An acoustic description of the vowels of northern and southern standard Dutch II: Regional varieties^{a)}

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An analysis is presented of regional variation patterns in the vowel system of Standard Dutch as spoken in the Netherlands (Northern Standard Dutch) and Flanders (Southern Standard Dutch). The speech material consisted of read monosyllabic utterances in a neutral consonantal context (i.e., /sVs/). The analyses were based on measurements of the duration and the frequencies of the first two formants of the vowel tokens. Recordings were made for 80 Dutch and 80 Flemish speakers, who were stratified for the social factors gender and region. These 160 speakers were distributed across four regions in the Netherlands and four regions in Flanders. Differences between regional varieties were found for duration, steady-state formant frequencies, and spectral change of formant frequencies. Variation patterns in the spectral characteristics of the long mid vowels /e o ø/ and the diphthongal vowels /ɛi œy ɔu/ were in accordance with a recent theory of pronunciation change in Standard Dutch. Finally, it was found that regional information was present in the steady-state formant frequency measurements of vowels produced by professional language users. © 2007 Acoustical Society of America. [DOI: 10.1121/1.2409492]

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I. INTRODUCTION

This paper describes the vowel system of Standard Dutch as spoken in the Netherlands and Flanders and examines regional patterns of variation in the acoustic characteristics of the 15 vowels of Dutch /a e i ɔ u y e o ø ɔu ɛi œy/. The reasons for describing these regional variation patterns were twofold.

First, in recent years it has become generally accepted that a language's vowel system is better characterized when its description includes regional varieties than when it includes only a single idealized set of acoustic-phonetic characteristics (Clopper *et al.*, 2005; Hagiwara, 1997). Earlier studies on the vowel system of Standard Dutch (Adank, van Hout, and Smits, 2004; Pols *et al.*, 1973; Van Nierop *et al.*, 1973) are therefore limited in that they do not include regional varieties. Pols *et al.* describe the acoustic characteristics of vowel tokens produced by 50 male speakers from the Netherlands, who spoke Standard Dutch, while Van Nierop *et al.* provide a description of vowel tokens produced by 25 female Standard Dutch speakers from the Netherlands. Adank *et al.* describe the acoustic characteristics (duration,

f_0 , and formant frequencies F_1 through F_3) of realizations of the vowels of Standard Dutch for ten male and ten female speakers from the Netherlands and ten male and ten female speakers from Flanders. Although Adank *et al.*'s description is an improvement over Pols *et al.*'s and Van Nierop *et al.*'s in the sense that speakers from Flanders are included as well, it is limited because it excludes regional varieties.

Second, it is at present not feasible to establish neither how the pronunciation of the vowels of Dutch varies across the Dutch language area, nor how this pronunciation of these vowels evolves over time, as no previous acoustic descriptions are available. This paper attempts to fill this gap by providing a comprehensive overview of the extent to which Dutch vowels vary in their acoustic characteristics across regional varieties in the Netherlands and Flanders. In doing so, this overview could serve as a point of reference for further studies on the vowel system of Standard Dutch.

The present study builds on Adank *et al.*, who describe recordings of 40 professional users of Standard Dutch (i.e., teachers of the Dutch language). These recordings were made using a sociolinguistic interview in which vowels and consonants were elicited through a wide variety of tasks. Adank *et al.*'s vowel tokens were recorded through a formal reading task, i.e., reading nonsense words in carrier sentences from a computer screen. Of the 40 speakers, 20 were from the socioeconomic core area (the culturally and economically dominant region) in the Netherlands and 20 were from Flanders' socioeconomic core area.

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TABLE I. The selected towns per speech community, for each of the eight selected regions.

Speech community	Region	Name	Selected towns
Netherlands Central	N-R	Randstad	Alphen aan de Rijn, Gouda
Intermediate	N-M	South-Gelderland	Tiel, Veenendaal, Ede, Culemborg, Elst
Peripheral 1	N-S	Limburg	Sittard, Geleen, Roermond
Peripheral 2	N-N	Groningen	Assen, Veendam, Winschoten
Flanders Central	F-B	Brabant	Lier, Heist-op-den berg
Intermediate	F-E	East-Flanders	Oudenaarde, Zottegem, Ronse, Brakel
Peripheral 1	F-L	Limburg	Tongeren, Bilzen
Peripheral 2	F-W	West-Flanders	Ieper, Poperinge

Originally, 160 speakers were recorded through Adank *et al.*'s sociolinguistic interview. The present study describes the remaining 120 speakers, who were distributed across six regional varieties of Standard Dutch, with ten female and ten male speakers per variety. In the description it is first established whether the variation patterns reported for the two standard varieties described in Adank *et al.* are representative for regional varieties of Standard Dutch and, second, the variation patterns across the six varieties are identified.

II. MATERIALS

A. Database design, recordings, and acoustic measurements

1. Speech communities, resigns, and towns

In each country, also referred to as "speech community," four regions were distinguished, a central region, and three noncentral regions: an intermediate region and two peripheral regions. Twenty speakers were recorded per region. The central region in each speech community was the socioeconomic core area of that community. It was thought that the speech from the speakers in the central region would reflect the most prestigious variety of Northern Standard Dutch, or NSD, (spoken in the Netherlands) and Southern Standard Dutch, or SSD, (spoken in Flanders) in both communities. In Adank *et al.*, the vowel tokens of the two central regions are described.

Regional pronunciation variation in Standard Dutch is directly influenced by the dialects of the regions in question. The more the regional dialects differ from Standard Dutch, the stronger the accent of that region is present when speaking the standard language (e.g., Chambers, 2003; Labov, 1972). Covering the range of pronunciation variation implies selecting peripheral areas. In both speech communities two peripheral regions were selected that were maximally distant geographically from each other and from the core area. The intermediate region was a region geographically next to the central region. The regional dialects of the intermediate region are closer to the standard language.

For NSD, the central region was the west, consisting of the provinces Northern-Holland, Southern-Holland, and Utrecht, also known as "the Randstad" and referred to as "N-R" (Netherlands-Randstad). The cities Amsterdam, Rotterdam, Utrecht, and The Hague are part of the Randstad. The intermediate region for NSD enclosed the southern part of the province Gelderland and part of the province Utrecht. This region is referred to as "N-M" (Netherlands-Middle).

The two peripheral regions for NSD were the province Limburg, or "N-S" (Netherlands-South), in the south of the Netherlands, and the province Groningen, or "N-N" (Netherlands-North), in the north of the Netherlands.

In SSD, the central region was "Brabant," denoted as "F-B" (Flanders-Brabant). Brabant enclosed the provinces Antwerpen and Flemish-Brabant, with the cities of Antwerpen and Leuven, respectively. The intermediate region was the province East-Flanders, referred to as "F-E" (Flanders-East). The two peripheral regions for SSD were the provinces (Flemish) Limburg, or "F-L" (Flanders-Limburg), and West-Flanders, or "F-W" (Flanders-West).

Several towns were selected per region, following three criteria. First, the selected towns in each region had a comparable socioeconomic profile. Second, they belonged to the same dialect group. Third, the Dutch spoken in the towns was regarded as characteristic of that region. No major cities were selected, because it was expected that the Dutch spoken in major cities is influenced by dialects (or languages) other than those spoken in the surrounding region, due to migration. Table I lists the selected towns per region and Fig. 1 shows the location of these towns in the Netherlands and Flanders.

2. Speakers

All 160 speakers were Dutch teachers at secondary education institutes at the time the interview was recorded. Dutch teachers were selected because they are professional language users who are expected to speak standard Dutch on a daily basis. Furthermore, they are instructors of the standard language and may therefore be regarded as having a normative role. A final reason for selecting Dutch teachers was that it was assumed that their speech would show more regional variation than broadcasters' (whose speech is generally used in pronunciation studies of the standard language, cf. Bell, 1983).

The teachers who participated in the interview taught at schools for secondary education in the selected towns. They had to meet the following requirements. First, at the time of the interview, they all lived in one of the selected towns, or near that town in the dialectal region characteristic for that region. Second, they were born in the region or moved there before their eighth birthday. Third, they had lived in the region for at least eight years prior to their 18th birthday. Finally, the speakers were divided into two age groups, a younger group and an older group. The speakers in the

FIG. 1. Map of the Netherlands and Flanders, showing all selected towns, '•' shows the location of each town.

younger group were between 22 and 44 years old at the time of the interview and speakers in the older group were between 45 and 50 years old. Each region in Table I was thus represented by 20 speakers: five young men, five older men, five younger women, and five older women. Note that speaking a regional dialect or not was not a criterion for selection. It was assumed that growing up in a specific region implies that regional features of the standard language play a role in the acquisition and socialization process.

3. Carrier sentences

Dutch vowels have traditionally been divided into phonologically short vowels, /a ɛ ɪ ɔ ʏ/, phonologically long vowels /a e ɪ ø o u y/, and diphthongs, /eɪ ou œy/ (Booij, 1995). All target vowels were produced in a carrier sentence. The sentences had the following generic structure for the short vowels ("V" indicates the target vowel):

In sVs en in sVsse zit de V
/ɪn sVs ɛn ɪn sVsɛ zɪt dɛ V/
[In sVs and in sVsse is the V]

The sentences had the following structure for the long vowels and the diphthongs:

In sVs en in sVze zit de V
/ɪn sVs ɛn ɪn sVzɛ zɪt dɛ V/
[In sVs and in sVze is the V]

Of the three different consonantal contexts (CVC, CVCV, or V), the CVC contexts were selected for further processing. The CVC-structure /sVs/ can be regarded as a neutral context for Dutch vowels.

4. Recording procedure

The vowels were elicited through the sentences that were presented to the speaker on a computer screen, with a 3 s interval between sentences. When the speaker made a mistake, the interviewer interrupted the computer program and went back at least two sentences and asked the speaker to repeat these sentences. This task was performed twice. A total of 4800 vowel tokens were thus recorded: two tokens of each of the 15 vowel categories of Dutch, produced by 160 speakers.

5. Acoustic measurements: Duration, F_1 and F_2

The start and end times for the duration of each token were labeled manually in the digitized speech wave. Labels were placed at zero crossings at the onset and offset of the glottal vibrations of the vocalic portion of the /sVs/ syllable. When labeling it was ensured that the surrounding speech sounds were not audible in the remaining signal. The duration of each vowel segment was defined as the interval between the segment labels at the start and end of the vocalic portion.

The frequencies of F_1 and F_2 were stored at nine points of the vowel token's duration, with the first point at the start of the vocalic portion and the ninth point at the end of the vocalic portion, and the remaining points spaced at equal-sized intervals, relative to the absolute duration. The nine monophthongal vowels /a ɛ ɪ ɔ u y/ were represented at one time point only, i.e., at 50%—the fifth of the nine time points—as Adank *et al.* (2004) report that these vowels can be separated fairly well based on their steady-state characteristics for their first two formants only. The diphthongal vowels /eɪ œy ou/ and the long mid vowels /e o ø/ were represented at two time points, i.e., 25% and 75%, or the third and seventh time point, as Adank *et al.* report that these vowels cannot be adequately separated unless information about their dynamic characteristics is supplied. They suggest that

the three long mid vowels for Dutch should not be treated as monophthongal vowels, but instead as semidiphthongal vowels, when describing Dutch vowels acoustically, especially for NSD. The monophthongal vowels, semidiphthongal vowels, and full diphthongal vowels were analyzed separately.

Finally, Adank *et al.* provided a description of the measurements of the fundamental frequency for the two central regions. However, as they found no differences between these two regions, it was decided to exclude the analysis of the fundamental frequency in the present paper. For further specifics of the acoustic measurements, see Adank, van Hout, and Smits (2004).

III. RESULTS

A. Duration

1. Duration variation within speech communities

Figure 2 shows the average duration measurements for all vowels across the four regions in the both speech communities and Figure 3 shows the average durations per region for both genders pooled across both speech communities.

A repeated-measures analysis of covariance (ANOVA) was run on the duration measurements for each vowel token, with vowel category as the within-subject factor and with the speaker's regional background (region) and gender as between-subjects factors. The analysis was carried out per speech community.

The analysis for NSD showed a significant main effect of the within-subjects factor vowel ($F[6.228, 104]=1253.32$, $p<0.05$, Huynh-Feldt corrected). Furthermore, effects were found for between-subjects factors region ($F[3, 152]=8.91$, $p<0.05$) and gender ($F[1, 152]=8.45$, $p<0.05$), whereas the region $\times$ gender interaction was not significant. This suggests that the duration of some vowels varied across the four NSD regions. Second, the effect for gender indicates that the female speakers produced longer vowels than male speakers, as can be observed in Fig. 3. A post-hoc analysis was carried out on region to further investigate the differences between NSD regions. The p value was set to 0.001 to correct for the large number of analyses. The results showed that the vowels of the central region N-R were overall shorter than for N-M and N-N (cf. Fig. 2). The results for SSD revealed an effect of the within-subjects factor vowel ($F[5.118, 104]=1256.81$, $p<0.05$, Huynh-Feldt corrected) and a significant main effect of the between-subjects factor gender ($F[1, 152]=20.45$, $p<0.05$), while region and the region $\times$ gender interaction were not significant. Again, the female speakers showed longer durations than the male speakers (cf. Fig. 3).

2. Duration variation between speech communities

Figure 4 shows the average duration per speech community, pooled across the four regions in each community. To establish which vowels varied in their duration measurements across both communities, a univariate ANOVA was carried out for each vowel separately. The duration measurements per vowel token served as the dependent variable, and community served as the independent variable. Two univariate ANOVAs were run: one for the two central regions and

FIG. 2. Error bars (bars represent one standard deviation) of average duration in ms per vowel, for the 80 NSD speakers (top panel) and the SSD speakers (bottom panel). ("ou"= $/\text{ou}/$, "ui"= $/\text{y}/$, "eu"= $/\text{ø}/$, "A"= $/\text{a}/$, "O"= $/\text{ɔ}/$, "Y"= $/\text{ɣ}/$, "I"= $/\text{i}/$; o=central region, $\square$ =intermediate region, x=peripheral I, and Δ =peripheral II).

one with the three noncentral regions nested under community, for NSD and SSD separately. Because of the large number of analyses, p was set to 0.001.

The analysis for the two central regions indicated that the durations for $/\text{æy}/$ ($F[1, 78]=14.46$, $p\leq 0.001$) $/\text{y}/$ ($F[1, 78]=30.52$, $p\leq 0.001$) and $/\text{i}/$ ($F[1, 78]=16.62$, $p\leq 0.001$) were different for both communities. The analysis for the six noncentral regions showed that the duration of $/\text{y}/$ ($F[1, 78]=84.84$, $p\leq 0.001$) was shorter for NSD and that the durations of $/\text{a}/$ ($F[1, 78]=30.76$, $p\leq 0.001$), $/\text{ɛ}/$ ($F[1, 78]=30.55$, $p\leq 0.001$), $/\text{ɔ}/$ ($F[1, 78]=65.75$, $p\leq 0.001$), $/\text{ɣ}/$ ($F[1, 78]=50.76$, $p\leq 0.001$), and $/\text{i}/$ ($F[1, 78]=44.17$, $p\leq 0.001$) were all longer for NSD. There-

FIG. 3. Error bars (bars represent one standard deviation) of average duration in ms per vowel, for the 80 female speakers (circles) and 80 male speakers (squares) per region; ("ou" = /ɔu/, "ui" = /æy/, "eu" = /ø/, "A" = /a/, "O" = /ɔ/, "Y" = /y/, "I" = /i/).

fore, additional variation patterns were observed when the six noncentral regions were taken into account, especially for /a ɛ ɔ y i y/.

Second, Adank, van Hout, and Smits (2004) report that the vowels for the two central regions can be divided into two durational groups, long /a e o ø ɔ u ɛɪ æy/ and short /a ɛ i ɪ ɔ u y y/. To establish whether the same division would be found across all NSD and SSD regions, a series of *t* tests was carried out (cf. Adank *et al.*). A total of 105 pairwise comparisons were run for the 15 vowels. These 105

FIG. 4. Error bars (bars represent one standard deviation) of average duration in ms per vowel, for NSD (circles) and SSD (squares); ("ou" = /ɔu/, "ui" = /æy/, "eu" = /ø/, "A" = /a/, "O" = /ɔ/, "Y" = /y/, "I" = /i/).

analyses were repeated for the eight regions. The vowels /a e o ø ɔ u ɛɪ æy/ displayed significantly ($p \leq 0.001$) longer durations than /a ɛ i ɪ ɔ u y y/ for all four NSD regions and for SSD's central region (F-B). The regions F-E, F-L, and F-W displayed a different pattern. For F-E and F-L, the vowels could be divided into three groups depending on their duration; long: /a e ɛɪ ɔ u o ø æy/, half-long: /y/ and short: /a ɛ i ɪ ɔ u y/. For F-W, the vowels could be divided into two groups; long: /a e o ø ɔ u ɛɪ æy y/ and short: /a ɛ i ɪ ɔ u y/.

The duration analysis shows that the division of vowels into phonetically long and short vowels was not identical in the two communities. A caveat must be made for F-B; this region's division into long and short vowels is not representative for the three noncentral SSD regions. Instead, it resembles the pattern found for all NSD regions.

B. Formant frequencies: Steady state

1. Steady-state variation within speech communities

The nine monophthongal vowels /a ɛ ɪ i ɔ u y y/ were represented by the formant measurements at 50% of each vowel token's duration. The formant frequencies were transformed using Lobanov's (1971) normalization procedure to enable comparison of formant frequencies across genders. Formant frequencies usually vary greatly across male and female speakers due to anatomical and physiological differences between both genders (Peterson and Barney, 1952). Therefore, Lobanov's normalization procedure was applied as it effectively reduces anatomical and physiological gender-related variation in formant measurements, while adequately preserving variation related to the speaker's regional background (Adank, Smits, and van Hout, 2004).

Two multivariate ANOVAs were run on the pooled measurements of F_1 and F_2 for each vowel token, one for NSD and one for SSD. In both analyses, the multivariate dependent variable consisted of pooled measurements of normalized F_1 (zF_1) and normalized F_2 (zF_2) for the nine monophthongal vowels, and region and gender were included as between-subjects factors. NSD showed a significant effect for region ($F[3,152] = 11.44$, $p < 0.05$), while gender and the region $\times$ gender interaction were not significant. This indicates that the shape of the vowel systems varied across the four NSD regions. A post-hoc analysis on region (Tukey, $p \leq 0.001$) indicated that N-S differed significantly from N-R and N-M. SSD showed an effect for region ($F[3,152] = 16.74$, $p < 0.05$). The post-hoc analysis for region showed that F-E and F-W differed significantly from central region F-B, and that F-W differed from F-L. These results indicate that the shapes of the vowel systems varied regionally in both speech communities and that speaker gender did not affect these measurements.

It was decided to use the raw (un-normalized) data for further analyses, as it is presumed (Clopper *et al.*, 2005; Disner, 1980) that Lobanov's normalization procedure may introduce artifacts when used for measurements based on vowel systems that differ in their overall size and shape (cf. Clopper *et al.*, 2005). In addition, as female speakers are not

FIG. 5. Vowel diagram showing average formant frequencies for all monophthongal vowels for NSD. Averages were taken at 50% of the duration. N per symbol is 40.

directly compared with male speakers in any of these analyses, it is not necessary to use normalized data (cf. Adank, Smits, and Van Hout, 2004).

Figures 5 and 6 show the vowel diagrams for the four NSD regions and the four SSD regions, respectively.

To get an impression of the specific effects of the speaker's regional background on the first two formant frequencies per vowel token, a univariate ANOVA was carried out for each of the nine monophthongal vowels per speech community. The raw values of F_1 or F_2 served as the dependent variable and the four regions per community served as the independent variable. Table II shows effects for /a ε ɪ ɔ u y/ for NSD and for /ε ɔ u/ for SSD. Overall, the effect sizes were largest for F_1 for /ε/, for F_2 for /a/, and for F_2 for /u/ for NSD. The small number of significant effects for SSD suggest that there was more regional variation within NSD. As it is generally assumed (e.g., Stevens, 1998) that F_2 correlates strongly with tongue position (front versus back) and F_1 with tongue height (high versus low), it may be that the monophthongal vowels varied more in tongue position than in tongue height, as the effects for F_2 outnumber those for F_1 .

2. Steady-state variation between speech communities

A univariate ANOVA was carried out for each of the nine monophthongal vowels for the raw values of F_1 and F_2 , respectively. The values of F_1 or F_2 served as the dependent variable, and community served as the independent variable. These analyses were run twice: once for all measurements of

the two central regions and once for the six noncentral regions. The results as listed in Table III for the two central regions show effects for two vowels: /ɪ u/, whereas for the six regions effects for /a ε ɪ ɔ u y/ were found. This suggests that more regional differences exist between the three non-central regions per community than between the two central regions. Furthermore, when Table III is compared with Table II it appears that more differences occurred within NSD than between NSD and SSD. Another remarkable outcome is that more differences occurred for F_2 than for F_1 .

C. Formant frequencies: Spectral change

1. Spectral variation within speech communities

The three long mid vowels /e o ø/ and the diphthongal vowels /εi œy ɔu/ were represented by the formant measurements at 25% and 75% of the vowel duration. All analyses were carried out for /e o ø/ and /εi œy ɔu/ separately, following Adank, van Hout, and Smits (2004). Eight multivariate repeated-measures ANOVAs were run to test for within-community differences. The first four were run for /εi œy ɔu/: two for the female and male NSD speakers and two for the female and male SSD speakers. The within-subjects factor vowel category consisted of a measure for the spectral change in each vowel token, which was defined as the absolute difference of the formant frequency between 25% and 75% of the vowel duration in Hz in F_1 and F_2 (the multivariate dependent variable). Thus ΔF_1 is the absolute difference in Hz between the values of F_1 at 25% and at 75% and ΔF_2 is the absolute difference in Hz between F_2 at 25% and

FIG. 6. Vowel diagram showing average formant frequencies for all monophthongal vowels for SSD. Averages taken at 50% of the duration. N per symbol is 40.

at 75%. The analyses were run on the pooled values for ΔF_1 and ΔF_2 and the four regions (region) served as the independent variable in all four analyses. The results showed one significant effect, for the female NSD speakers ($(F[3,76] = 5.83, p < 0.05)$). A post-hoc analysis ($p \leq 0.001$) on region showed that regions N-M and N-S differed, indicating some spectral-change differences between these two regions for the female speakers in Fig. 7 for the full diphthongs. No other effects were found.

The four multivariate repeated-measures ANOVAs for /e o ø/ used the same design as for /ei œy ou/. Effects were found for NSD only, for the female ($F[3,76] = 6.41, p < 0.05$) and male speakers ($F[3,76] = 2.20, p < 0.05$). A post-hoc analysis (Tukey, $p \leq 0.001$) indicated that N-M differed

from N-S for the female speakers. Figure 7 shows longer spectral change trajectories for the three long mid vowels for N-M than N-S.

Onset and offset frequencies. Figures 7 and 8 show both spectral change and onset and offset frequencies. Eight multivariate repeated-measures ANOVAs were run to ascertain the significance of the differences observed in both figures. The first four were run on the onsets for /ei œy ou/, repeated for F_1 and F_2 and for NSD and SSD. The within-subjects factor vowel category was made up of the formant measurements at 25% of the vowel's steady-state portion, and the eight regions served as the between-subjects factor region in each analysis. The results for F_1 showed no effects for NSD, but a significant main effect of region was found for SSD

TABLE II. Partial η^2 for the significant effects ($p \leq 0.001$) for REGION for the ANOVAs on frequencies for F_1 and F_2 for the nine monophthongal vowels.

Vowel	NSD		SSD	
	F_1	F_2	F_1	F_2
/a/	...	0.208	...	...
/a/	...	...	...	...
/e/	0.413	0.181	0.126	...
/ɪ/	0.174	0.132	...	...
/i/	...	...	...	...
/ɔ/	0.169	0.151	...	0.125
/u/	...	0.213	...	0.179
/x/	...	0.130	...	...
/y/	...	...	...	...

TABLE III. Partial η^2 for the significant effects ($p \leq 0.001$) for COMMUNITY for the ANOVAs on frequencies for F_1 and F_2 for the nine monophthongal vowels.

Vowel	Two regions		Six regions	
	F_1	F_2	F_1	F_2
/a/	...	...	...	0.048
/a/	...	...	...	...
/e/	...	...	...	0.100
/ɪ/	...	...	0.046	0.096
/i/	...	...	...	...
/ɔ/	...	...	...	...
/u/	...	0.202	...	0.111
/x/	...	...	...	...
/y/	...	...	...	0.169

FIG. 7. Spectral change patterns for NSD. The phonetic symbol is plotted at the average formant frequency at 75% of the duration and the line originates from the average formant frequencies at 25% of the duration. N per symbol is 40.

FIG. 8. Spectral change patterns for SSD. The phonetic symbol is plotted at the average formant frequency at 75% of the duration and the line originates from the average formant frequencies at 25% of the duration. N per symbol is 40.

($F[3,156]=6.95$, $p<0.05$), and a post-hoc analysis (Tukey, $p\leq 0.001$) showed that the F-B speakers started their diphthongal vowels more open than the F-W speakers (cf. Fig. 7). For F_2 , a significant main effect was also found for region for SSD ($F[3,156]=3.70$, $p<0.05$), while the post-hoc analysis showed no effects.

The next four ANOVAs were run on the offsets for /*ei* *œy* *œu*/ for F_1 or F_2 per community. The within-subjects factor vowel category was made up either of the F_1 measurements or of the F_2 measurements at 75% of the vowel token's steady-state portion, and region served again as the between-subjects factor. For SSD, the results for F_1 showed an effect for region ($F[3,156]=7.85$, $p<0.05$), and the post-hoc analysis (Tukey, $p\leq 0.001$) showed that the F-B speakers ended their diphthongs at a more fronted position than the F-W speakers (cf. Fig. 8). F_2 showed effects for NSD ($F[3,156]=3.10$, $p<0.05$) and SSD ($F[3,156]=4.01$, $p<0.05$), but the post-hoc analysis showed no effects.

The second set of eight ANOVAs was run on the onsets and offsets for /*e* *o* *ø*/. The design was similar to the ANOVAs for /*ei* *œy* *œu*/. The results for F_1 's onsets showed an effect for NSD ($F[3,156]=8.70$, $p<0.05$) and SSD ($F[3,156]=3.10$, $p<0.05$). The post-hoc analysis indicated that the N-M speakers pronounced the long mid vowels with a more open onset than the N-S speakers (cf. Fig. 8). The results for F_2 showed an effect for SSD ($F[3,156]=8.16$, $p<0.05$). The post-hoc analysis revealed a significant difference between SSD regions F-E and F-L; /*e* *o* *ø*/ were more fronted in F-L than in F-E. The results for F_1 's offsets showed a significant main effect for SSD ($F[3,156]=3.96$, $p<0.05$). The post-hoc analysis showed no significant effects. F_2 showed an effect for SSD only ($F[3,156]=7.69$, $p<0.05$), and the post-hoc analysis indicated that the F-L speakers ended their vowels at a more fronted position than the F-E speakers, as can be observed in Fig. 8.

2. Spectral variation between speech communities

a. Diphthongization. Adank, van Hout, and Smits (2004) showed that /*ei* *œy* *œu*/ are more diphthongized for the female N-R speakers than for the female F-B speakers. Second, /*e* *o* *ø*/ are more diphthongized for N-R than for F-B for both genders. Two repeated-measures ANOVAs were run to establish whether this variation pattern would also be observed when all regions were included. In the first ANOVA, the within-subjects factor consisted of pooled values of ΔF_1 and ΔF_2 for /*ei* *œy* *œu*/, while the eight regions served as the between-subjects factor. The analysis was repeated for both genders. A significant main effect was found for region for the female speakers only ($F[1,158]=6.44$, $p<0.05$), indicating that the spectral change characteristics for the female speakers varied for /*ei* *œy* *œu*/ in NSD and SSD, with longer spectral change characteristics for NSD than for SSD (cf. Figs. 7 and 8). A post-hoc analysis (Tukey, $p\leq 0.001$) showed that N-M differed significantly from F-B and F-E and that N-N differed from F-E. No effects were found for the male speakers. The second ANOVA was set up as the first, only here the values of ΔF_1 and ΔF_2 for /*e* *o* *ø*/ served as the within-subjects factor. The results showed a significant main effect for region for the female speakers ($F[1,158]$

$=15.89$, $p<0.05$) and for the male speakers ($F[1,158]=13.19$, $p<0.05$), indicating that the spectral change characteristics varied across the three long mid vowels in NSD and SSD, with longer spectral change characteristics for NSD. The post-hoc analysis (Tukey, $p\leq 0.001$) for the female speakers showed significant differences between N-R and F-E, between N-M and all four SSD regions, and between N-N and F-B, F-E, and F-W. For the male speakers, significant differences were found between N-R and F-B, F-E, and F-W, between N-M and all four SSD regions, and between N-N and F-B and F-W.

Overall, these results first show that Adank *et al.*'s finding of more extensive diphthongization for /*ei* *œy* *œu*/ for female speakers in N-R than in F-B can be extended to most regions in both speech communities. Second, Adank *et al.*'s finding that /*e* *o* *ø*/ are more diphthongized for N-R than for F-B for both genders is also valid for most regions in NSD and SSD.

b. Onset and offset frequencies. Eight repeated-measures ANOVAs were carried out to identify differences in the onset and offset frequencies of /*ei* *œy* *œu*/ and /*e* *o* *ø*/ between both communities. The first two were run on the onsets for /*ei* *œy* *œu*/, for both formants separately. In each analysis, the within-subjects factor vowel was made up of the formant measurements at 25% of the vowel's steady-state portion, and the eight regions served as the between-subjects factor. The results for F_1 showed an effect of region ($F[7,312]=7.48$, $p<0.05$), and a post-hoc analysis (Tukey, $p\leq 0.001$) revealed that the F-W speakers started their diphthongal vowels less open than the N-R, N-M, and N-N speakers. The results for F_2 showed an effect for region ($F[7,312]=3.12$, $p<0.05$), but the post-hoc analysis showed no significant effects.

The two analyses for the offsets showed the following results. For F_1 for /*ei* *œy* *œu*/ an effect was found of ($F[7,312]=3.59$, $p<0.05$), but the post-hoc analysis showed no effects. For F_2 , an effect of region was found ($F[7,312]=5.95$, $p<0.05$) and the post-hoc analysis showed that the F-L speakers ended their diphthongal vowels at a more fronted position than the N-M and N-N speakers (cf. Fig. 8).

For /*e* *o* *ø*/, an effect was found for region ($F[7,312]=11.29$, $p<0.05$) for F_1 's onsets. The post-hoc analysis showed F_1 differences between N-R and F-L, between N-R and F-W, between N-M and F-B, F-L, and F-W, and between N-N and F-L and F-W. Figures 7 and 8 show that the NSD speakers started their long mid vowels at a more open position than the SSD speakers, as all F_1 averages are lower for the SSD regions. For F_2 , an effect for region ($F[7,312]=4.88$, $p<0.05$) and the post-hoc analysis showed that the F-L speakers started their long mid vowels more fronted than the speakers from N-R, N-M, and N-N (cf. Fig. 8). For the offsets of F_1 , an effect for region ($F[7,312]=2.43$, $p<0.05$) was found, but the post-hoc analysis showed no effects. For F_2 , an effect for region ($F[7,312]=4.60$, $p<0.05$) was found. The post-hoc analysis showed that the F-L speakers ended their long mid vowels more fronted than the N-M speakers (cf. Fig. 8).

D. Discriminant analyses

1. Steady-state measurements

Following Adank *et al.*, a quadratic discriminant analysis (QDA) was carried out to establish whether individual formant measurements show regional variation that allowed the speakers to be assigned to the corresponding region. The formant frequencies (F_1 and F_2) per vowel token for all nine monophthongal vowels were entered simultaneously as predictors. The QDA was set to classify each speaker into one of the eight regions, setting the chance level to 12.5%. A high percentage of correctly classified speakers suggests that regional accents are highly discriminable. The results showed that 72.2% of the speakers could be classified correctly. The formant frequencies of the speakers thus contained sufficient information about the speaker's regional background to allow the majority of the speakers to be assigned to the correct region.

A second QDA was carried out with community as the variable to be predicted (chance level 50%), with the F_1 and F_2 values of the nine monophthongal vowels entered simultaneously as predictors. The results showed that 84.4% of the speakers were classified correctly, meaning that the majority of speakers could be correctly assigned to either NSD or SSD.

2. Spectral change

Two QDAs were carried out to establish whether the speakers could be classified into the corresponding region or speech community based on the spectral change patterns in the formant frequencies of / ϵ i œ y ɔ u e o $\emptyset$ /. In the first analysis, ΔF_1 and ΔF_2 , pooled for all 160 speakers for / ϵ i œ y ɔ u e o $\emptyset$ / served as predictors, and region served as the dependent variable. This QDA showed that 48.8% of the speakers were classified correctly, which is above chance level (12.5%), but considerably lower than the percentages found for the monophthongal vowels. A second analysis was run with the same set of predictors, this time with community as the dependent variable, setting the chance level to 50%. The results showed that 78.4% of the speakers could be classified correctly.

These results indicate that the spectral change measurements contained sufficient information for a large proportion of the speakers to be assigned to the corresponding region or speech community, although the spectral change information conveyed less regional information than the steady-state measurements.

IV. DISCUSSION

A. Duration

First, considerable within-community differences were found for NSD, but not for SSD. The duration of the vowels from N-M and N-N was overall longer than for N-R. Furthermore, the division of vowels into phonetically long and short vowels was not identical for NSD and SSD. For the intermediate region (N-M) and the two peripheral regions (N-S and N-N) in NSD, the statistical analysis classified the vowels into two groups: / ϵ i œ y ɔ u e o $\emptyset$ a/ and / a ϵ i ɔ u y ɤ /.

Figure 2 shows that there is hardly any overlap between these two groups, especially for NSD, with longer durations for all vowels for the former group. The three noncentral SSD regions show a different pattern: for the intermediate region (F-E) and the peripheral I region (F-L), the vowels were divided into three groups, longer, / a ϵ ɪ ɔ u o $\emptyset$ œ y/, half-long: /y/ and shorter: / a ϵ i ɔ u ɤ / and for peripheral II, the vowels were divided into two groups, i.e., longer: / a ϵ o $\emptyset$ ɔ u ɛ i œ y y/ and shorter: / a ϵ i ɔ u ɤ /. This pattern could be explained by variation in the duration of /y/; it was either phonetically long, or half long in the nonjcentral SSD varieties of Dutch, while it was phonetically short in NSD and in SSD's central region (F-B). The duration analysis revealed one further pattern within the Flanders speech community: the division into longer and shorter vowels in SSD's central region (F-B) was identical to the division in the four NSD regions, but differed from the three noncentral SSD regions. The division in Flanders' central variety was thus not representative for all SSD regions. The duration division for NSD and SSD's central regions was generally in agreement with phonological descriptions of the duration of Dutch vowels (Rietveld *et al.*, 2004). The results for regions F-E and F-L were more in accordance with the description of Koopmans-van Beinum (1980), who classifies /y/ as a half-long vowel. Nevertheless, the results for F-E and F-L did not fully comply with Koopmans-van Beinum's analysis as she classifies /i/ and /u/ as half-long, while they were short for F-L and F-E.

Second, the analysis indicated between-community differences for /y/ and / a ϵ ɔ ɤ i/; /y/ was found to be significantly longer for SSD than for NSD, while / a ϵ ɔ ɤ i/ were significantly longer for NSD (cf. Fig. 4).

Third, the duration results show longer overall durations for female speakers across all central and noncentral regions, and this gender-specific variation pattern was especially prominent for NSD's intermediate region (N-M). A similar difference between male and female speakers was previously reported for American English vowels (cf. Hillenbrand *et al.* 1995; Clopper *et al.*, 2005) and for Swedish vowels, in read speech as well as in more natural speaking styles (Simpson, 2001). It is not clear what causes their gender-related differences, although some authors suggest physiological explanations. For instance, Simpson proposes that these differences may be partly explained by differences in the synchronization of tongue body and tongue tip movements in female and male speakers.

B. Steady-state F_1 and F_2

The analysis for the steady-state measurements for the nine monophthongal vowels first showed within-community differences. The analyses per vowel showed regional differences across the majority of NSD's monophthongal vowels, i.e., for / a ϵ i ɔ u y ɤ /. For SSD, regional differences were only found for three vowels, / ϵ ɔ u/. The vowels / ϵ ɔ u/ thus showed the most within-community variation as they show differences within both speech communities. Overall, the monophthongal vowels in both speech communities varied mostly in their tongue position, and less in their tongue

height, especially for SSD. Adank *et al.* reported that the central regions' vowel systems are anchored on the point vowels /a i u/, which were largely unaffected by language changes between the two central regions. However, the non-central varieties appeared to be anchored on /a/ and /i/ alone, as /u/ showed substantial variation in its F_2 dimension. Figures 6 and 7 show that /u/ was relatively backed in regions N-R, N-N and F-B, but fronted in the five remaining regions. The vowel /u/ may be undergoing a pronunciation change and become more fronted in certain regional varieties in NSD as well as SSD.

The analysis of the steady-state measurements showed some differences between speech communities as well. More differences were found between the three noncentral regions of NSD and SSD than between the two central regions. Differences between the two central regions were found for the two vowels /u/, while differences between the six noncentral regions were found for six vowels, i.e., /a e i u y y/.

C. Spectral change of F_1 and F_2

For the long mid vowels /e o ø/ and the diphthongs /ei œy ou/, the spectral change, or diphthongization, was investigated for F_1 and F_2 . For the two central regions, Adank *et al.* reported considerably more diphthongization for /e o ø/ for N-R than for F-B for both formants. An effect of gender was also found: /ei œy ou/ showed greatest F_1 -diphthongization for the female speakers. The analyses first revealed some differences within NSD for /e o ø/; which showed more diphthongization in the intermediate region in the Netherlands than in the peripheral I region (N-S). No differences in diphthongization were found within the SSD speech community, neither for the diphthongal vowels nor for the long mid vowels.

The analysis indicated between-community effects only for the female speakers for /ei œy ou/, which was also reported in Adank *et al.* It was found that the female NSD speakers showed more diphthongization than the female SSD speakers. Furthermore, /e o ø/ were more diphthongized in NSD than in SSD, for all speakers. These findings are also in agreement with Adank *et al.*

The analysis of the onset and offset frequencies showed a prominent between-community difference for the long mid vowels: most NSD speakers started their long mid vowels at a more open position than the SSD speakers. This result is in agreement with one of the predictions of a recent theory on pronunciation change in Standard Dutch (Jacobi *et al.*, 2004; van Heuven *et al.*, 2002; Stroop, 1998). This theory states that a new sociolect of Dutch, "Polder Dutch" is evolving in the Netherlands. Stroop (1998) claims that this variety is typical of (relatively) young, highly educated, progressive Dutch women, but that men are most likely to follow suit. Stroop further claims that Polder Dutch is not based on any existing regiolect (regional variety) of Dutch and is spoken throughout the Dutch language area. The most conspicuous characteristics of Polder Dutch are a more open pronunciation of /ei œy ou/, and a more open pronunciation and increased diphthongization of the long mid vowels /e o ø/. The analysis of the onsets of /ei œy ou/ indicated that

the NSD speakers started these vowels at a more slightly more open position than the SSD's peripheral II speakers, but these effects should not be overrated as they were relatively small. The results for the long mid vowels displayed more aspects of Polder Dutch, as they showed considerably more diphthongization for the NSD speakers than for the SSD speakers. Furthermore, the analysis indicated that the NSD speakers started these vowels at a more open position than the SSD speakers. However, to establish whether Polder Dutch is emerging in the Netherlands, more extensive analyses on, preferably, more spontaneous recording material are required.

D. Differences between and within speech communities

The results showed differences between as well as within speech communities. Overall, it seems that more within-community variation patterns were found for NSD than for SSD; for NSD regional differences were found for duration, the steady-state measurements, and the spectral change measurements for the long mid vowels. The results indicated that the vowels of Standard Dutch show more regional variation in the Netherlands than in Flanders. A similar difference between the Netherlands and Flanders was described in Van de Velde *et al.* (1997). Van de Velde *et al.* suggest that the difference in uniformity originated from a divergence in the pace at which the standard variety evolves in the two speech communities, with NSD changing more rapidly than SSD.

E. Regional traces

The results of the discriminant analyses indicated that there was sufficient regional variation present in the measurements of the steady-state formant frequencies to allow most of the speakers to be classified into the appropriate region or speech community. When the analyses were run on the measurements for the long mid vowels and the diphthongal vowels, a similar pattern was found in the results (although the percentages were lower). This is noteworthy, given the specific speaking style used for recording the vowel tokens, i.e., reading aloud nonsense sentences from a computer screen. It is well documented (Chambers, 2003; Labov, 1972) that speakers tend to use more lower-prestige utterances (e.g., more dialect words) in more informal speaking styles such as spontaneous conversation. In more formal speaking styles, they tend to use more high-prestige utterances (i.e., more variants in the standard language). The interview was conducted in a relatively formal setting and the vowels were pronounced in nonsense sentences. When reading aloud words, especially in nonsense sentences, speakers are generally over conscious of their speaking style and tend to carefully monitor their pronunciation. The formal setting in conjunction with the specific task used may have induced them to monitor their speech in such a way that relatively little regional traces were present. However, the results illustrated that regional traces may very well be present in the speech from professional language users, even when the speech is recorded in a formal setting. It would therefore be

interesting to compare the present results with acoustic measurements of vowels recorded in one of the more informal tasks present in the sociolinguistic interview. This may lead to even more extensive regional variation patterns to be uncovered between these eight varieties of Standard Dutch. Another prospect would be to compare the classifications of the statistical analyses with classification scores from listeners, to establish whether listeners can perceive the reported regional differences as well. Alternatively, a perceptual similarity test could be run that presents listeners with a pair of vowel tokens and requires them to decide whether the two tokens were produced by speakers of different regional varieties (cf. Clopper *et al.*, 2006). Clopper *et al.* used a paired comparisons similarity task to estimate the perceptual distance between six regional varieties of Standard American-English. The results from such a perceptual similarity test may lead to more insights in the perceived linguistic distances between specific regional varieties in the Dutch language area.

F. Final remarks

It seems justified to conclude that the differences between the two central regions of NSD and SSD as described in Adank *et al.* were, to a large extent, also found for the noncentral regions within each speech community. However, the analysis revealed additional variation patterns within and between NSD and SSD. Most notably, the fronting of /u/ in five of the noncentral regions across NSD and SSD and the lengthening of /y/ in the three SSD varieties F-E, F-L, and F-W. Second, the analysis indicated that SSD was more uniform with respect to the variation in the vowel system than NSD. Furthermore, regional variations patterns in the production of long mid vowels /e oø/ supported a recent theory on an emergent sociolect of Standard Dutch in the Netherlands. Finally, the present study illustrated that distinct regional variation patterns can be observed in the speech of relatively highly educated (i.e., university level or comparable), professional users of the standard language.

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