Acoustic characteristics of monophthong realisation in Southern Standard Dutch

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0. Introduction

The vowel system of Southern Standard Dutch in Flanders consists of 12 vowels which can be distinguished on the basis of three articulatory dimensions. The degree of opening of vowels (closed vs. open) correlates with the degree of constriction of the vocal tract, while a distinction can be made between front, mid and back vowels on the basis of place of articulation. This vertical and horizontal classification combines with the dimension of lip rounding. All vowels in the Flanders area are monophthongs and this is one of the main pronunciation differences with Northern Standard Dutch.

Vowel systems in languages of the world differ considerably in terms of the number of vowel qualities. According to Maddieson (1984) the number of vowels varies between 3 and 15 with 5 vowels being the most frequently observed system. The vowel system of standard Dutch in Flanders can thus be regarded as relatively dense.

From an acoustic point of view vowels have a clear formant structure. It is generally assumed that F1 and F2 are most relevant for a vowel's identity. The relationship between vowel acoustics and vowel articulation is by no means a simple matter, but is accepted that F1 mainly correlates with articulatory degree of opening, while F2 reflects place of articulation. Besides vowel identity, the acoustic structure of vowels also contains speaker-related information such as anatomical differences between speakers: "(…) some speakers with big heads will have large resonating cavities, producing formants with comparatively low frequencies; and other will have higher formant frequencies because they have smaller vocal tracts." (Ladefoged, 2001: 39). This is clear in comparisons of vowels produced by men and women. Since men's vocal tracts are generally bigger than women's, formant values of vowels tend to be lower in men.

Another source of speaker-related information is a speaker's habitual articulatory setting. This is defined in Laver (1994) as "any co-ordinatory tendency underlying the production of the chain of segments in speech towards maintaining a particular configuration or state of the vocal apparatus" (p. 396). The habitual setting of individual speakers can differ and this may influence the acoustic characteristics of vowels. A palatal setting will clearly influence the realisation of open back vowels, while a velar setting will be mainly visible in closed front vowels. Honikman (1964) suggests that settings may systematically differ between languages. However, it is not clear how these differences may be identified acoustically.

In the past, the acoustics of Dutch vowels have been investigated in quite some detail. Early studies mainly concentrated on the acoustic characteristics of vowels in Northern Standard Dutch. Reference should be made to large-scale investigations by Pols, Tromp & Plomp (1973) and Van Nierop, Pols & Plomp (1973), which measured formant fequencies of male and female speakers respectively. Although these studies clearly had a speech recognition aim in mind, they have provided a reference frame for the acoustics of Dutch vowels.

Other publications focused on regional pronunciation variation. Koopmans-van Beinum (1973) investigated differences between Northern Standard Dutch and the dialect of Utrecht, while Adank, Van Heuven & Van Hout (1999) and Van Hout, Adank & Van Heuven (2000) compared vowel realisation in Northern Standard Dutch and the Valkenburg regional variety. Although these publications focus on the relationship between vowel production, acoustics and perception, it was shown that the description of regional differences in vowel realisation may provide interesting insights.

From this short survey it is clear that the acoustics of Dutch vowels have only been investigated systematically with respect to Northern Standard Dutch. The interest for vowels in Flanders has been restricted to a few impressionistic descriptions which often provide pronunciation guidelines for dialect speakers who want to improve their pronunciation of Standard Dutch. Well-known examples are Blancquaert (1950), De Coninck (1970) and Van Maele (1984). This paper is an attempt to explicitly describe vowel acoustics in Southern Standard Dutch. The study focuses on three geographical regions in Flanders in order to investigate possible structural differences in vowel realisation.

1. Method

In this study the 12 Dutch monophthongs were recorded in different phonetic contexts: they were produced by informants from three geographical regions in Flanders, i.e. the provinces of Limburg (south-east), Antwerp (north) and East-Flanders (West). Speakers' realisations were analysed acoustically and duration measurements were made.

1.1. Materials

The 12 monophthongs of Southern Standard Dutch were embedded in monosyllabic words in two phonetic contexts: in the first series of words, the vowel was preceded by a voiceless labial stop and followed by a voiceless alveolar stop. This gave rise to the following series of words: “Piet, pit, peet, pet, pad, spaad, pot, poot, spoed, put, puut, peut”. In the second series, the vowel was preceded by a voiced resonant with a lateral aspect of articulation and followed by a voiceless alveolar fricative. This created the word series “Lies, lis, lees, les, las, blaas, los, loos, Loes, lus, luus, leus.” The final consonant was chosen to be alveolar since impressionistic observation had revealed that this context often gives rise to extreme lengthening of the vowels in the local Antwerp dialect.

The test words were embedded in the standard carrier sentence “In ___ hoor je ___” (In ___ you hear ___). Informants were asked to insert the test words in the first position of the carrier phrase and to pronounce the vowel from the test word in the second position of the phrase. Every sentence occurred twice in the corpus which yielded a total of 48 stimuli per informant (2 phonetic contexts x 12 vowels x 2 repititions). In addition, 28 stimuli with diphthongs were added to this list. All stimuli were randomised and 5 additional stimuli were added at the beginning and end of the list in order to avoid begin and end effects. The measurements of these stimuli were not included in the results.

The use of a standardised carrier phrase instead of entirely natural speech has advantages and disadvantages. One of the advantages of carefully controlled data collection is that the data are highly comparable. The segments of interest occur in the same phonetic environments and the influence of preceding and following segments remains constant. In addition, the speech segments occur in accented position so that the articulatory targets of the vowels can be assumed to be better achieved than in unaccented position: the latter often gives rise to a certain degree of vowel reduction. Since the objective of this investigation was the comparison of vowel realisation in regional variants of the standard language, a standardised method of data collection was preferred.

1.2. Informants

The sentences were presented to 10 informants from the Limburg area (Kempen), 12 informants from the Antwerp region (Greater Antwerp Agglomeration) and 12 informants from the province of East-Flanders (town of Eeklo). In each regional group men and women were equally represented. The average age of the informants was 61, 54 and 59 years respectively. All informants had been living in the stated areas most of their lives and they all spoke the southern standard variety of Dutch in most of their daily encounters.

1.3.Procedure

Informants were instructed to read the carrier sentences as naturally as possible. It was not emphasized specifically that they had to use a standard language register. It was assumed that they would do so spontaneously since the researchers used standard language and a reading task automatically invites a standard register. Recordings were made by means of high-quality equipment (TASCAM DAT-recorder, Sennheiser microphone) in quiet rooms without disturbing background noise.

1.4.Analysis

The recordings were digitised and the vowels and diphthongs were segmented on the basis of visual information in a wide band spectrogram. For the vowels, F1 and F2 were determined by means of the Burg algorithm implemented by Boersma & Weenink (2000) in PRAAT. Formants of the monophthongs were measured in the middle of the vowel since it can be assumed that the influence of adjacent segments is minimal and the articulatory target is maximally achieved. For the formant measurements the standard analysis parameters in PRAAT were used.

Besides visual identification and acoustic analysis, the vowels in the second position of the carrier phrase were also assessed perceptually, since it emerged that some informants had realised a different vowel than the one suggested by the orthography.

2. Results

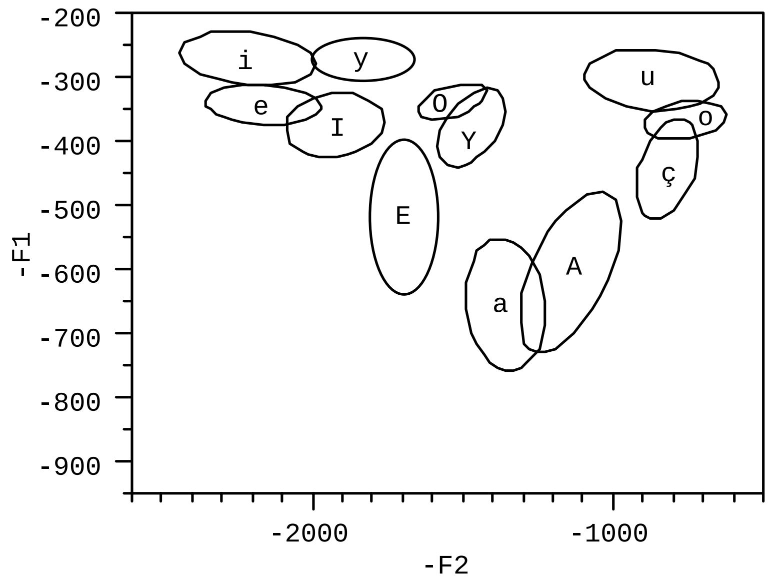
This investigation provided a total of 3739 formant measurements and 1789 duration measurements. The discussion will first focus on the normalisation of these measurements before presenting a detailed analysis.

2.1. Data normalisation

It has often been suggested that formant values are the acoustic reflex of different articulatory dimensions. The acoustic description of vowels mainly focuses on the dimensions of place of articulation (front vs. back) and degree of constriction (closed vs. open). Speaker-related factors such as e.g. anatomical differences between men and women are less relevant for this kind of investigation, but deserve some attention in the discussion of the results.

In order to normalise speaker-related differences, several techniques are available. These are discussed in Disner (1980), Adank, Van Heuven & Van Hout (1999) and Van Hout, Adank & Van Heuven (2000). Apart from the well-known Bark transformation which transforms formant values to a scale which more closely reflects the perceptual response of the human ear to formant values, extrinsic normalisation has often been

proposed. This type of normalisation positions each vowel of an individual speaker relatively with respect to the other vowels in his system. This can be achieved by amongst others a transformation of formant values to z-scores. In this transformation the vowels of all individual speakers are positioned on a scale with mean 0 and a standard deviation 1. Van Hout, Adank & Van Heuven (2000) suggest that this transformation may be highly efficient in separating the vowels in the vowel space since it significantly reduces the scatter of the vowels in the acoustic vowel space.
In order to determine whether this applies to the results of this investigation, F1 and F2 values of individual speakers were transformed to z-scores. Subsequently, both types of measurements were visualised on an acoustic vowel diagram and a 50% ellipsoid was drawn for each vowel, which gives an indication of the spread of the measurements. The result of this procedure is illustrated in figure 1:



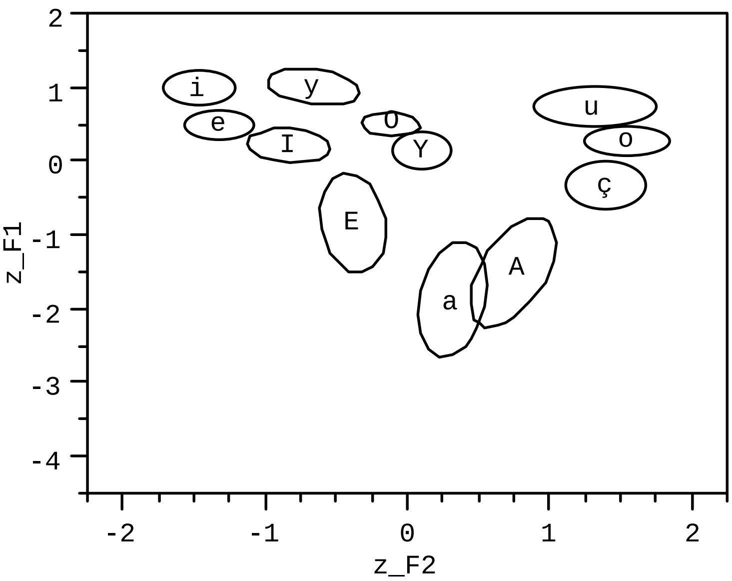


Figure 1: Scatterplot of the vowels of Limburg men on the basis of formant values (in Hz, upper diagram) and the transformations of F1 and F2 to z-scores (lower diagram).

From figure 1 it appears that the transformation of F1 and F2 to z-scores (lower diagram) substantially reduces the spread of the vowels in the acoustic space as compared to a representation of formant values in Hz. This indicates that the vowels are better separated, which is consistent with the observations in Van Hout, Adank & Van Heuven (2000).

Although Van Hout, Adank & Van Heuven (2000) do not make predictions about the potential of this technique to the normalisation of differences between men and women, it seemed interesting to transform the formant values of this investigation to z-scores in order to assess to what extent differences between male and female speakers can be normalised: the differences between the two groups of speakers are quite big in terms of a representation of formant values. This is illustrated in figure 2. Figure 2 indicates that the acoustic vowel spaces of men and women generally have the same geometrical shape, but that they differ considerably in size: the vowel space of the female speakers extends further down and to the left. An analysis of variance on the difference between F1 and F2 for the different vowels of male and female speakers indicates that formant values of men and women differ significantly ($F(1,11)=589$, $p < 0.0001$). Post hoc analysis reveals that the differences between men and women are mainly related to the front and mid vowels. In the back vowels the differences are not significant.

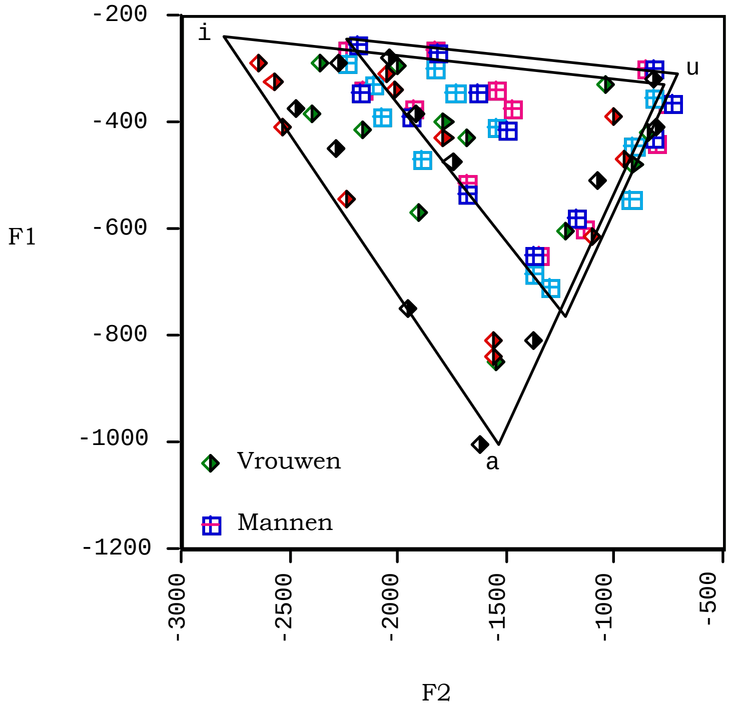


Figure 2: Acoustic vowel diagram on the basis of F1 and F2 (in Hz) for men and women in the regions Antwerp, Limburg and East-Flanders.

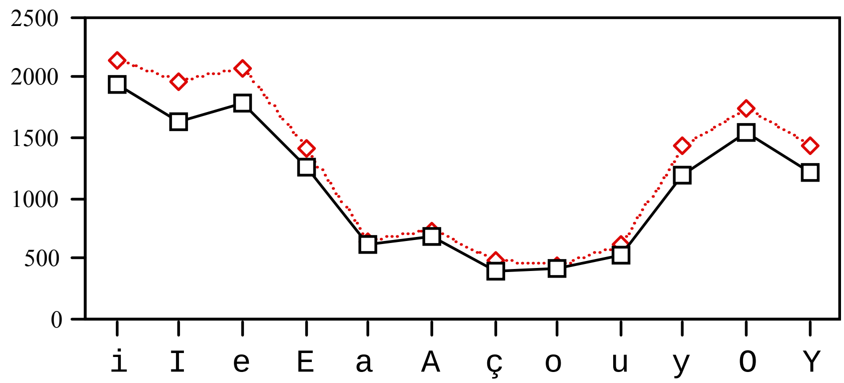


Figure 3: Average values of F2-F1 (in Hz) for the Dutch vowels in men and women.

The result of the z-score transformation of male and female formant values is illustrated in figure 4:

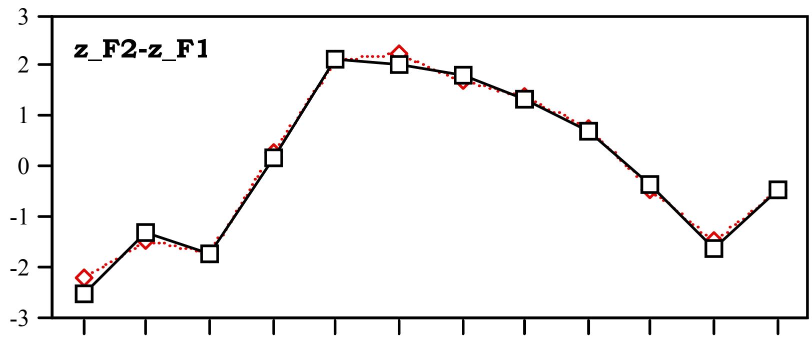


Figure 4: Acoustic vowel space on the basis of z-score transformation of F1 and F2 for men and women in Limburg, Antwerp and East-Flanders.

Figure 4 shows that the differences in formant values between men and women have entirely disappeared on the transformed scale: women's z-scores occupy the same space as those of men. This visual impression is confirmed by an analysis of variance on the basis of z_F2-z_F1 which indicates that the z-scores of men and women for the different vowels are not significantly different ($F(1,11)=1.1378$, $p < 0.2511$). This is also obvious in figure 5 which illustrates the average z_F2-z_F1 values for the Dutch vowels:

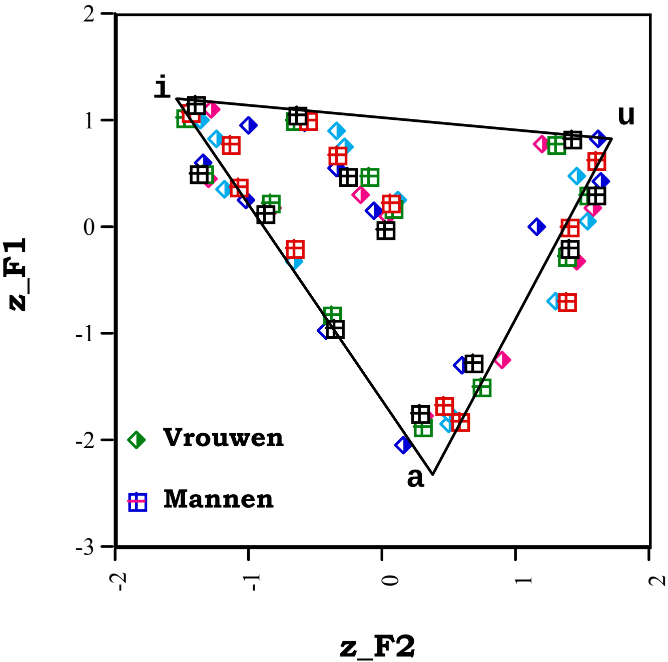


Figure 5: Average values of z_F2-z_F1 for the Dutch vowels in men and women.

These observations indicate that z-transformation is a useful technique to normalise vowel realisation.

2.2.Acoustic characteristics of monophthongs

The first aim of this investigation is to establish the extent of regional variation in the pronunciation of the Dutch monophthongs. On the basis of the arguments presented above, the z-transformations of formant values of female and male speakers in the different geographical regions were pooled together for corresponding vowels. The results of this are summarized in figure 6:

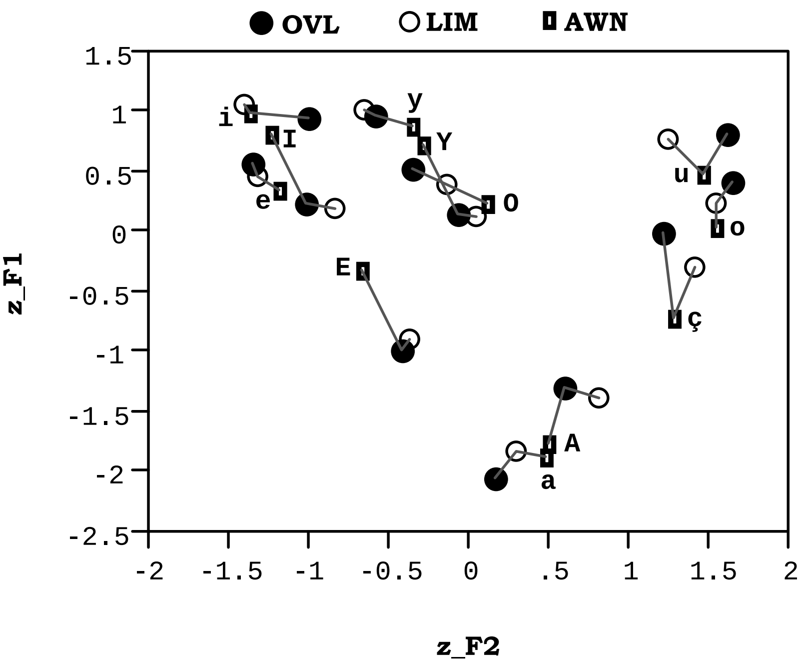


Figure 6: Average z-scores for the Dutch monophthongs in male and female speakers from the Antwerp (AWN), Limburg (LIM) and East-Flanders (OVL) region. The connecting lines between the symbols relate the regions to the individual vowel realisations.

Figure 6 summarizes the differences in vowel realisation in the three regions. A comparison of the formant values indicates that the acoustic characteristics of the vowels in Limburg and East-Flanders are very similar. This is especially true for the front and mid vowels [I], [e], [E], [y] and [Y]. An exception to this observation are [i] and [O] the realisations of which are quite different in Limburg and East-Flanders: East-Flemish [i] is realised more backward, while East-Flemish [O] is realised more forward than in Limburg. This visual impression is confirmed by a statistical analysis (Tukey

Kramer) which indicates that the differences between Limburg and East-Flemish front and mid vowels are not significant. The realisations of back vowels are clearly different in the two regions, which is indicated by the equal distances between de regional symbols for these vowels. Statistical analysis confirms that these differences are significant. The differences between the Limburg and East-Flemish [I] and [O] are also significant.

The vowels from the Antwerp region are without exception positioned differently from their Limburg and East-Flemish counterparts. Concerning the back vowels, it should be observed that Antwerp [u], [o] and [ç] occupy a lower position on the vowel chart than their Limburg and East-Flemish counterparts. It can also be seen that the average formant values for [a] and [A] are very similar in Antwerp, while they are clearly different in Limburg and East-Flanders.

Concerning the front and mid vowels, it is observed that the average formant values for [I] are very similar to those of [i]; the same holds for [Y] and [y]. In addition, Antwerp [E] is considerably more closed than its Limburg and East-Flemish counterpart, while [e] and [O] are slightly more open and central in comparison to the other regions.

2.3. Vowel duration

Besides an investigation of formant values, vowel duration was also measured. For this purpose, only the vowels embedded in the test words were included. The vowels that were pronounced in isolation in the second position of the carrier phrases were left out. Average vowel durations are summarized in figure 7.

Figure 7 clearly indicates that the three varieties of Southern Standard Dutch distinguish between intrinsically short and long vowels. However, there are a few clear differences between the three regional variants, which are statistically significant on the basis of a three-way analysis of variance ($F(1,22)=17.28$, $p < 0.0001$). In the first instance, it is observed that two Antwerp vowels are intrinsically long, while they are realised short in Limburg and East-Flanders: [I] and [u] have average vowel durations of 261 and 246 msec respectively. The averages in Limburg and East-Flanders are 123 and 97 msec for [I] and 104 and 109 msec for [u]. The second observation is that Antwerp [o] and [y] are considerably longer than their Limburg and East-Flanders counterparts: average values are 282 and 290 msec in Antwerp versus 195/233 and 151/193 msec in Limburg and East-Flanders, where they are also relatively long.

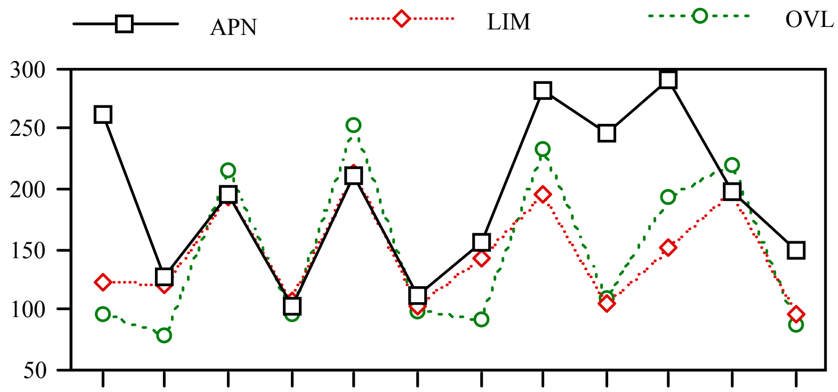


Figure 7: Average vowel duration (in msec) of the 12 Dutch vowels in Antwerp (APN), Limburg (LIM) and East-Flanders (OVL).

The third observation is that a number of short vowels in East-Flanders are extra short in comparison to the other regions. This holds specifically for [i], [I] and [ç] with average durations of 97, 78 and 91 msec. In comparison to the Limburg area, the long vowels in East-Flanders are extra long. This extra short realisation of short vowels and the extra long realisation of long vowels seems to suggest that the durational difference between short and long vowels is perceptually stronger in the East-Flemish regional variety. This is also reflected in the average difference between the duration of long vowels and that of short vowels. For Limburg vowels this difference is 77 msec, while in East-Flanders this value amounts to 132 msec. Antwerp occupies an intermediate position with 98 msec.

3. Discussion

This paper is a systematic analysis of regional variation in the pronunciation of Dutch vowels in three Flemish regions, i.e. Antwerp, Limburg and East-Flanders. For this purpose the formant values of a substantial number of vowel realisations were measured. The formant values were converted to z-scores in order to investigate whether speaker-related influences could be normalised. This procedure revealed that this transformation was able to sharper separate the vowels in the acoustic vowel space by reducing the scatter of the measured formant values. This is consistent with Van Hout, Adank & Van Heuven (2000). It was also investigated whether z-score transformation of formant valoues enabled normalisation of differences between male and female speakers. In a comparison of formant values between male and female speakers, it emerged that the geometrical shape of the vowel space was the same for both groups of speakers, but that the values for women extended further down and to the left. This result is consistent with Most, Amir & Tobin (2000). For the Hebrew vowel system, they found similar differences in formant values for vowels produced by men, women, boys and girls. In a comparison between the different groups, the vowel space the formant values extended downward and to the left:

> Observation of F1 values of the four groups revealed that the lower the vowel the greater the differences among groups (i.e., maximal differences were observed for the vowel /a/, while minimal differences were observed for the vowels /i, u/). For the F2 values of the four groups, however, maximal differences were observed for the front vowels (i,e) gradually dimishing towards the back vowels (/o, u/). (Most, Amir & Tobin, 2000: 299).

Most, Amir & Tobin (2000) conclude that:

> (…) similar geometrical shapes were obtained for all four groups. The figure illustrates the expansion of the vowel space as an inverse function of vocal tract length, with back vowels remaining more stable than nonback vowels. The small differences between the four groups in F1 and F2 values of the back vowels might be explained by the mobility limitations of the tongue in the back of the oral cavity. The front of the oral cavity allows better and easier mobility of the articulators, resulting in greater variability among speaker groups (p. 299).

The differences in formant values between men and women in this study and the similar observations in Most, Amir & Tobin (2000) refine Ladefoged who seems to imply that sex differences influence all vowels to the same extent:

> The men's vowels have lower formant frequencies, resulting in their [vowel] chart being more compressed with all the points being moved upward and to the right. This is because men have larger vocal tracts, containing bigger bodies of air. These larger bodies of air vibrate more slowly, so that the formants have lower frequencies (Ladefoged, 2001: 43).

In this study the differences in formant values between men and women are mainly related to front vowels, while the values of back vowels are highly comparable.
The transformation of formant values to z-scores revealed that the observed differences between men and women disappear: the differences are no longer statistically significant. This indicates that a transformation of formant values to z-scores can be

considered as a simple but powerful technique which deserves careful consideration in this kind of investigation.

Concerning the similarities and differences between the three regional varieties, it is clear that the acoustic characteristics of the Limburg and East-Flemish vowels are in good agreement, while the vowels of the Antwerp variety are considerably different. A comparison between the Limburg and East-Flemish regional varieties revealed that the Limburg closed vowels [i], [y] and [u] have a more fronted realisation than their East-Flemish counterparts. In addition, all other vowels (except [ç]) are realised more backward than their East-Flemish counterparts. This suggests a slight anti-clockwise rotation of the Limburg vowel space.

It can furthermore be seen that the Limburg and East-Flemish vowels are part of a system that is characterised by five degrees of opening. The closest degree of opening is represented by [i], [y] and [u]. The vowels [e], [O] and [o] are situated on the second degree of opening. The third degree has the vowels [I], [Y] and [ç]. The fourth degree of opening has the vowels [E] and [A], while [a] occupies the most open position. It is characteristic that the degrees of opening are not horizontally aligned, but the back vowels are positioned somewhat lower than the front vowels on the corresponding degree of opening.

Measurements of vowel duration indicate that both regional vairants have 7 short and 5 long vowels. In the East-Flemish variety the duration difference between short and long vowels is perceptually stronger than in the Limburg regional variety in the sense that in the East-Flemish variety the durational difference between long and short vowels is bigger: short vowels are extra short, while long vowels are extra long. This is a remarkable observation since the East-Flemish dialects are generally characterised by a neutralisation of long and short vowels (De Schutter, personal communication). Thus, the strong difference between short and long vowels in East-Flemish Standard Dutch may have to be accounted for in terms of hypercorrection.

A further conclusion of this investigation is that the vowel realisations in the Antwerp regional variety differ substantially from those in the other regions. From the comparison of the vowel positions in the three varieties it is clear that the Antwerp regional variety is characterised by a shift in position of three vowels: [A] moves towards [a], [I] moves towards [i] and [Y] moves towards [y]. The other vowels also occupy different positions: all back vowels are realised more open, while the front vowel [E] has a more close realisation. In addition, [e] and [O] have a more open and central position than their Limburg and East-Flemish counterparts. These observations are consistent with the principle of maximal vowel dispersion which holds that "(…) vowels tend to be evenly distributed in the available phonetic space and also widely

distributed within the limitations of the particular system." (Maddieson, 1984: 137). The principle of maximal vowel dispersion implies that vowels may shift in the vowel space in order to maintain the perceptual distance between the vowels within a system when e.g. two vowels have merged. These shifts usually move towards the gap in the vowel space. If this principle is applied to the Antwerp vowel system, it can be seen that shifts of [A] to [a], [I] to [i] and [Y] to [y] create three gaps in the vowel space. The gap resulting from the shift of [A] is compensated by a shift of all back vowels towards the gap: all back vowels are realised substantially more open. The shift of [I] towards [i] creates a gap which is compensated by a shift from [e] and [E] in the direction of [I]'s normal position. This leads to a more open and central realisation of [e] and a more closed and front realisation of [E]. The shift from [Y] to [y] creates a vacant position which is taken up by [O] in the Antwerp regional variety.
Besides vowel shifts, durational measurements show that irrespective of maximal acoustic dispersion, the 'threatened' vowels distinguish themselves temporally from the 'intruders'. As a result [i] is realised long in order to distinguish itself from short [I] and [y] is realised long so as to distinguish itself from the somewhat longer [Y]. The duration of [a] does not have to change since it was already long in comparison to [A]. Although [u] is not threatened by another vowel, duration measurements show that it is also realised long in comparison to the other regions. This might be accounted for by a generalising tendency to maintain symmetry in the vowel system: [i] and [y] are lengthened to create a perceptual distance with respect to their respective intruders and this may have been extended to [u].
These phenomena create a vowel system in the Antwerp regional variety of Standard Dutch with four degrees of opening and three places of articulation. The vowels with the closest degree of opening are [i], [I], [y], [Y] and [u]. The second degree of opening has [e], [O] and [o]. The third degree of opening is constituted by [E] and [ç], while [a] and [A] are situated on the most open degree.

4. Conclusion

This study of acoustic vowel characteristics in different geographical regions in Flanders indicates that this kind of investigation may provide insightful results. Apart from a number of fundamental conclusions concerning vowel normalisation, the study revealed clear differences concerning vowel realisation in the different regional varieties. The comparison between Limburg and East-Flanders indicated a good correspondence in terms of vowel realisation. It was noted that the Limburg realisations are slightly rotated in anti-clockwise direction with respect to the East-Flemish vareity. The East-Flemish vowels were characterised by a stronger durational difference between short and long vowels: short vowels are extra short, while long vowels are extra long. This was accounted for in terms of hypercorrection.

The vowel system of the Antwerp regional variety differs substantially from the other two and it was hypothesised that this is caused by three vowel shifts, i.e. [A] to [a], [I] to [i] and [Y] to [y]. In order to achieve maximal dispersion, these shifts are compensated by a more open realisation of the back vowels and a shift of the acoustic characteristics of [e] and [E] in the direction of the gap for [I] and of [O] in the direction of the gap left by [Y]. In addition, the Antwerp regional variety is characterised by an intrinsic longer duration of all vowels at the closest degree of opening.

Generally, it can be concluded that these insights can only be achieved by the method of comparison which focuses on the systematic aspects of systemic differences, rather than considering them as isolated observations. Thus, the results do not only provide insights into regional differences in vowel realisation, but may also contribute fundamentally to a better understanding of the organisation principles which are at the basis of vowel systems generally.

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