply to the vowels /y ʏ ø/, ('new' vowels for Spanish learners). But this need not necessarily be the case: "The poor production of French /u/ by many of the inexperienced Americans might have stemmed from a lack of awareness of the linguistic distinction between the /u/ and /y/ categories of French" (Flege & Hillenbrand 1984: 713). In other words, speakers should know what they are doing, they should be aware of the vowel distinctions of the language they are learning (e.g. there being a tense/lax distinction in Dutch). Further, the idea that the Spanish and Dutch have five vowels in common that can be described with the same IPA symbol (namely /i e a o u/), does not necessarily mean that they are phonetically equal. Indeed, Boersma & Escudero (2008), who study L2-Spanish perception for Dutch learners of Spanish, found that Dutch /i e a o u/ will initially be mapped to Spanish /i ɛ ɑ ɔ u/, respectively, because Dutch listeners will weight duration cues much higher than the spectral cues (Gerrits 2001:89, as cited in Boersma & Escudero 2008). Further, a perfect bilingual's Dutch and Spanish vowels were plotted in a F1-F2 space, revealing that, apart from duration, the Spanish and Dutch vowels lie spectrally apart from each other. Another example is given by Mendez (1982), who finds that Spanish and American English have the vowels /i a u/ in common, but only /i/ and /a/ are acoustically equivalent in speech production. English speakers pronounced the isolated vowels that occur in "heed", "father" and "food", and Spanish speakers pronounced the words "si", "paso" and "tu". Statistically significant differences in formant values were only found for /u/.

Another main issue will be the influence of orthography. Fashola *et al.* (1996) studied spelling issues in Spanish learners of L2-English, and note that "Spanish-speaking spellers are at a disadvantage because they have not had much experience dealing with the exceptions to the rules of spelling" (Fashola *et al.* 1996:832). This argument can be reversed for the current study to make it applicable for reading instead of spelling: Spanish speakers may encounter difficulties pronouncing Dutch vowels, because the (Dutch) orthographic representations they have to read and pronounce do not necessarily match with their (Spanish) phonological or phonetic representations. One could predict errors in the pronunciation of written Dutch words, pronouncing them as Spanish instead: for instance written "u" (Dutch /y/ or /ʏ/) will be pronounced as Spanish /u/; written “eu” (Dutch /ø/) will be diphthongized (since it is a valid vowel combination in Spanish); and written “a”, “e” and “o” will be pronounced as /a/, /e/ and /o/ (whereas in Dutch they could be pronounced as /a/ or /ɑ/, /e/ or /ɛ/, and /o/ or /ɔ/, respectively). Rolla *et al.* (2006) make the same point: “Spanish-English bilingual children who have a stronger knowledge of their L1 phonology and orthography are likely to use that knowledge in an L2 phonemic segmentation task” (Rolla *et al.* 2006:242).

Having covered the most important background topics, the next section will discuss the method used for the current study.

3. Method

The current study deals with speakers of Spanish who are learning Dutch as a second (or third) language. Sixty speakers were recorded. The recordings of one female speaker were discarded because of the extremely low sound level; at high volume levels, speech was faintly audible through the noise, but undiscernable, making it impossible to label the vowels. This leaves 59 speakers for analysis (34 female, 25 male), of which 22 were from Spain (12 female, 10 male), and 37 speakers came from various countries in Latin America (22 female, 15 male). The target sentences were displayed on a computer screen; after reading the sentence aloud, the speaker could press a mouse button to display the next sentence, so the speed was user controlled. Each speaker read the same sentence as in the Adank *et al.* studies, for example: “In sies en in sieze zit de ie.” /ɪn sis ɛn ɪn sizə zɪt də i/ [*in sees and in seese is the ee*]. Within this frame, a total of twelve vowels was recorded: /i ɪ y ʏ e ɛ ø a ɑ o ɔ u/. Table 1 provides a list with all sentences spoken by the speakers in this study, and the IPA-symbols for the target vowels. Underlining indicates that the syllable should be stressed. Please note that there are some false friends in the list: for example the Dutch word “soes” is pronounced /sus/, just as the Spanish word “sus”. However, Dutch “sus” is pronounced /sʏs/, and “suus” is pronounced /sys/. Both the Dutch vowels have no equivalent in Spanish. For Spanish, all five vowels are written with the same character as their IPA symbol (Martínez-Celdrán *et al.* 2003) (i.e. “sus” is pronounced /sus/, etc).

Table 1: List of Dutch sentences spoken by all subjects, with IPA-symbols for the target vowel.

IPA target vowel (“lax”)	Dutch sentence		IPA target vowel (“tense”)	Dutch sentence
/ɪ/	In sis en in sisse zit de i.		/i/	In sies en in sieze zit de ie.
/ʏ/	In sus en in susse zit de u.		/y/	In suus en in suze zit de uu.
/ɛ/	In ses en in sesse zit de e.		/e/	In sees en in seze zit de ee.
			/ø/	In seus en in seuze zit de eu.
/ɑ/	In sas en in sasse zit de a.		/a/	In saas en in saze zit de aa.
/ɔ/	In sos en in sosse zit de o.		/o/	In soos en in soze zit de oo.
			/u/	In soes en in soeze zit de oe.

The list in table 1 contains one set of sentences. For most speakers (n = 37), the set was recorded four times, for 11 speakers five times, for three speakers three times, for seven speakers two times and for one speaker the set was recorded only once. This adds up to a total of 227 sets (37 x 4 + 11 x 5 + 3 x 3 + 7 x 2 + 1 x 1) of 12 sentences. In each sentence, two instances of the vowel were labelled and analysed, so for instance in the case of /i/, only the /i/ in /sis/ and in /sisə/ (and not the sentence-final /i/). For various reasons, such as background noise, or the participant blowing accidentally in the microphone while pronouncing the vowel, several tokens were discarded for analysis, making the number of tokens per vowel vary between 431 and 454 in total (for male and female speakers together).

All sound files were read into the Praat computer program (Boersma & Weenink 2008-2009) for segmentation. The criteria used for segmentation were that the onset of the vowel would be set at the zero crossing nearest to the beginning of the first clear and complete period, and the offset of the vowel would be set at the zero crossing nearest to the end of the last clear and complete period. The amount of frication was kept to a minimum, but could sometimes not be avoided. If a speaker would repeat a word, only the repeated instance was analysed. The segmentation resulted in TextGrid files, containing all start and end points of the vowels in all sentences of a speaker. With the locations of the vowels known, several Praat-scripts were run to do the various analyses on the vowels. The relevant scripts are included in the appendix.

For formant analysis, an adapted version was used of the method proposed by Escudero *et al.* (accepted). In an acoustic analysis of the vowels of two dialects of Portuguese, Escudero *et al.* argued that the standard settings in Praat (searching for five formants, with a fixed formant ceiling of 5000 Hz for male speakers or 5500 Hz for female speakers) yielded some unlikely results, in that for several back vowels the F2 values were nearly identical to the F1 values (Escudero *et al.* accepted:7). Therefore, a method was devised to establish the best (optimal) formant ceiling per vowel per speaker. This could be done because Escudero *et al.* had 20 tokens for each vowel per speaker. Given a speaker and a vowel, the first two formants of all 20 tokens of that vowel are determined for all formant ceilings between 4000 and 6000 Hz (for male speakers) or between 4500 and 6500 Hz (for female speakers), in steps of 10 Hz[1]. This results in 201 F1-F2 pairs per token, each with a different formant ceiling. Of these 201 ceilings, the optimal one is chosen as the one having the smallest variation in F1 and F2 across the 20 tokens of the vowel. This variation is computed as the variance of the twenty log(F1) values plus the variance of the twenty log(F2) values (Escudero *et al* accepted:8).

The Escudero *et al.* method cannot straightforwardly be used for the analysis of the current set of vowels, since for some speakers only two sentences per vowel were recorded, yielding a maximum of four tokens per vowel. I consider this sample too small to do a variation analysis on. However, one way to get around this is to minimize speaker differences. When we assume that we can use the same formant ceiling for a certain vowel for all speakers of a certain gender, we will have between 431 and 454 tokens per vowel (see page 8). This way, the method of Escudero *et al.* can be used to calculate the optimal formant ceiling per vowel. The same adaptation of the Escudero method was used in Bank (2009), where a re-analysis of Adank *et al.*'s (2004) vowels was compared with newly recorded Dutch vowels. These Dutch vowels will be used as a comparison for the current study later on.

So, for all vowel tokens in the current study, formant ceilings were varied between 4000 Hz and 6000 Hz (for male speakers) or 4500 Hz and 6500 Hz (for female speakers) in steps of 10 Hz. A formant analysis was carried out for each of these ceilings, looking for five formants, using the Burg algorithm that is built-in in Praat. The formant ceiling of the F1-F2-pair that yielded the lowest variation in F1 and F2 across all tokens of a vowel is chosen as the optimal formant ceiling for that vowel. After establishing the optimal formant ceiling, all vowel tokens were re-analysed using the optimal formant ceiling for that vowel. All analyses were done on the central 40% of the vowel. A table showing all pitch, duration, F1, F2 and formant ceiling values is presented in the next section.

[1] With each formant ceiling, five formants were searched for, but only the first two were reported.

Additionally, for each token a separate analysis was done to check for any spectral change, or diphthongization. For this, the optimal formant ceiling found for the central 40% of the vowel was used. Two additional formant analyses were carried out, one over the central 40% of the first half of the vowel, and one over the central 40% of the second half of the vowel. In the next section, results of various analyses will be reported, which will be discussed in the section after that.

4. Results

In this section, the results will be presented for duration, pitch and formant analyses. Before computing the mean values, first the median values per vowel per speaker were computed. This way, the influence of the variation in number of tokens per vowel per speaker is minimized. So, for example for F0, first the median pitch of all tokens of a vowel for a speaker is established[2] for each vowel and speaker, resulting in 708 F0-values for all vowels (59 speakers x 12 vowels). From these values, geometric means are computed[3]. Table 2 shows geometric means for pitch, duration, F1 and F2 values, and the formant ceilings that were used for the analysis, for all vowels, for male and female speakers respectively. All values were calculated from the middle 40% of the vowel, so any spectral changes in time are not taken into account here.

Table 2: Geometric means of F0, F1, F2 (all in Hz) and duration (in milliseconds), and used formant ceilings (in Hz) of Dutch vowels by male and female Spanish learners of Dutch.

Male speakers

vowel	i	ɪ	e	ɛ	y	ʏ	ø	u	o	ɔ	a	ɑ
F0	151.99	143.73	139.64	137.76	147.18	145.92	137.36	144.65	135.61	130.91	130.51	128.22
F1	321.75	323.62	471.63	490.93	332.10	341.48	446.57	359.61	476.25	489.54	725.71	709.06
F2	2371.07	2347.83	1996.89	1908.77	1526.63	1518.43	1717.37	1259.98	1027.13	1060.20	1453.11	1450.55
duration	123	109	175	128	133	116	192	145	169	137	186	148
ceiling	5540	5550	5170	4650	4660	4790	5100	4090	4430	4460	4550	4490

Female speakers

vowel	i	ɪ	e	ɛ	y	ʏ	ø	u	o	ɔ	a	ɑ
F0	250.35	243.87	225.69	226.82	245.89	246.17	229.58	239.41	227.62	227.15	215.14	217.68
F1	398.85	399.72	534.56	556.75	398.62	414.05	512.01	448.33	529.95	540.95	856.29	816.08
F2	2548.70	2535.60	2225.17	2126.77	1573.27	1561.04	1807.32	1297.79	1157.48	1216.53	1679.22	1664.66
duration	170	138	208	169	177	140	234	181	225	171	224	181
ceiling	6480	6220	6310	6270	5120	5220	5860	5460	5360	5670	6340	6280

2 The median is taken instead of the mean, in order to reduce the influence of outliers.

3 A geometric mean is computed by taking the mean of the log-transformed values, and exponentiate the found mean value. This way, the *ratio* between values is taken into account, instead of their *difference*.

4.1. Duration

Let's first take a closer look at the durations. Figure 1 shows the geometric mean durations for all 12 vowels for male and female speakers. In the plots, the bars represent two standard deviations, one above and one below the geometric mean. The black lines refer to the vowels in the current study, the grey lines refer to the native Dutch vowels studied by Adank *et al.* (2004). The plots show that the vowels commonly referred to as long vowels (i.e. /e o a ø/) do indeed have a longer duration than their shorter counterparts (/ɛ ɔ ɑ/, and possibly /ʏ/ as counterpart for /ø/). Adank *et al.* (2004) showed that Dutch vowels can be divided into two groups based on their duration: the longer vowels /a e o ø/ and the shorter vowels /ɑ ɛ i ɪ ɔ u y ʏ/. I have not carried out a repeated measures analysis of variance, like Adank *et al.* (2004) did, but based upon figure 1, the current study confirms the L2-Dutch vowels /a e o ø/ to be on the long side of the continuum, although the division is not as clear-cut as for native speakers. I did check for a possible difference in duration between the vowels that have a tense/lax contrast: the /i/-/ɪ/, /y/-/ʏ/, /e/-/ɛ/, /o/-/ɔ/ and /a/-/ɑ/ pairs. As will be shown below in section 4.3 (for formants), these vowel pairs show an overlap when plotted in an F1-F2 space, so if speakers want to distinguish between the members of a pair, they could do so by means of duration. A *t*-test was carried out for each vowel pair, with separate tests for each gender. With the exception of the male /i/-/ɪ/-pair, all tense vowels (i.e., /i y e o a/) are found to be reliably longer than their lax counterparts (/ɪ ʏ ɛ ɔ ɑ/). For the male /y/-/ʏ/-pair, /y/ is only just significantly longer ($t = 2.06$, $p = 0.044$ (two-tailed), $df = 24$). For all other vowel pairs, the tense vowel is significantly longer than the lax one (for male speakers: $t > 2.45$ and $p < 0.01$ for any of the four vowel pairs, $df = 24$; for female speakers: $t > 2.8$ and $p < 0.005$ for any of the five vowel pairs, $df = 33$).

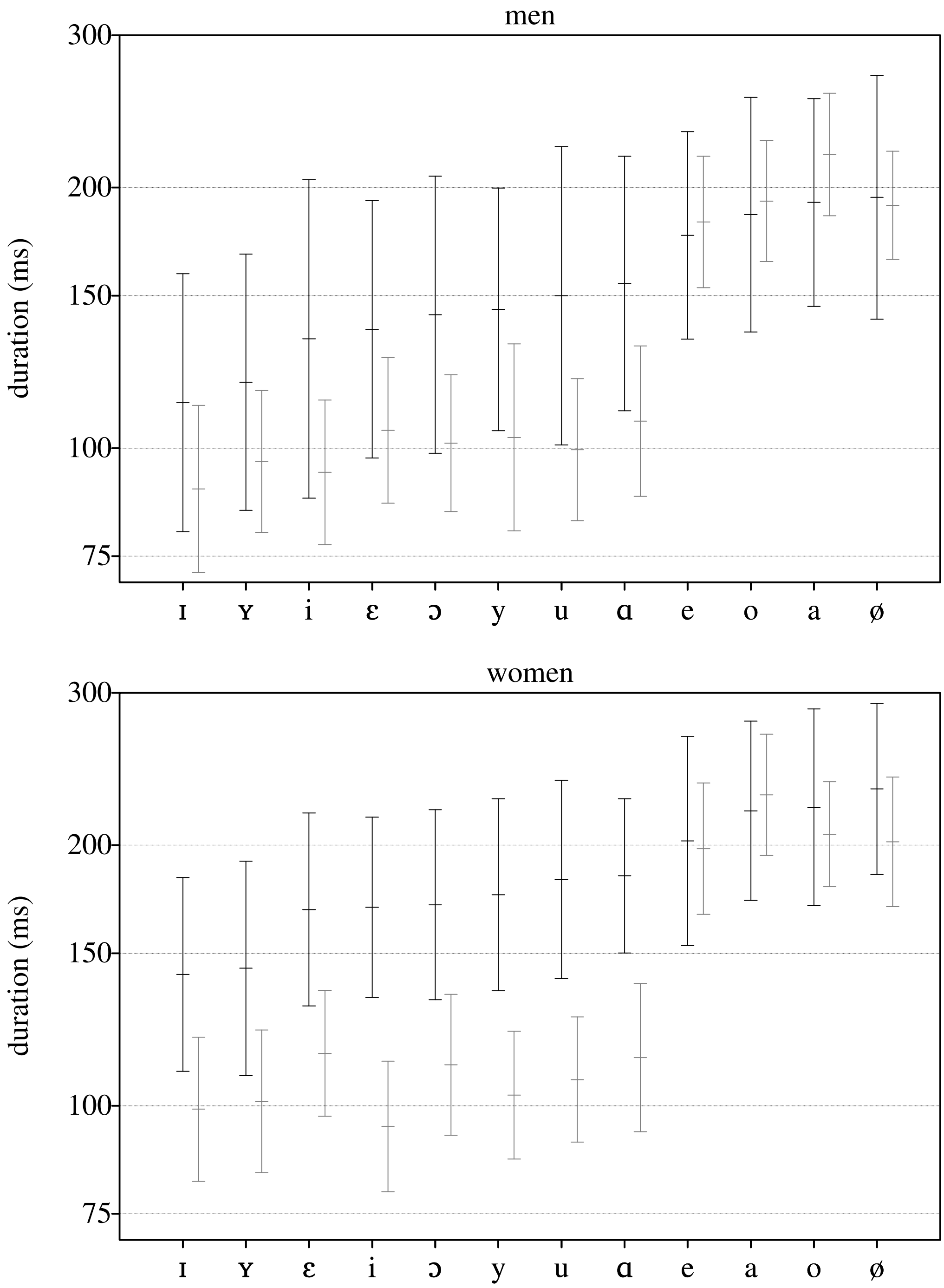

Figure 1: Geometric mean durations in milliseconds of Dutch vowels. Black: male (n=25) and female (n=34) Spanish learners of Dutch. Grey: male (n=40) and female (n=40) native speakers of Dutch (data from Adank et al. (2004). Bars represent two standard deviations, one above and one below the geometric mean. Vowels are ordered by increasing mean length of the L2-vowels.

Adank *et al.* (2004) observed that vowel durations were longer for female speakers than for male speakers, and they note that Hillen brand *et al.* (1995) have reported this before. Escudero *et al.* (accepted:17) and Ericsdotter & Ericsson (2001) make the same observation, and table 3, which contains the findings of the current study, confirms this.

Table 3: Geometric mean vowel durations (in milliseconds) of Dutch vowels by Spanish learners of Dutch.

vowel	i	ɪ	e	ɛ	y	ʏ	ø	u	o	ɔ	a	ɑ
Duration (males)	123	109	175	128	133	116	192	145	169	137	186	148
Duration (females)	170	138	208	169	177	140	234	181	225	171	224	181

When taking all vowels together, a *t*-test shows that gender turns out to be a significant factor for duration. Female vowels are on average 182.2 milliseconds (geometric mean), and male vowels 151.4 milliseconds. Female vowels are therefore a factor 1.203 higher than male vowels, with a 95% confidence interval of 1.146-1.264 ($t = 7.36$, $p = 2.6*10^{-13}$ (one-tailed), $df = 57$). One can say that female vowels are 20.3% longer than male vowels, or that male vowels are 16.9% shorter than female vowels.

Ericsdotter & Ericsson (2001) suggest that female speakers do not merely make longer vowels, but that they use greater contrasts between vowels in stressed and in unstressed position. Thus it may be that longer female vowels are an artefact of strategies for applying stress. This idea can not be verified in the current study, because all recorded vowels occur in stressed position.

4.2. Pitch

For pitch (or fundamental frequency, F0) analysis, figure 2 shows the geometric means for male and female speakers. In the plots, the bars represent two standard deviations, one above and one below the mean.

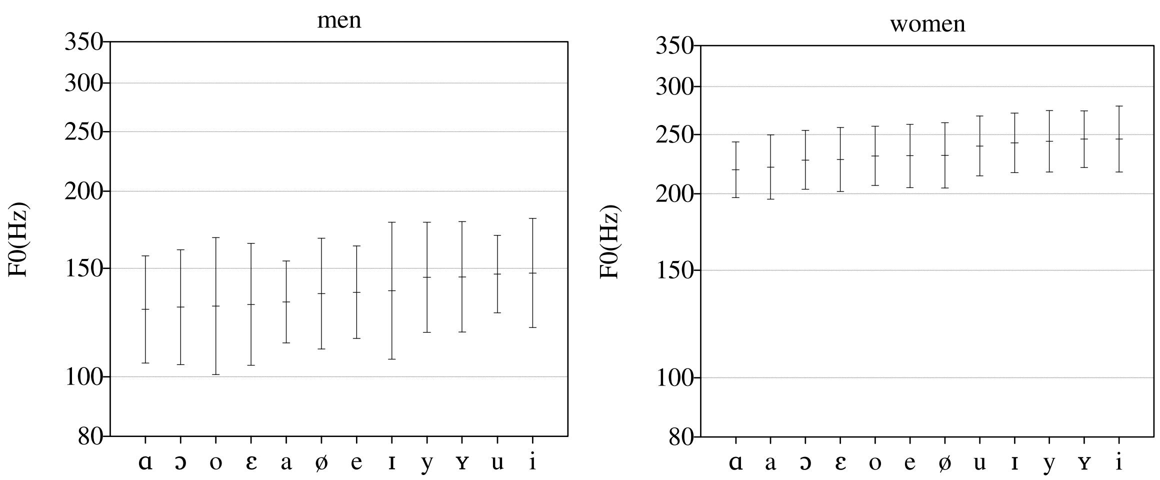

Figure 2: Geometric mean pitch of Dutch vowels by male (n=25) and female (n=34) Spanish learners of Dutch. Bars represent two standard deviations, one above and one below the geometric mean.

It is clear from these figures that female speakers have higher F0's than male speakers. This has been found in many studies and is expected from the differences in male/female physiology: females have shorter and lighter vocal folds that will vibrate easier and faster than the vocal folds of males. When taking all vowels together, the geometric mean fundamental frequency of female speakers is 233.7 Hz, and that of male speakers 137.1 Hz. Thus, female pitch is higher than male pitch with a factor 1.704, with a 95% confidence interval of 1.663-1.747 (t = 42.8, p = $1.3*10^{-198}$ (one-tailed), df = 57). One can say that female vowels have a 70.4% higher pitch than male vowels, or that male vowels have a 58.7% lower pitch than female vowels.

Also, figure 2 neatly shows a higher F0 for high vowels than for low vowels. This effect appears to be universal across languages, and is considered to be intrinsic to vowel height (Whalen & Levitt 1995).

4.3. Formant analysis

Figures 3, 4 and 5 show several vowel diagrams for Dutch vowels by Spanish speakers[4]. In figures 3 and 4, these values are compared with those of native Dutch speakers. The Dutch speaker data is taken from Bank (2009). The number of speakers for the Dutch data is 10 for the male speakers and 3 for the female speakers. Figure 3 compares geometric mean F1 and F2 values for Spanish and Dutch speakers. Figure 4 shows ellipses of one standard deviation, to get an idea of how the vowels are spread in an F1-F2-space. Figure 5 shows a scatter plot with median F1 and F2 values per speaker (i.e., for every speaker twelve median vowel values are depicted, so the number of tokens per gender diagram is 12 x the number of speakers of that gender). All formant analyses were done with the optimal formant ceiling method discussed above.

[4] To make it easier to compare the three figures, all three have the same scale (per gender).

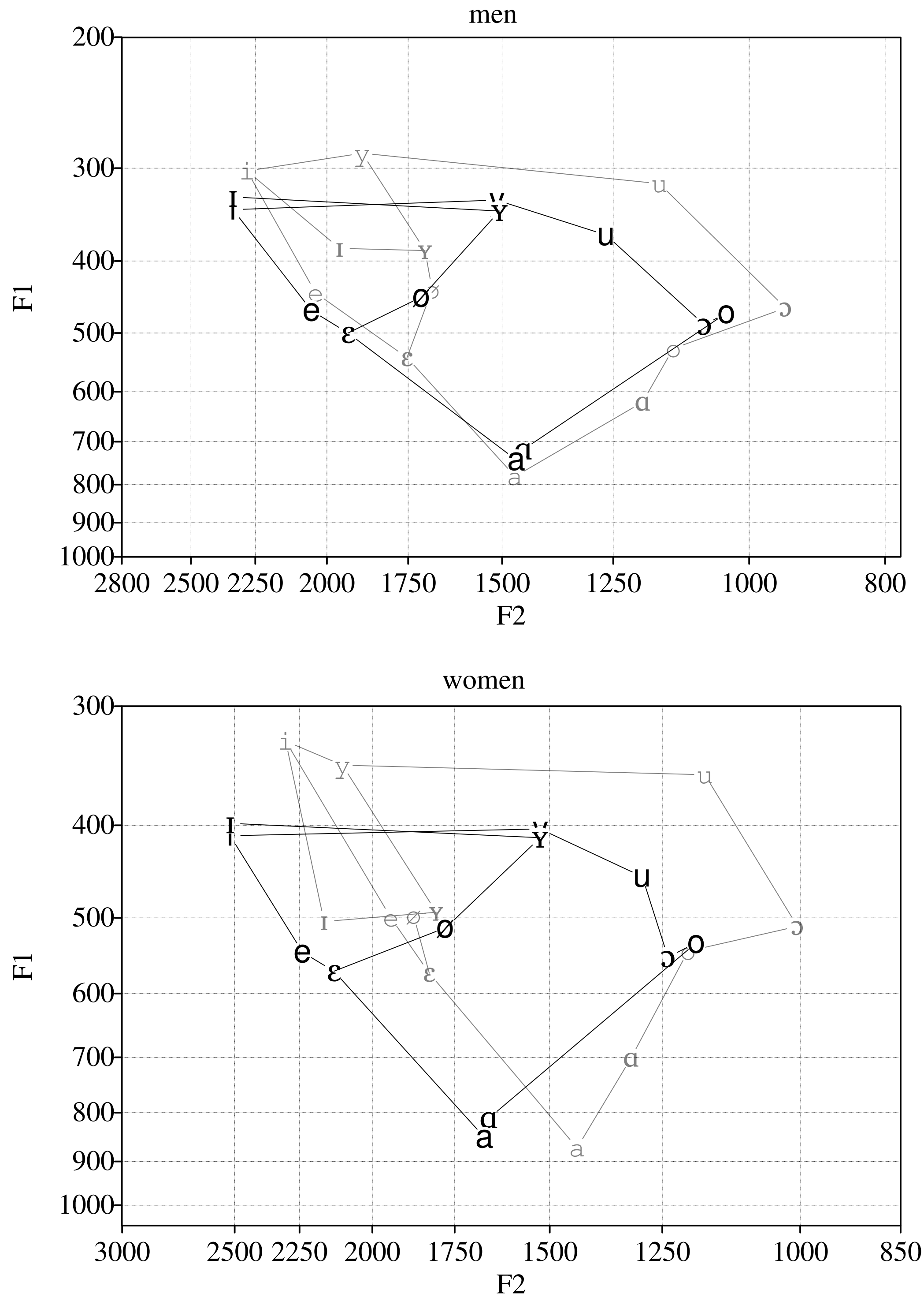

Figure 3: Vowel diagrams for Dutch vowels. Top: male Spanish learners (n=25) in black lines, Dutch speakers (n=10) in grey lines; bottom: female Spanish learners (n=34) in black lines, Dutch speakers (n=3) in grey lines (data from Bank 2009). Vowel symbols represent geometric means.

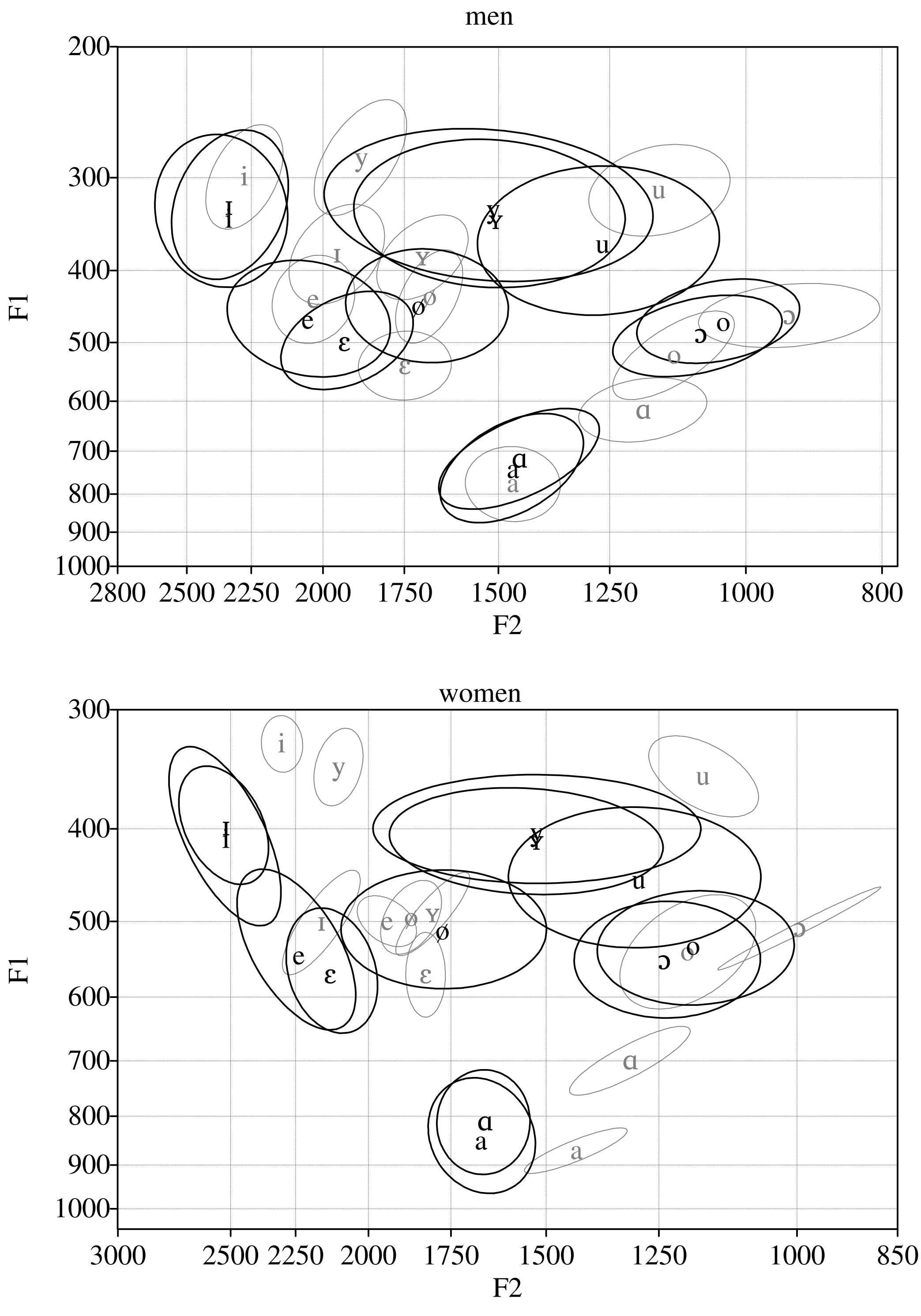

Figure 4: Vowel diagram for Dutch vowels. Ellipses represent 1 standard deviation, vowel symbols represent the geometric mean. Top: male Spanish learners (n=25) in black circles, Dutch speakers (n=10) in grey circles; bottom: female Spanish learners (n=34) in black circles, Dutch speakers (n=3) in grey circles (data from Bank 2009).

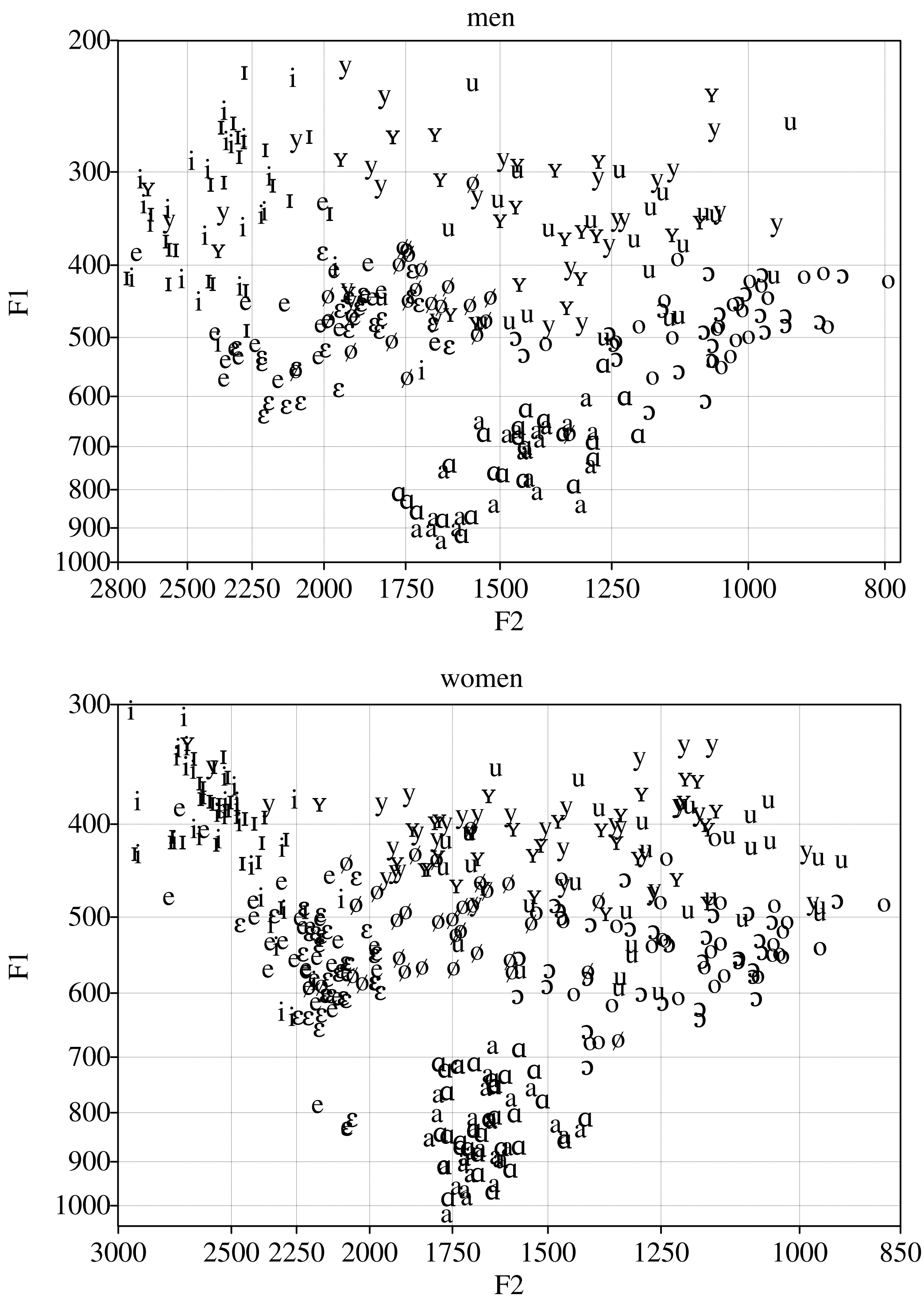

Figure 5: Scatter Plot for Dutch vowels by Spanish learners. Vowel symbols represent the median value per speaker. Top: male speakers (n=25); bottom: female speakers (n=34).

Two things spring to attention. First, as figures 4 and 5 show, for several vowels there is so much overlap that they become almost indistinguishable. This is the case for the /a/-/ɑ/, /i/-/ɪ/, /o/-/ɔ/ and /y/-/ʏ/ pairs, that show a tense/lax contrast. Remarkably, there seems to be a clear contrast between /e/ and /ɛ/. Second, the low F2 values of /y/ and /ʏ/ stand out. For female speakers, the geometric mean /y/ and /ʏ/ F2-values are even lower than those of /a/ and /ɑ/, whereas for female L1-Dutch speakers, F2-values of /y/ are much higher than those of /a/. These two salient features will now be analysed more closely, starting with the vowel pair overlaps.

As noted above, in the vowel diagrams of figures 3, 4 and 5, four vowel pairs seem to overlap almost completely: /a/-/ɑ/, /i/-/ɪ/, /o/-/ɔ/ and /y/-/ʏ/. For /e/-/ɛ/ there seems to be a difference. To see if the members of these five vowel pairs are reliably different from each other in F1 and F2, several two-tailed *t*-tests were carried out. Table 4 shows the results.

Table 4: Ratios and 95% confidence intervals for F1 and F2 for male and female speakers, for five vowel pairs. For male speakers: df=24. For female speakers: df=33.

Male speakers	Ratio for F1	95% confidence interval for F1:		Ratio for F2	95% confidence interval for F2:	
/i/-/ɪ/	1.0395	0.9181	1.1768	0.9994	0.9449	1.0572
/y/-/ʏ/	0.9666	0.8587	1.0880	1.0044	0.8725	1.1562
/e/-/ɛ/	0.9338	0.8671	1.0056	1.0617	0.9965	1.1313
/o/-/ɔ/	0.9633	0.9084	1.0214	0.9638	0.8974	1.0351
/a/-/ɑ/	1.0336	0.9564	1.1170	1.0116	0.9539	1.0728

Female speakers	Ratio for F1	95% confidence interval for F1:		Ratio for F2	95% confidence interval for F2:	
/i/-/ɪ/	1.0313	0.9592	1.1089	0.9987	0.9638	1.0349
/y/-/ʏ/	0.9797	0.9350	1.0265	0.9998	0.8978	1.1133
/e/-/ɛ/	0.9546	0.8920	1.0215	1.0518	1.0193	1.0853
/o/-/ɔ/	0.9664	0.9188	1.0164	0.9544	0.8909	1.0224
/a/-/ɑ/	1.0486	1.0015	1.0979	1.0055	0.9777	1.0340

Please note that all values in table 4 are ratios, so, for instance for the /i/-/ɪ/-comparison in F1 for female speakers, a ratio of 1.0313 means that F1 for /i/ is 3.13% higher than F1 for /ɪ/. However, this 1.0313 ratio is not reliably different from 1, because the 95% confidence interval includes 1 itself. Indeed, the confidence intervals for the various vowel pairs show that there is almost no pair whose members are reliably different from one another, with two exceptions: for female speakers, F1 for /a/ is reliably higher than F1 for /ɑ/ (t = 2.06, p = 0.043, df = 33), and F2 for /e/ is reliably higher than F2 for /ɛ/ (t = 3.22, p = 0.0020, df = 33). When pooling the two genders, under the assumption that gender does not have an effect on

F1/F2 *ratios*, the result becomes more clear-cut: the /e/-/ɛ/ ratios for both F1 and F2 are reliably different from 1. For F1, /e/ is reliably lower than /ɛ/ (t = -2.00, p = 0.048, df = 58), and for F2, /e/ is reliably higher than /ɛ/ (t = 3.02, p = 0.004, df = 58). In either way, table 4 justifies the observation that most vowel pairs with a tense/lax difference overlap (i.e., most pairs are not reliably different form each other); moreover, the difference between /e/ and /ɛ/ that was observed on the basis of figures 3 and 4 holds when pooling the genders.

Another salient feature of figures 3 and 4 is the low mean F2 values for /y/ and /ʏ/. The F2 values in figure 3 are geometric means over the medians of the vowels per speaker. To see what really happens, figure 6 presents scatter plots for /y/ and /ʏ/. Please note that the scale of the diagrams is the same as in figures 3, 4 and 5. This makes it all the more clear that in the plots in figure 6, there is a large spread in F2 for these two vowels. All other vowels show more or less round token clouds, that are relatively compact. The spread in F1 for /y/ and /ʏ/ is not particularly big, but the spread in F2 is. For female speakers, /y/ and /ʏ/ show similar behaviour as for the male speakers.

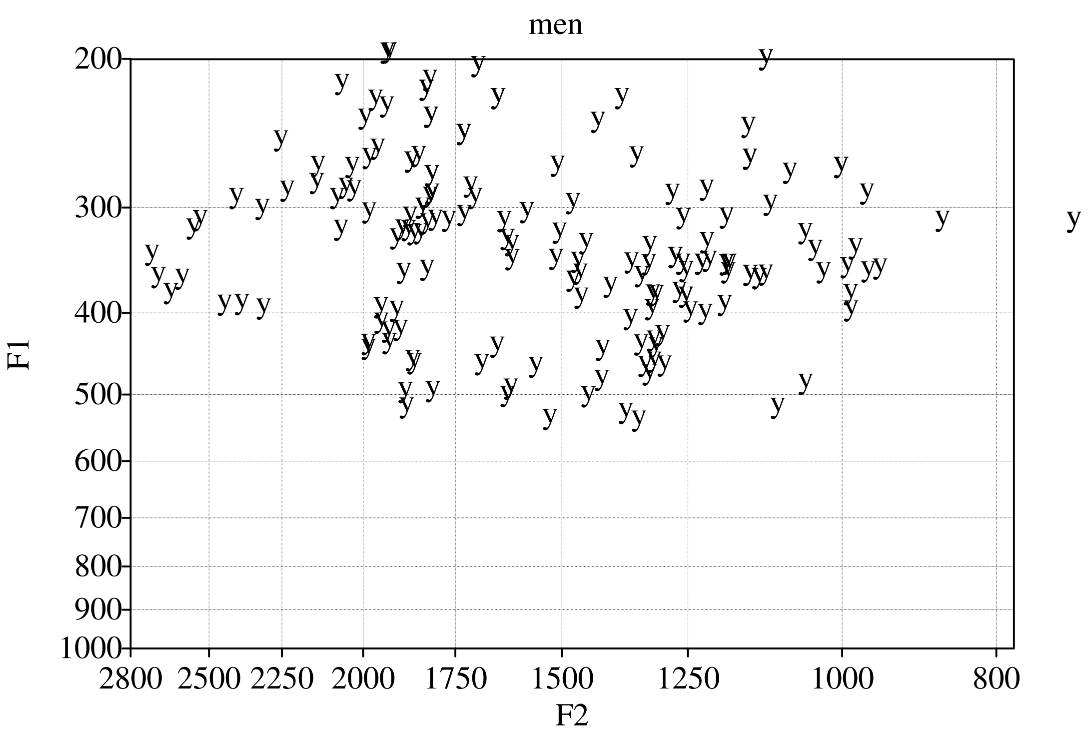

Figure 6a: Scatter plot for the Dutch vowel /y/ (n=173), for male Spanish learners (n=25). Each vowel in the plot represents one token.

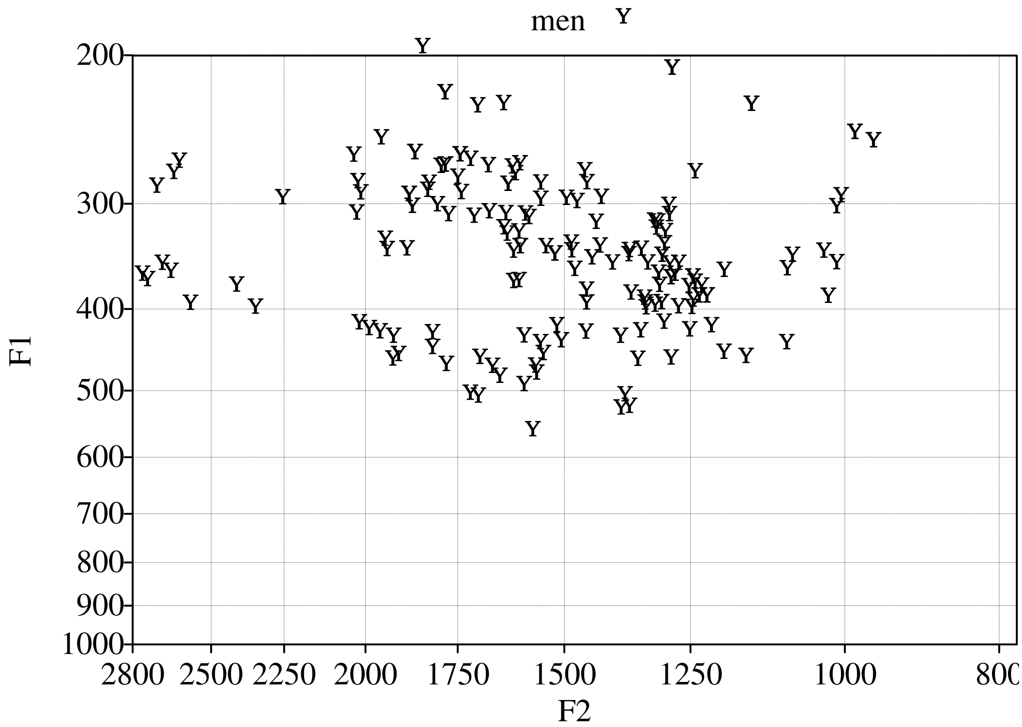

Figure 6b: Scatter plot for the Dutch vowel /ʏ/ (n=178), for male Spanish learners (n=25). Each vowel in the plot represents one token.

But even these scatter plots do not present the whole picture. Figure 7 shows the distributions across the F2-values of the vowels /y/ and /ʏ/.

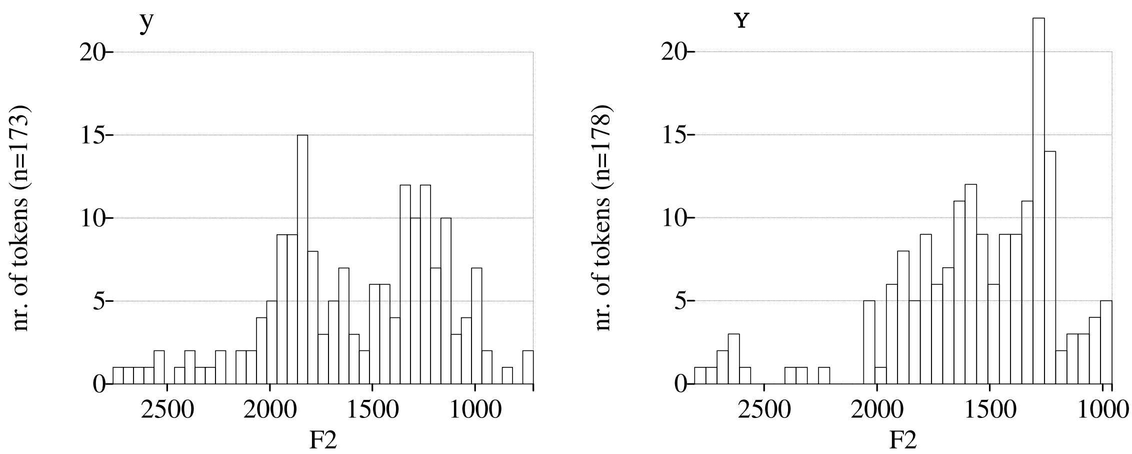

Figure 7: Distribution of F2 for /y/ (left) and /ʏ/ (right), for male Spanish learners (n=25). Bars represent the number of vowels in ranges of 50 Hz.

From the distribution plots, it becomes clear that /y/ and – to a somewhat lesser extent – /ʏ/ have a bimodal distribution. Although not depicted here, this also applies to female speakers.

In addition to a formant analysis of the centre of the vowel, another analysis was carried out to check for diphthongization. Most vowels appear to be hardly diphthongized; exceptions are /e/, /ø/ and /o/, as expected for Dutch (Adank *et al.* 2004, Gussenhoven 1999). Figure 8 shows the results, where for female speakers especially /ø/ stands out.

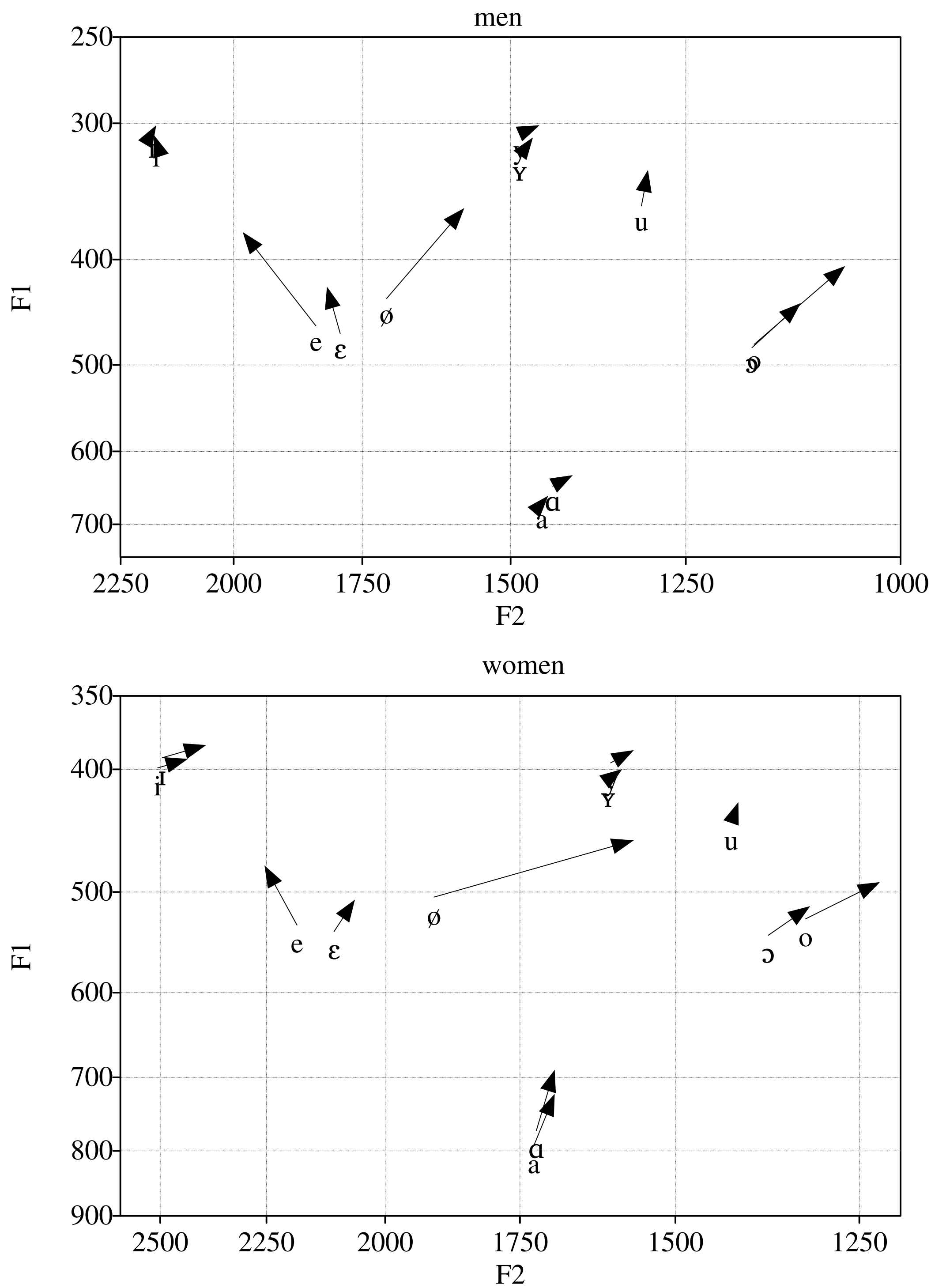

Figure 8: Diphthongization of Dutch vowels by male (n=25) and female (n=34) Spanish learners of Dutch. Arrows represent shift in geometric mean from 25% (start of line, near vowel token) to 75% (point of the arrow) of the vowel.

An important observation to be made from these pictures is that a comparable pattern can be seen as in the vowel diagrams of figures 4 and 5 earlier in this section: the /a/-/ɑ/, /i/-/ɪ/, /o/-/ɔ/ and /y/-/ʏ/ pairs, which overlapped almost completely both for male and for female speakers, hardly diphthongize, and when they do, they often move in the same direction. The only vowel pair whose members were shown to be reliably different was the /e/-/ɛ/ pair; this is also the vowel pair whose members clearly differ in spectral change. For male speakers, the vowel /e/ has, on average, a glide towards a lower F1 (from 460 Hz to 377 Hz, geometric means) and a higher F2 (from 1837 Hz to 1980 Hz). Measured at the 25% and 75% points in the vowel, this is a difference of factor 1.220 for F1 (95% c.i. 1.142-1.303, $t = 6.21$, $p = 1.0*10^{-6}$, $df = 24$), and a difference of factor 0.928 for F2 (95% c.i. 0.903-0.954, $t = -5.67$, $p = 3.8*10^{-6}$, $df = 24$). Diphthongization for /e/ for native Dutch speakers was also found by Adank *et al.* (2004:1735). Scatter plots and distribution ratios will be shown in section 5.3. For /ɛ/, there is a slight (but reliable) glide towards a lower F1: the 25% and 75%-points of the vowel differ with a factor 1.104 (95% c.i. 1.070-1.139, $t = 6.57$, $= 4.2*10^{-7}$, $df = 24$). There is no reliable change in F2 for /ɛ/.

The results found in this section will be discussed next.

5. Discussion

First, the results of the close analysis of /y/ and /ʏ/ will be discussed, and the diphthongization of /ø/. Then, some hypotheses are tested that follow from this discussion.

5.1. Backness of /y/and /ʏ/

As shown in the previous section, one of the salient features in the formant analysis was the backness of /y/ and /ʏ/, or low F2 values. The vowels /y/ and /ʏ/ do not exist in Spanish. Figure 7 showed a bimodal distribution for /y/ and /ʏ/, for male Spanish learners of Dutch. From this figure, it appears that some speakers do manage to produce the target vowel (low F1, high F2), and some speakers do not, producing a back vowel instead (low F1, Low F2, like the /u/ in figure 7). There are two possible influences. One is roundedness; this causes the difference between /i/ and /y/ (or /ɪ/ and /ʏ/). Although no /y/ or /ʏ/, Spanish does have [+ roundedness] as a feature in its vowel inventory, namely in /u/. So, when pronouncing the un-

Spanish /y/ or /ʏ/, speakers apply rounding, and because roundedness is connected with a low F2, the high F2 target is not met. The other possible influence is orthography. Remember that the Spanish word “sus” is pronounced /sus/, but the Dutch word “sus” is pronounced /sʏs/, and “suus” is pronounced /sys/. For Spanish learners of Dutch, it will be easy to mistake the Dutch word for a Spanish one (that is, where its pronunciation is concerned). Clearly, proficiency in the second language will play a role in this. It seems that some speakers fall back on the way they would pronounce the written text in their own language. So, learners will need the knowledge that certain graphemes of the L2 have a different pronunciation than they are used to in their L1. In this light, it's not surprising that non-proficient learners would pronounce Dutch targets /y/ and /ʏ/ as /u/.

5.2. Diphthongization of /ø/

An effect possibly related to orthography may be the diphthongization of /ø/. This vowel is usually considered a monophthongal vowel in Dutch, although it may be slightly diphthongized (see for example Gussenhoven 1999). In Dutch, the vowel is written as digraph “eu”. Adank *et al.* (2004:1735) report a diphthongization of /ø/ with only a slight shift in F2, but quite a big shift towards a lower F1. Gussenhoven (1999) reports the same. Spanish learners of Dutch show, on average, a big shift towards a lower F1 *and* a big shift towards a lower F2. In the light of the influence of orthography, this is hardly surprising: in Spanish, “eu” is a diphthong, and would be pronounced as a glide from /e/ towards /u/ (Martínez-Celdrán *et al.* 2003). And possibly, some speakers just have no clue, as illustrated by the title of this thesis: the reader who spoke the sentence “in soes en in sieze zit de a.” (/ɪn sus ɛn ɪn sizə zɪt də a/) had the vowel /ø/ as her target[5]. To get a clearer picture of what individual speakers are doing, figure 9 shows scatter plots of the vowel /ø/ for male and female speakers.

[5] Because in all figures the mean and median values of all vowels are shown, this individual case is not visible in any figure.

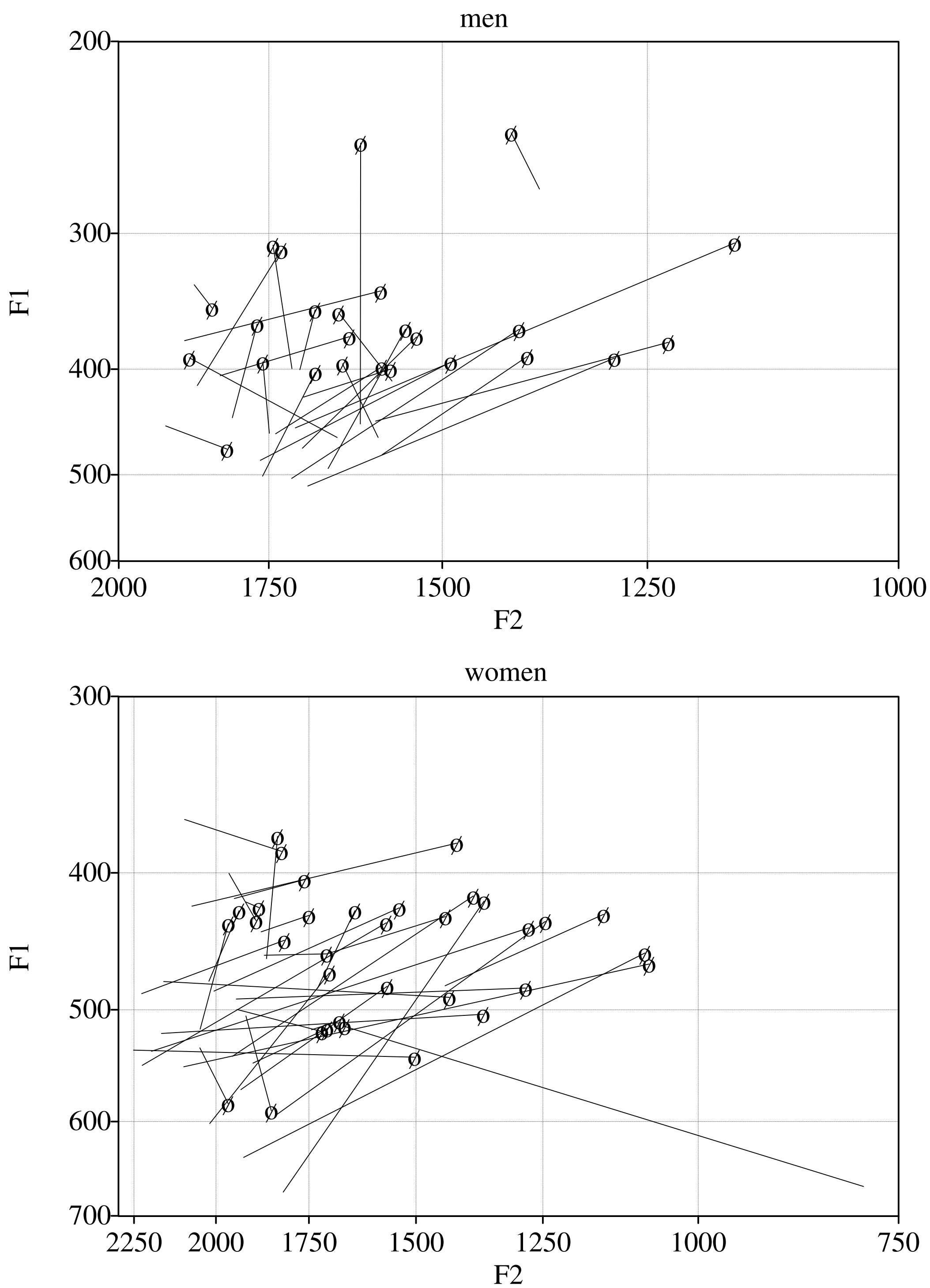

Figure 9: Diphthongization of Dutch /ø/ by male (n=25) and female (n=34) Spanish learners of Dutch. Lines represent shift in median value per speaker from 25% (start of line) to 75% (vowel symbol) of the vowel /ø/.

Figure 9 shows that only a few of the Spanish learners pronounce the Dutch vowel /ø/ native-like (that is, in the way reported by Adank *et al.* 2004). The majority of speakers pronounce "eu" the Spanish way, as a glide from /e/ towards /u/, and some speakers do other things. To

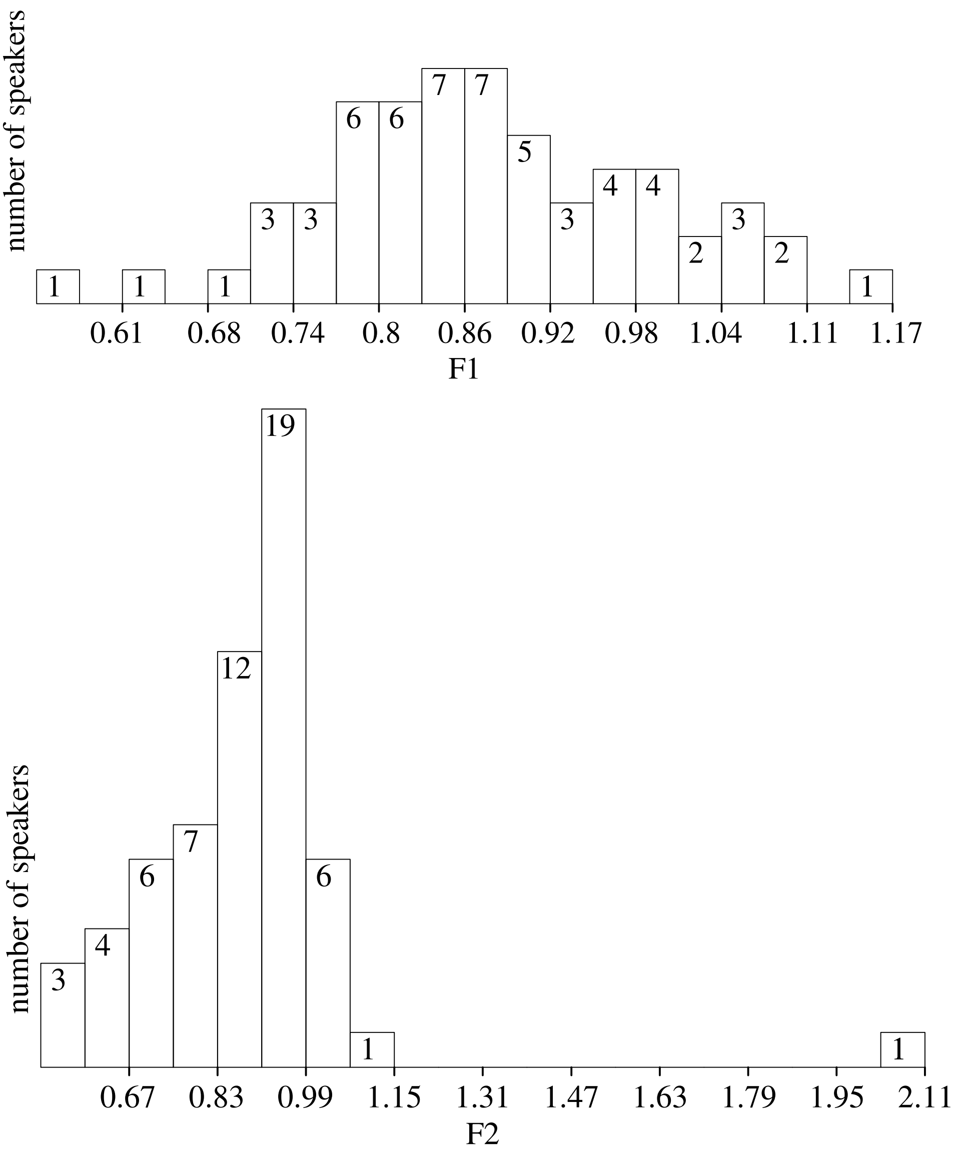

Figure 10: Ratio disttribution of the change in F1 (top) and F2 (bottom) between the 25% and 75% points in the vowel, for Dutch /ø/ by Spanish learners of Dutch (both genders, n=59). The width of a bar represents 5% of the total ratio-difference. The numbers in the bars represent the number of speakers in this 5% range.

see if the distribution of the differences between the 25% and 75%-points in the vowel is bimodal, figure 10 gives an overview. This shows that there is no clear bimodal distribution of the 25-75% ratios. This also applies for the distribution for male speakers alone, or for female speakers alone. The majority of speakers have an F1-ratio lower than 1, indicating a shift towards a lower F1. Twenty-one speakers have a ratio around 1 for F2, indicating that their F2 hardly changes. The rest of the speakers shifted towards a lower F2. The female speaker who shifted her /ø/ almost a 1000 Hz towards a higher F2 is clearly marked in figure 10.

5.3. Diphthongization of /e/

Section 4.3 showed a reliable change in F1 and F2 for /e/. Like /ø/, the vowel /e/ is a monophthongal vowel that shows slight diphthongisation (Adank *et al.* 2004, Gussenhoven

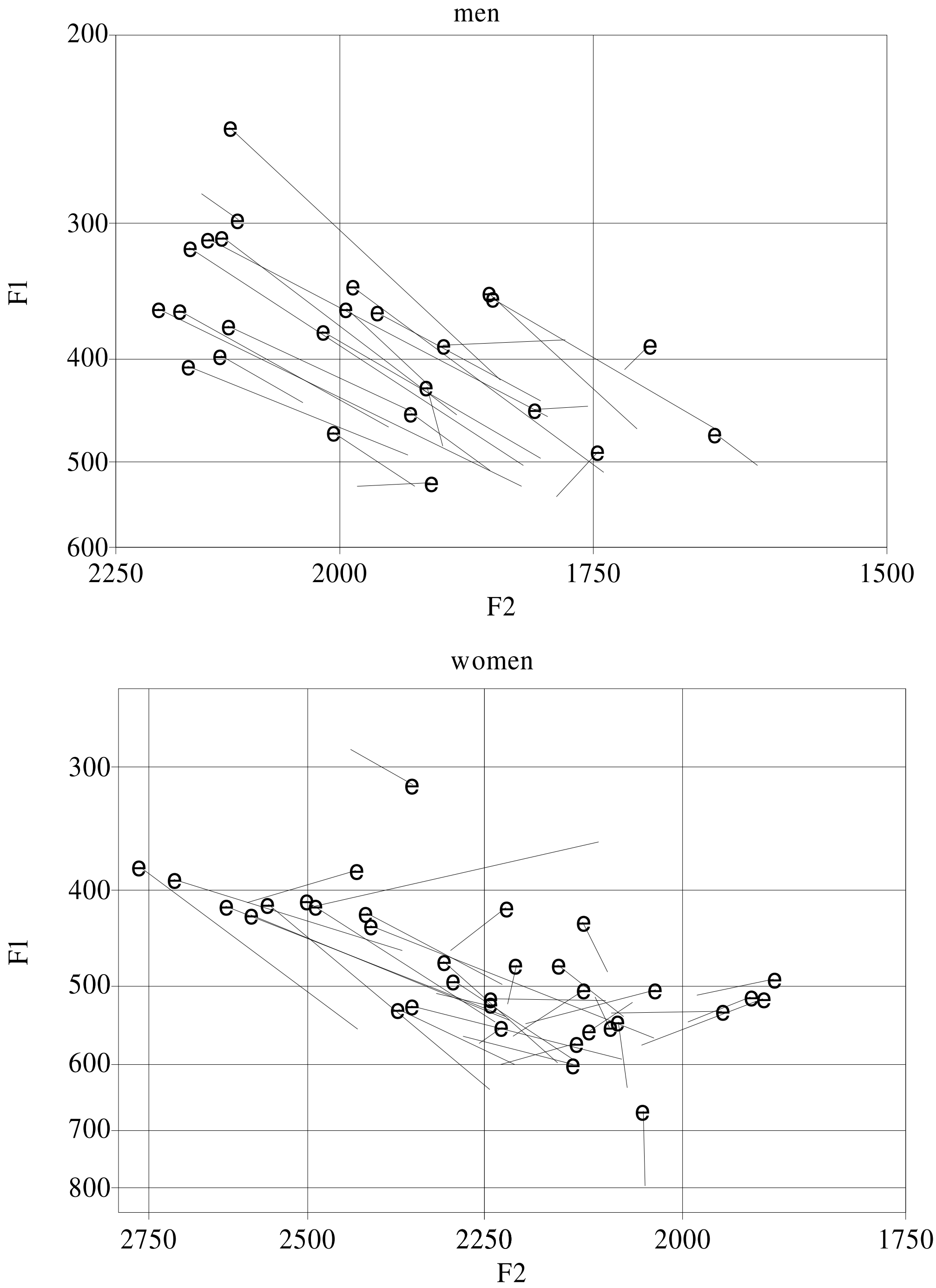

Figure 11: Diphthongization of Dutch /e/ by male (n=25) and female (n=34) Spanish learners of Dutch. Lines represent shift in median value per speaker from 25% (start of line) to 75% (vowel symbol) of the vowel /e/.

1999). Figure 11 shows scatter plots of the vowel /e/ for male and female speakers. Especially for male speakers, a clear shift towards a lower F1 and a higher F2 is visible. Female speakers show a clear shift towards a lower F1, but have no clear direction in F2. Figure 12 shows the distribution. As expected, the majority of speakers show a negative ratio in their F1-shift.

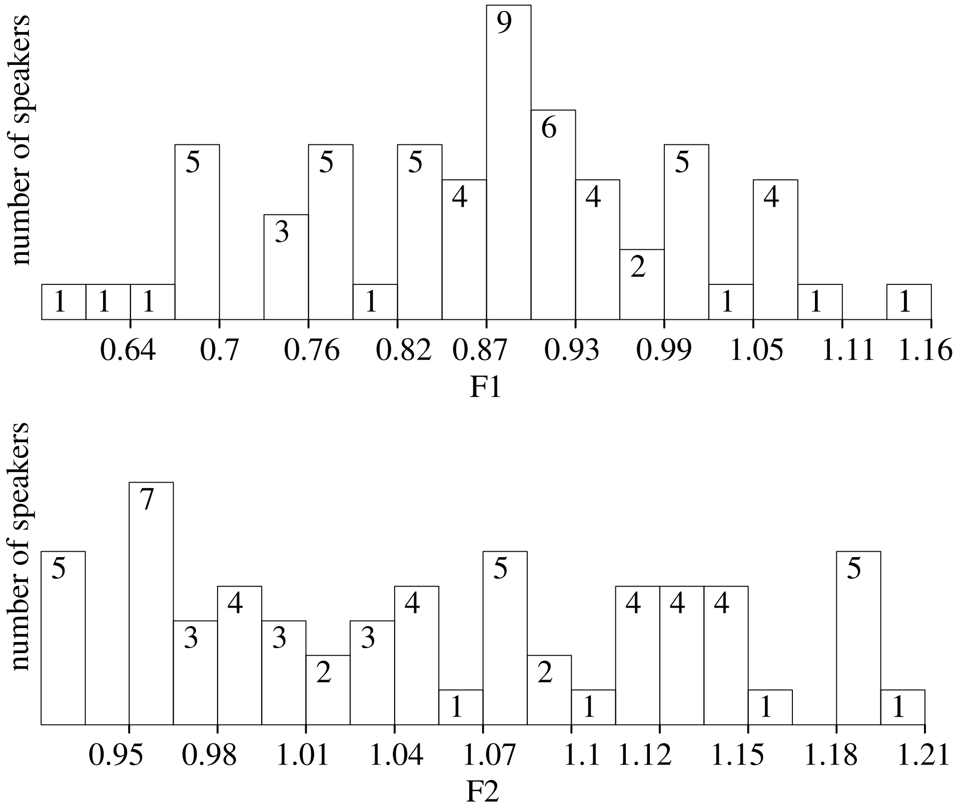

Figure 12: Ratio disttribution of the change in F1 (top) and F2 (bottom) between the 25% and 75% points in the vowel, for Dutch /e/ by Spanish learners of Dutch (both genders, n=59). The width of a bar represents 5% of the total ratio-difference. The numbers in the bars represent the number of speakers in this 5% range.

5.4. Tense/lax overlap under influence of orthography

Other results could be traced back to the Spanish L1-origins of the speakers as well. The big overlap of tense and lax vowels is likely to be the result of the fact that in Spanish there is no distinction between these two. However, please recall that for most tense/lax vowel pairs, there was a significant difference in duration between the tense and the lax member of the pair. This can also be explained with Dutch orthography: in order to disambiguate between, say, /y/ and /ʏ/ in the "sVs"-context, the word with the tense vowel is written with two graphemes, as an indication for tense pronunciation. So, tense /sys/, /sas/, /sos/ and /ses/ are written "suus", "saas", "soos" and "sees", whereas lax /sʏs/, /sɑs/, /sɔs/ and /sɛs/ are all written with one grapheme (i.e., “sus”, “sas”, “sos” and “ses”). For the “sVse”-context, there is no difference in writing for the vowels, all are written with one grapheme. The tense/lax-distinction in this context is made by doubling the following consonant (e.g., “suse” for /sysə/ and “susse” for /sʏsə/). Please note that the tense vowels in /sis/, /søs/ and /sus/ are always written with two graphemes, in both contexts (e.g., “sies” vs. “siese”, “seus” vs. “seuse”). Table 5 sums up.

Table 5: Indication of tenseness/laxness, for written form of “u”, “a”, “o” and “e”. The number of “V”‘s stands for the number of graphemes in the written text.

	“sVs”-context	“sVse”-context
tense	“sVVs”	“sVse”
lax	“sVs”	“sVsse”

Against this background, I hypothesize that the double graphemes in “suus”, “saas”, “soos” and “sees”, indicating the tense vowels /y/, /a/, /o/ and /e/, will trigger longer durations than for their lax counterparts, and longer durations than in the “sVse”-context. This is hypothesis 1, which is testable with the current data. This will be discussed in section 5.6.

5.5. Duration: Latin American vs. European Spanish

There is another hypothesis that can be made from, and is testable with, the current data, hypothesis 2: Morrison & Escudero (2007) observed that there are substantial differences in vowel length for Spanish vowels between European Spanish and Peruvian Spanish dialects, in that European Spanish vowels have shorter durations. I hypothesize that with the current data, comparable differences will be found for the duration of Dutch vowels, spoken by Spanish learners of Dutch. This hypothesis also will be tested and discussed in section 5.7.

5.6. Hypothesis 1: tense/lax overlap under influence of orthography

Under the influence of orthography, I hypothesized that, for /y/, /a/, /o/ and /e/, the vowel in the first word of a sentence (“sVs”) will be longer than the vowel in the second word (“sVse”), and within the “sVs”-context, that the vowel will be longer than its lax counterpart (i.e., for /ʏ/, /ɑ/, /ɔ/ and /ɛ/). Figure 13 gives the results for male and female speakers.

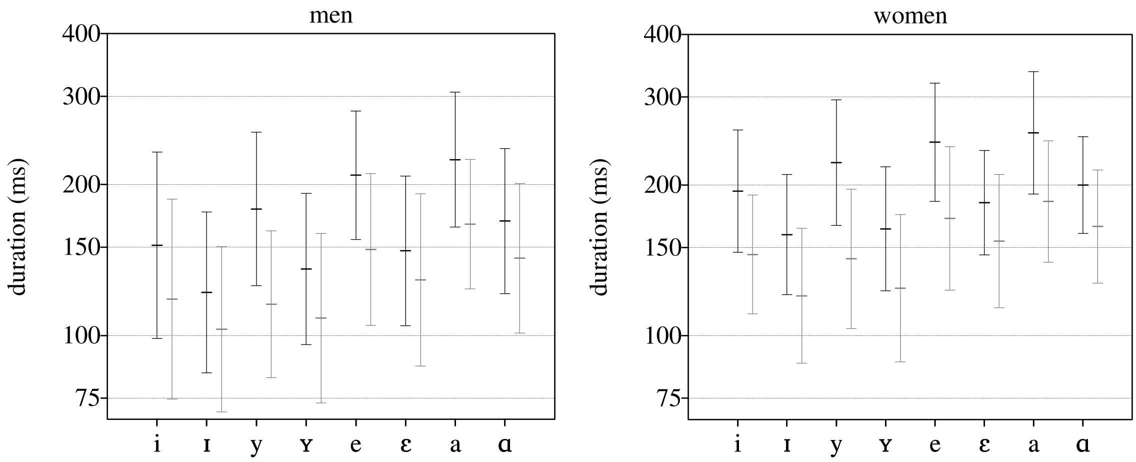

Figure 13: Geometric mean vowel durations of Dutch vowels by male (n=25) and female (n=34) Spanish learners of Dutch, in "sVs"-context (black lines) and "sVse"-context (grey line). Bars represent two standard deviations, one above and one below the geometric mean.

It does not immediately become clear from these pictures whether there are big differences in duration depending on the context. The figures do show, as observed before, the duration differences between tense and lax vowels. I carried out several one-tailed *t*-tests to see if tense vowels in "sVs"-contexts are reliably longer than in "sVse"-context. For male speakers, this turns out to be true for /y/, /e/, /o/ and /a/ (within a 95% confidence interval; for all vowels: $t > 3.4$, $p < 0.0012$, $df = 24$). However, with lax /ʏ/ there is also a reliable difference found (95% c.i. 1.0162-1.5455, $t = 2.16$, $p < 0.036$, $df = 24$). As expected, no reliable difference is found for tense /i/, /u/ and /ø/, and neither for lax /ɪ/. Oddly[6], for female speakers, all vowels in "sVs"-context are reliably longer than vowels in "sVse"-context, with ratios between 1.194 (for /ɔ/, 95% c.i. 1.0451-1.3648, $t = 3.11$, $p = 0.0028$, $df = 31$) and 1.557 (for /y/, 95% c.i. 1.3436-1.8053, $t = 5.99$, $p = 9.6*10^{-8}$, $df = 31$). The four vowels /y/, /e/, /o/ and /a/ do have the highest differences between the two contexts, as was expected.

Leaving the "sVs"/"sVse"-context, I now turn to the tense/lax-ratios. These can be expressed in one number per speaker per combination. So, for the "sVs"-context, for each speaker, a ratio can be computed between her median /y/ and her median /ʏ/. If this ratio is reliably different from 1, one can say that tense and lax vowels differ in duration, with

[6] Actually, this is not so odd; Shatzman & McQueen (2006), report that short duration of a syllable tends to be interpreted by a listener as the first syllable in a bisyllabic word, and that a long syllable duration tends to be interpreted as a monosyllabic word. However, they do not report a gender difference. In the current study, the odd thing is that this duration difference is not consistently found for male speakers.

orthography as the only factor. As table 6 shows, this is indeed the case, except for the male /i/-/ɪ/-difference, as was expected.

Table 6: Ratios and 95% confidence intervals for duration ratios of Dutch vowels in "sVs"-context, with t- and p-values.

male speakers	duration ratio	95% confidence interval for duration:		*t*	*p*
/i/-/ɪ/	1.2414	0.9888	1.5585	1.911	0.062
/y/-/ʏ/	1.3175	1.0801	1.6072	2.790	0.0076
/e/-/ɛ/	1.4145	1.1789	1.6971	3.827	0.00038
/o/-/ɔ/	1.4094	1.1554	1.7191	3.472	0.0011
/a/-/ɑ/	1.3262	1.1044	1.5925	3.102	0.0032
female speakers	duration ratio	95% confidence interval for duration :		*t*	*p*
/i/-/ɪ/	1.2204	1.0660	1.3972	2.940	0.0046
/y/-/ʏ/	1.3570	1.1810	1.5593	4.387	0.000042
/e/-/ɛ/	1.3198	1.1656	1.4944	4.458	0.000032
/o/-/ɔ/	1.3761	1.2094	1.5658	4.936	$5.6*10^{-6}$
/a/-/ɑ/	1.3262	1.1255	1.4392	3.917	0.00022

The fact that no reliable difference is found for the male /i/-/ɪ/-pair is an indication of the point being made that it is orthography that is of influence here. In other words, it is not possible to say that *all* tense vowels are reliably longer than their lax counterparts, only the tense vowels that are written with double (and equal) graphemes.

In "sVse"-context, almost no reliable differences are found. Exceptions are /i/-/ɪ/ and /o/-/ɔ/ for female speakers, with /i/ being reliably different from /ɪ/ with a factor 1.2106 (95% c.i. 1.0506-1.3950, t = 2.69, p = 0.0090, df = 33), and /o/ being reliably different from /ɔ/ with a factor 1.1701 (95% c.i. 1.0012-1.2781, t = 2.01, p = 0.048, df = 33).

In perception, Spanish learners of L2-English are known to take duration into account when classifying a tense/lax difference in vowels (see for instance Kondaurova & Francis 2008). The fact that here (almost) no duration distinction was found for this contrast in "sVse"-context does not necessarily mean that speakers do not make this distinction in production, the point being that orthography is of influence here. To test if speakers do make a tense/lax duration contrast in vowel production, it would possibly be better to use a picture naming task to elicit speech.

5.7. Hypothesis 2: duration of Latin American vs. European Spanish

Morrison & Escudero (2007) report 33.9% shorter vowels for European speakers in comparison to Peruvian speakers. The authors suggest that this may be an artefact of speaking rate, because Spaniards have a reputation for speaking quickly (Morrison & Escudero 2007:1508). If this suggestion is correct, a corresponding difference would be predicted for the data in the current study. For simplicity, I will assume that all Latin American Spanish dialects can be taken together as one group[7].

Figure 14 does indeed suggest that, when speaking Dutch, speakers from both dialects show a substantial difference in vowel length. The dashes in the middle of the bars represent the geometric mean in duration, the bars themselves represent two standard deviations (one above and one below the mean).

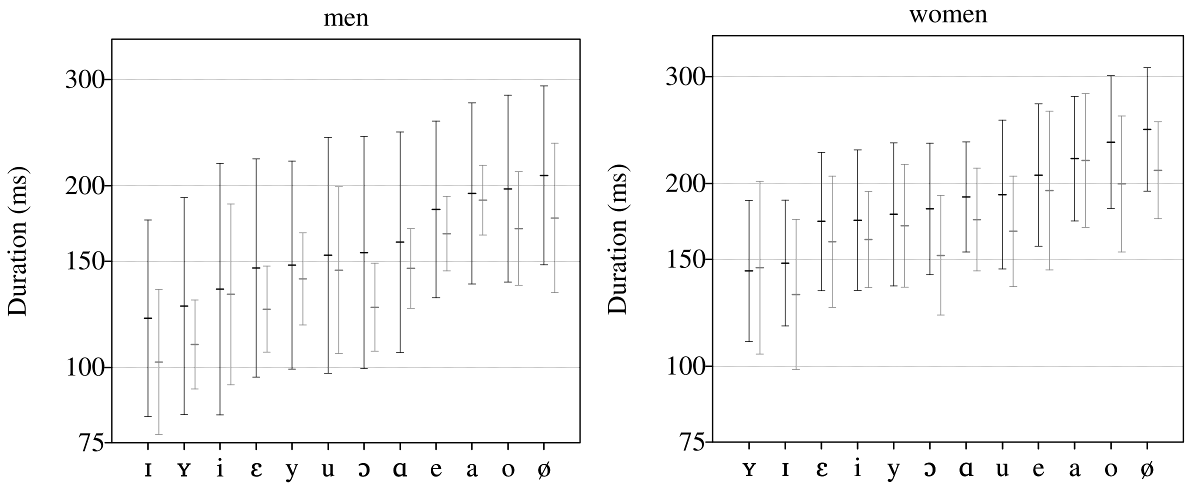

Figure 14: Geometric mean vowel durations of Dutch vowels by male and female speakers of Latin American Spanish (black lines; men: n=15, women: n=22) and European Spanish (grey lines; men: n=10, women: n=12). Bars represent two standard deviations, one above and one below the geometric mean.

Although the mean vowel duration for European speakers appears to be lower, the range in two standard deviations is for many vowels a lot smaller than for Latin American speakers. I conducted several *t*-tests to check if Dutch vowels by Latin American speakers of Spanish are reliably longer than those of European speakers of Spanish. This is indeed the case: for male speakers, vowel duration is longer for Latin American speakers with a factor 1.1182 (95% c.i.

[7] although Morrison & Escudero (2007:1508) do warn that "[w]hether these results will generalise to other phonetic contexts or to other sets of Spanish dialects remains to be tested".

1.0253-1.2196, $t = 2.54$, $p = 0.012$, $df = 24$)[8]. For female speakers it is slightly less, but still reliably different: Latin American speakers have longer vowel durations with a factor 1.0942 (95% c.i. 1.0316-1.1605, $t = 3.00$, $p = 0.0028$, $df = 33$)[9].

Because the plots show big differences in duration range between the dialects per vowel, I also carried out *t*-tests per vowel, to see if all Dutch vowels by Latin American speakers (DLA) vowels are reliably longer than those of European speakers (DES) vowels. It turns out that this is not the case. For male speakers, all DLA vowels were found to be longer than their DES counterparts, however, none was found to be reliably different (at the $\alpha = 0.05$ level, $df = 23$). For female speakers, two DLA vowels (/ɛ/ and /ʏ/) were found to be shorter than their DES counterparts, and all others were longer, but just as for the male speakers, no vowel was found to be reliably different across the two dialects (at the $\alpha = 0.05$ level, $df=32$).

6. Conclusion

An acoustic analysis of Dutch vowels spoken by Spanish learners of Dutch was presented. The differences between Dutch vowels by Spanish learners and native speakers can be explained on the basis of orthography. It is likely that Spanish learners of Dutch would benefit from a training in orthographic differences. L2-literacy should therefore be as important as L2-speech proficiency. Rolla *et al.* (2006) suggest that teachers should be aware of the phonology and orthography of their pupil's L1, in order to distinguish between real errors in pronunciation or spelling, or substitution errors between L1 and L2. This is also applicable to the current study. For testing a tense/lax duration contrast in vowel production, a picture naming task or reading out easy L2-words may be more suitable than the method of the current study.

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[8] Or, to turn it around and follow Morrison & Escudero (2007), vowel duration is 10.6% shorter for male European speakers.

[9] Or 8.6% shorter for female European speakers.

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Appendix

1.0_CreateTable_and_add_pitch_and_formants.praat

```
# Richard Bank, March 2009
# 1.0_CreateTable_and_add_pitch_and_formants.praat
#
# This script does the following:
# - Create maintable
# - Load wav-files into Objects window (location is assumed to be
#      one level down from current directory)
# - Fill table with all info such as length and F0
#   Values that are zero are reported and have to be filled in manually.
# - Fill in the columns "F1" / "B3" and genderceiling (standard analysis)

maintable = Create Table with column names... maintable 0
... filename speaker vowel token dialect gender
... start end duration F0 F1 B1 F2 B2 F3 B3 ceiling

row = 0
numberOfUndefinedF0Values = 0
pitchredo = 0
path1$ = "Spanish"
path2$ = "LatinAmerican"

# make filelists for the two dialects (Spanish and Latin American)
for idialect to 2
	path$ = path'idialect'$
	fileList'idialect' = Create Strings as file list...
	... fileList'idialect' 'path$'\*.wav
endfor

# Read files from directories
for ilist to 2
	select fileList'ilist'
	numberOfFiles = Get number of strings
	for ifile to numberOfFiles
		select fileList'ilist'
		fileName$ = Get string... ifile

		# some files were split in two to avoid memory issues
		# the following makes that both files like ES_01_F.wav
		# and ES_02a_F.wav can be read:
		if length(fileName$) = 11
			fileName$ = left$(fileName$,7)
		else
			fileName$ = left$(fileName$,8)
		endif
		gender$ = right$(fileName$,1)
		path$ = path'ilist'$
		textgrid = Read from file... 'path$'/'fileName$'.TextGrid
		sound = Read from file... 'path$'/'fileName$'.WAV

		pitchFloor = if gender$ = "M" then 60 else 120 endif

		pitch = To Pitch (cc)... 0 pitchFloor 15 no 0.03 0.45 0.01 0.35 0.14
400
		Write to binary file... 'path$'/'fileName$'.Pitch

		call write_to_table 'idialect'

		select sound
		plus textgrid
		plus pitch
		Remove
		if pitchredo = 1
			select pitch2
```

```
                    Remove
                    pitchredo = 0
            endif
    endfor

    select fileList'idialect'
    Remove
endfor

printline numberOfUndefinedF0Values: 'numberOfUndefinedF0Values'
select maintable
Write to table file... maintable(standard_settings).txt

#########################
# Procedures are below: #
#########################

procedure write_to_table dialect
    if 'ilist' = 1
            dialect$ = "ES"
    else
            dialect$ = "LA"
    endif

    select textgrid
    numberOfIntervals = Get number of intervals... 1
    for iinterval to numberOfIntervals
            select textgrid
            label$ = Get label of interval... 1 iinterval
            if label$ <> ""
                    start = Get starting point... 1 iinterval
                    end = Get end point... 1 iinterval
                    duration = end - start
                    assert duration > 0.010
                    token$ = right$(label$,1)
                    vowel$ = left$(label$, length(label$) - 1)
                    speaker$ = mid$(fileName$, 4, 2)

                    call add_pitch
                    call add_formants_(standard_ceilings)

                    # write to table
                    select maintable
                    Append row
                    row = row + 1
                    Set string value... row filename 'fileName$'
                    Set string value... row speaker 'speaker$'
                    Set string value... row token 'token$'
                    Set string value... row vowel 'vowel$'
                    Set string value... row dialect 'dialect$'
                    Set string value... row gender 'gender$'
                    Set string value... row start 'start:6'
                    Set string value... row end 'end:6'
                    Set string value... row duration 'duration:6'
                    Set string value... row F0 'f0:3'
                    for iformant to 3
                            formant = if f'iformant' = undefined then 0 else
f'iformant' fi
                            bandwidth = if b'iformant' = undefined then 0 else
b'iformant' fi
                            Set string value... row F'iformant' 'formant:3'
                            Set string value... row B'iformant' 'bandwidth:3'
                    endfor
                    Set numeric value... row ceiling genderCeiling
            endif
    endfor
endproc
```

```
procedure add_pitch
	# Determine the middle 40 percent of the vowel.
	mid = start + duration / 2
	startpart = mid - duration / 5
	endpart = mid + duration / 5

	# Determine the median pitch of those 40 percent.
	select pitch
	f0 = Get quantile... startpart endpart 0.5 Hertz

	if f0 = undefined
		# Perhaps a creaky lady or a noisy guy.
		if pitchredo = 0
			select sound
			if gender$ = "F"
				# lower pitch floor (75) for F
				pitch2 = To Pitch (cc)... 0 75 15 no 0.03 0.45 0.01 0.35
0.14 400
				Write to binary file... 'path$'/'fileName$'.Pitch2
			else
				# lower voicing threshold (0.25) for M
				pitch2 = To Pitch (cc)... 0 60 15 no 0.03 0.25 0.01 0.35
0.14 400
				Write to binary file... 'path$'/'fileName$'.Pitch2
			endif
			pitchredo += 1
		else
			select pitch2
		endif

		f0 = Get quantile... startpart endpart 0.5 Hertz

		if f0 = undefined
			numberOfUndefinedF0Values += 1
			rowx = row + 1
			printline Failed: F0 analysis of speaker 'fileName$' between
'startpart:3' and 'endpart:3' seconds failed. Please set manually.
		else
			printline Retried: F0 of speaker 'fileName$' between
'startpart:3' and 'endpart:3' seconds has been analysed with different analysis
settings.
		endif
	endif
endproc

procedure add_formants_(standard_ceilings)
	select sound

	segment = Extract part... startpart endpart Rectangular 1.0 no
	windowLength = Get total duration

	# Determine the average formants of those 40 percent.
	genderCeiling = if gender$ = "M" then 5000 else 5500 fi
	noprogress
	To Formant (burg)... 0 5 genderCeiling windowLength 50
	for iformant to 3
		f'iformant' = Get value at time... iformant windowLength/2 Hertz
Linear
		b'iformant' = Get bandwidth at time... iformant windowLength/2 Hertz
Linear
		assert f'iformant' <> 0
	endfor
	plus segment
	Remove
endproc
```

1.1_Modify_Main_Table_for_25-75.praat

```
# Richard Bank, March 2009
# 1.1_Modify_Main_Table_for_25-75.praat
#
# This script does the following:
# - Modify maintable to include 25% and 75% points in the vowel:
#   add columns for all vowels to store the 25% and 75% values of F1 and F2
# - Fill in these columns for "F1" / "B3" (standard analysis)

maintable = Read Table from table file... maintable(standard_settings).txt
Append column... digraph
Append column... F1-25
Append column... B1-25
Append column... F1-75
Append column... B1-75
Append column... F2-25
Append column... B2-25
Append column... F2-75
Append column... B2-75
Append column... F3-25
Append column... B3-25
Append column... F3-75
Append column... B3-75
numberOfRows = Get number of rows
# set all values in digraph column to 0:
for irow to numberOfRows
	Set numeric value... irow digraph 0
endfor

row = 0
path1$ = "Spanish"
path2$ = "LatinAmerican"

# make filelists for the two dialects (Spanish and Latin American)
for idialect to 2
	path$ = path'idialect'$
	fileList'idialect' = Create Strings as file list... fileList'idialect'
'path$'\*.wav
endfor

# Read files from directories
for ilist to 2
	select fileList'ilist'
	numberOfFiles = Get number of strings
	for ifile to numberOfFiles
		select fileList'ilist'
		fileName$ = Get string... ifile

		# make that both files like ES_01_F.wav and ES_02a_F.wav
		# can be read:
		if length(fileName$) = 11
			fileName$ = left$(fileName$,7)
		else
			fileName$ = left$(fileName$,8)
		endif
		gender$ = right$(fileName$,1)
		path$ = path'ilist'$
		textgrid = Read from file... 'path$'/'fileName$'.TextGrid
		sound = Read from file... 'path$'/'fileName$'.WAV

		call write_to_table 'idialect'

		select sound
		plus textgrid
		Remove
	endfor
```

```
	select fileList'ilist'
	Remove
endfor

select maintable
Write to table file... maintable(standard_settings)_incl_digraphs.txt

#########################
# Procedures are below: #
#########################

procedure write_to_table dialect
	if 'ilist' = 1
		dialect$ = "ES"
	else
		dialect$ = "LA"
	endif

	select textgrid
	numberOfIntervals = Get number of intervals... 1
	for iinterval to numberOfIntervals
		select textgrid
		label$ = Get label of interval... 1 iinterval
		vowel$ = left$(label$, (length(label$) - 1))
		if (vowel$ <> "")
			row = row + 1
			start = Get starting point... 1 iinterval
			end = Get end point... 1 iinterval
			duration = end - start
			assert duration > 0.010
			token$ = right$(label$,1)
			speaker$ = mid$(fileName$, 4, 2)

			call add_formants_(standard_ceilings)

			# write to table
			select maintable
			if (vowel$ = "i") or (vowel$ = "\o/") or (vowel$ = "u")
				Set string value... row digraph 1
			endif
			for iformant to 3
				formant25 = if f'iformant'25 = undefined then 0 else
f'iformant'25 fi
				bandwidth25 = if b'iformant'25 = undefined then 0 else
b'iformant'25 fi
				Set string value... row F'iformant'-25 'formant25:3'
				Set string value... row B'iformant'-25 'bandwidth25:3'
				formant75 = if f'iformant'75 = undefined then 0 else
f'iformant'75 fi
				bandwidth75 = if b'iformant'75 = undefined then 0 else
b'iformant'75 fi
				Set string value... row F'iformant'-75 'formant75:3'
				Set string value... row B'iformant'-75 'bandwidth75:3'
			endfor
			Set numeric value... row ceiling genderCeiling
		endif
	endfor
endproc

procedure add_formants_(standard_ceilings)
	# Formants will be averaged at two parts in the vowel:
	# the mid 40% of the left half, and the mid 40% of the right half.
	mid = start + duration / 2
	durationleft = mid - start
	midleft = start + durationleft / 2
	durationright = end - mid
	midright = mid + durationright / 2
```

```
        startleftpart = midleft - durationleft / 5
        endleftpart = midleft + durationleft / 5
        startrightpart = midright - durationright / 5
        endrightpart = midright + durationright / 5

        # left half of the vowel:
        select sound
        segment = Extract part... startleftpart endleftpart Rectangular 1.0 no
        windowLength = Get total duration

        # Determine the average formants of those 40 percent.
        genderCeiling = if gender$ = "M" then 5000 else 5500 fi
        To Formant (burg)... 0 5 genderCeiling windowLength 50
        for iformant to 3
                f'iformant'25 = Get value at time... iformant windowLength/2 Hertz
Linear
                b'iformant'25 = Get bandwidth at time... iformant windowLength/2 Hertz
Linear
                assert f'iformant'25 <> 0
        endfor
        plus segment
        Remove

        # right half of the vowel:
        select sound
        segment = Extract part... startrightpart endrightpart Rectangular 1.0 no
        windowLength = Get total duration

        # Determine the average formants of those 40 percent.
        genderCeiling = if gender$ = "M" then 5000 else 5500 fi
        To Formant (burg)... 0 5 genderCeiling windowLength 50
        for iformant to 3
                f'iformant'75 = Get value at time... iformant windowLength/2 Hertz
Linear
                b'iformant'75 = Get bandwidth at time... iformant windowLength/2 Hertz
Linear
                assert f'iformant'75 <> 0
        endfor
        plus segment
        Remove
endproc
```

1.3.1_add_multiple_colums_to_table.praat

```
# Richard Bank, March 2009
# 1.3.1_add_multiple_colums_to_table.praat
#
# This script adds 251 columns per formant & bandwidth,
# with formant ceilings from 4000 till 6500 Hz,
# increasing in steps of 10 Hz

maintable = Read Table from table file...
maintable(standard_settings)_no_errors.txt
numberOfRows = Get number of rows

for iceiling from 400 to 650
        formantCeiling = 10 * iceiling
        Append column... F1_'formantCeiling'
        Append column... B1_'formantCeiling'
        Append column... F2_'formantCeiling'
        Append column... B2_'formantCeiling'
        Append column... F3_'formantCeiling'
        Append column... B3_'formantCeiling'
        Append column... nform_'formantCeiling'
        printline formantceiling: 'formantCeiling'
endfor
```

```
Write to table file... maintable(multiple_ceilings).txt
```

1.3.2_add_least_variable_formants.praat

```
# Richard Bank, March 2009
# 1.3.2_add_least_variable_formants.praat
#
# This script does the following:
# - select the multiple-ceilings table
# - calculate the least variant ceiling, and write to table

select all
nocheck Remove

maximum_warping = 1000
ceiling_step = 10

multitable = Read from file... maintable(multiple_ceilings)_filled.txt
maintable = Read from file... maintable(standard_settings)_no_errors.txt

call vowel
call doGender M
call doGender F

########################
# procedures are below #
########################

procedure vowel
	vowel1$ = "\as"
	vowel2$ = "a"
	vowel3$ = "\ef"
	vowel4$ = "e"
	vowel5$ = "\o/"
	vowel6$ = "\ic"
	vowel7$ = "i"
	vowel8$ = "\ct"
	vowel9$ = "u"
	vowel10$ = "o"
	vowel11$ = "\yc"
	vowel12$ = "y"
endproc

procedure doGender gender$
	# extract chosen gender from main table
	select multitable
	genderTable = Extract rows where column (text)... gender "is equal to"
'gender$'
	for ivowel to 12
		vowel$ = vowel'ivowel'$
		call doVowel
	endfor
	select genderTable
	Remove
endproc

procedure doVowel
	# extract vowels from genderTable
	select genderTable
	vowelTable = Extract rows where column (text)... vowel "is equal to" 'vowel$'
	numberOfRows = Get number of rows

	guessedFormantCeiling = if gender$ = "F" then 5500 else 5000 fi
	formantCeiling = guessedFormantCeiling - maximum_warping
	stdevBest = 1e300

	# determine optimal formant ceiling
```

```
	while formantCeiling <= guessedFormantCeiling + maximum_warping
		stdev1 = Get standard deviation... F1_'formantCeiling'
		stdev2 = Get standard deviation... F2_'formantCeiling'
		stdev = sqrt (stdev1 ^ 2 + stdev2 ^ 2)
		if stdev < stdevBest
			formantCeilingBest = formantCeiling
			stdevBest = stdev
		endif
		formantCeiling += ceiling_step
		;printline 'stdev' 'stdevBest' 'formantCeiling' 'formantCeilingBest'
	endwhile
	stress += stdevBest
	printline F/M:'gender$' vwl:'vowel$' fc:'formantCeilingBest'
stdev:'stdevBest:1'

	# write to table
	select maintable
	Formula... ceiling if (self$["gender"] = gender$
	... and self$["vowel"] = vowel$)
	... then formantCeilingBest else self fi
	for irow to numberOfRows
		select vowelTable
		token = Get value... irow token
		speaker = Get value... irow speaker
		f1$ = Get value... irow F1_'formantCeilingBest'
		b1$ = Get value... irow B1_'formantCeilingBest'
		f2$ = Get value... irow F2_'formantCeilingBest'
		b2$ = Get value... irow B2_'formantCeilingBest'
		f3$ = Get value... irow F3_'formantCeilingBest'
		b3$ = Get value... irow B3_'formantCeilingBest'
		select maintable
		Formula (column range)... F1 B3 if (self["speaker"] = speaker
		... and self["token"] = token and self$["vowel"] = vowel$)
		... then if col$ [col] = "F1" then f1$ else if col$ [col] = "B1" then
b1$
		... else if col$ [col] = "F2" then f2$ else if col$ [col] = "B2" then
b2$
		... else if col$ [col] = "F3" then f3$ else if col$ [col] = "B3" then
b3$
		... else self$ [row, col] fi fi fi fi fi fi else self$ [row, col] fi
	endfor
	select vowelTable
	Remove
endproc

select maintable
Write to table file... maintable(optimal_ceilings).txt
```

1.3.3_add_least_variable_formants_incl_25-75.praat

```
# Richard Bank, March 2009
# 1.3.3_add_least_variable_formants_incl_25-75.praat
#
# This script does the following:
# - select the multiple-ceilings table and the optimal_ceilings table
# - read the least variant ceiling, and
# calculate the formants for the 25% and 75% points in the vowel,
# - write to table

maintable = Read Table from table file... maintable(optimal_ceilings).txt
numberOfRows = Get number of rows

row = 0
path1$ = "Spanish"
path2$ = "LatinAmerican"

# make filelists for the two dialects (Spanish and Latin American)
```

```
for idialect to 2
	path$ = path'idialect'$
	fileList'idialect' = Create Strings as file list... fileList'idialect'
'path$'\*.wav
endfor

# Read files from directories
for ilist to 2
	select fileList'ilist'
	numberOfFiles = Get number of strings
	for ifile to numberOfFiles
		select fileList'ilist'
		fileName$ = Get string... ifile

		# make that both files like ES_01_F.wav and ES_02a_F.wav
		# can be read:
		if length(fileName$) = 11
			fileName$ = left$(fileName$,7)
		else
			fileName$ = left$(fileName$,8)
		endif
		gender$ = right$(fileName$,1)
		path$ = path'ilist'$
		textgrid = Read from file... 'path$'/'fileName$'.TextGrid
		sound = Read from file... 'path$'/'fileName$'.WAV

		call write_to_table 'idialect'

		select sound
		plus textgrid
		Remove
	endfor

	select fileList'ilist'
	Remove
endfor

select maintable
Write to table file... maintable(optimal_ceilings)_incl_25-75.txt

#########################
# Procedures are below: #
#########################

procedure write_to_table dialect
	if 'ilist' = 1
		dialect$ = "ES"
	else
		dialect$ = "LA"
	endif

	select textgrid
	numberOfIntervals = Get number of intervals... 1
	for iinterval to numberOfIntervals
		select textgrid
		label$ = Get label of interval... 1 iinterval
		vowel$ = left$(label$, (length(label$) - 1))
		if (vowel$ <> "")
			row = row + 1
			start = Get starting point... 1 iinterval
			end = Get end point... 1 iinterval
			duration = end - start
			assert duration > 0.010
			token$ = right$(label$,1)
			speaker$ = mid$(fileName$, 4, 2)

			# check if values in table correspond with vowel
			# in current interval (because row may have been deleted
```

```
			# because of errors in the recording)
			select maintable
			filename2$ = Get value... row filename
			vowel2$ = Get value... row vowel
			token2$ = Get value... row token
			if (filename2$ = fileName$) and (vowel2$ = vowel$) and (token2$
= token$)

				call add_formants_(optimal_ceilings)

				# write to table
				select maintable
				for iformant to 3
					formant25 = if f'iformant'25 = undefined then 0
else f'iformant'25 fi
					bandwidth25 = if b'iformant'25 = undefined then 0
else b'iformant'25 fi
					Set string value... row F'iformant'-25
'formant25:3'
					Set string value... row B'iformant'-25
'bandwidth25:3'
					formant75 = if f'iformant'75 = undefined then 0
else f'iformant'75 fi
					bandwidth75 = if b'iformant'75 = undefined then 0
else b'iformant'75 fi
					Set string value... row F'iformant'-75
'formant75:3'
					Set string value... row B'iformant'-75
'bandwidth75:3'
				endfor
			else
				# current interval is apparently not in table, so
				# the same row should be checked for the next interval
				row = row - 1
			endif
		endif
	endfor
endproc

procedure add_formants_(optimal_ceilings)
	# Formants will be averaged at two parts in the vowel:
	# the mid 40%'s of the left and right halves.
	mid = start + duration / 2
	durationleft = mid - start
	midleft = start + durationleft / 2
	durationright = end - mid
	midright = mid + durationright / 2

	startleftpart = midleft - durationleft / 5
	endleftpart = midleft + durationleft / 5
	startrightpart = midright - durationright / 5
	endrightpart = midright + durationright / 5

	# determine formantceiling
	select maintable
	tempgendertable = Extract rows where column (text)... gender "is equal to"
'gender$'
	Extract rows where column (text)... vowel "is equal to" 'vowel$'
	ceiling = Get value... 1 ceiling
	plus tempgendertable
	Remove

	# left half of the vowel:
	select sound
	segment = Extract part... startleftpart endleftpart Rectangular 1.0 no
	windowLength = Get total duration

	# Determine the average formants of those 40 percent.
```

```
	To Formant (burg)... 0 5 ceiling windowLength 50
	for iformant to 3
		f'iformant'25 = Get value at time... iformant windowLength/2 Hertz
Linear
		b'iformant'25 = Get bandwidth at time... iformant windowLength/2 Hertz
Linear
		assert f'iformant'25 <> 0
	endfor
	plus segment
	Remove

	# right half of the vowel:
	select sound
	segment = Extract part... startrightpart endrightpart Rectangular 1.0 no
	windowLength = Get total duration

	# Determine the average formants of those 40 percent.
	To Formant (burg)... 0 5 ceiling windowLength 50
	for iformant to 3
		f'iformant'75 = Get value at time... iformant windowLength/2 Hertz
Linear
		b'iformant'75 = Get bandwidth at time... iformant windowLength/2 Hertz
Linear
		assert f'iformant'75 <> 0
	endfor
	plus segment
	Remove
endproc
```