PROMINENCE EFFECTS ON DUTCH LOW VOWELS

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ABSTRACT

This paper investigates the acoustic realisation of the Dutch low vowels /a(ː)/ and /ɑ/ based on a large corpus of speech recordings (the CGN corpus). Variation in the realisation of these vowels has been observed, specifically of cases where lax /ɑ/ appears to substitute for tense /a/ in non-prominent positions, but no large-scale acoustic investigation comparing the formant distributions of these vowels has yet been carried out. The present study looks at F1 and F2 of ca. 1 million low vowels to investigate the role of prominence (4 different levels of stress) in conditioning variation in vowel quality. Results show that secondary stressed /a/ is indeed realised much like /ɑ/, i.e. further back and higher in the vowel space. This holds generally for both Netherlandic and Belgian Dutch. Unstressed /a/ on the other hand approaches /ə/ in the Netherlands, but not in Belgium.

Keywords: vowel quality, prominence, variation, Dutch

1. INTRODUCTION

1.1. Variation and alternation in Dutch vowels

The Dutch vowel system has 12 monophthongs (both Netherlandic and Flemish), with schwa counting as an additional phonological vowel for Netherlandic Dutch. Monophthongs are typically described as having a phonological length distinction, phonetically realised reliably as a tense/lax quality opposition, yielding the following 5 pairs: /i/-/ɪ/, /y/-/ʏ/, /e(ː)/-/ɛ/, /o(ː)/-/ɔ/, /a(ː)/-/ɑ/, and unpaired /u/, /ø/, and /ə/ [1, 2, 3].

This paper is concerned with known variation in the vowel quality (F1, F2) of members of pairs across the tense/lax divide, with a focus on the low vowel pair (/a/-/ɑ/). There are at least two different views in the literature on the nature of this variation.

The first sees the phenomenon as phonological substitution: long/tense vowels may be realised as their short/lax counterparts, e.g. the lexical vowel /a/ in words like /ˌka.bi.ˈnɛt/ may be realised as [ɑ] (‘vowel shortening’ in [1], ‘lexical vowel reduction’ in [4]). According to [1], this particularly targets word-initial vowels, but can apply to all non-primary stressed syllables alike. The second view considers variation to reflect a general reduction process that targets only unstressed vowels (‘vowel reduction’ in [1], ‘acoustic vowel reduction’ in [4]).

Some confusion nevertheless remains about which phenomenon applies to which vowels. For words like /ba.ˈnan/, realisational variants ranging from [a] (expected) to [ɑ] and [ə] have been noted for the first (unstressed) vowel [4], and this particular word is listed as an example both of ‘vowel reduction’ (to schwa) and ‘vowel shortening’ (substitution) [1]. As unstressed vowels may be targeted by either of the two processes it is not clear at this point that the phenomena are entirely distinct.

Until now, production studies have not directly addressed tense/lax variation in detail, with the exception of [2, 5] on Belgian varieties of Dutch, which revealed a great degree of overlap between realisations of /a/ and /ɑ/ in Antwerp Dutch. On the perception side, there is evidence that /a/ may be mistaken for /ɑ/, at least when the vowel is presented excised from a word in isolation ([6], and cf. [7]).

1.2. Research aim

In order to provide acoustic substance to the aforementioned observations and claims about variation across the tense/lax opposition, the present work documents the realisational distributions of the low vowel pair /a/-/ɑ/ based on corpus data. The focus is on low vowels because i) these do not diphthongise, in contrast to Dutch mid vowels (in the Netherlands), and ii) observations about reduction and substitution suggest that alternations are readily observable, in contrast to what is the case for high vowels [1].

The main aim of this paper is therefore descriptive: What are the distributions of /a/ and /ɑ/ vowels as a function of prominence, and more specifically stress status?

2. METHODOLOGY

2.1. Speech materials

2.1.1. Corpus extraction & preprocessing

This study uses the *Corpus Gesproken Nederlands* [8], excluding only those parts that consist of (live sports) commentaries (folders *comp-i* and *comp-l*), which were characterised by considerable background noise. F1 and F2 were measured at three timepoints (25%, 50% and 75% into the vowel) for all Dutch vowels, for the first three speakers in each sound file, based on the automatically generated transcriptions provided with the corpus. Vowels followed by /r, l/ were categorically excluded from analysis due to known coarticulatory effects [9]. Lobanov-normalisation [10] was performed on a by-speaker basis to determine the relative position of each vowel within the speaker's vowel space. Vowels with F1/F2 values more than 3 SD away from the mean for that vowel category were excluded from further analysis. This method yielded a total of over 8 million vowel tokens.

2.1.2. Identification of target items with low vowels

The tense/lax contrast in Dutch is correlated with syllable structure. Tense variants tend to be restricted to closed syllables, whereas lax variants may also occur in open syllables [11]. Identical syllabic environments for /a/ and /ɑ/ are thus only found for monosyllabic words (e.g. *kap* /kɑp/ and *kaap* /kap/), where polysyllabic minimal pairs are assumed to have different syllabification (e.g. *kapen* /ka.pən/ but *kappen* /kap.pən/ with an ambisyllabic intervocalic consonant). The present investigation uses two kinds of target words (full list available online, see link for scripts below):

1. a (near-)complete set of Dutch monosyllabic words of the structure (C)(C)(C)V(C)(C)(C) where V is either /ɑ/ or /a/ (N=830);
2. a set of polysyllabic words (2–5 syllables), containing /ɑ/ or /a/ in the initial syllable (N=284).

Target words were identified based on the orthographic occurrence of 'a' and 'aa' in initial syllables of items occurring on the lemma lists of the CGN. Words in which the target vowel was followed by a tautosyllabic /r/ or /l/ were again not included. Phonological vowel category (/ɑ/ or /a/) was manually determined and a number of words with non-target vowels were excluded.

The vowels in the monosyllabic set carry lexical stress by definition. The expectation is that vowels in this set will be maximally distinct if prominence plays a role in determining distributions. In contrast, prominence status is varied (as a variable of interest) for the vowels in the polysyllabic set. Three levels are identified: i) primary stress, ii) secondary stress (assigned based on the principle of alternating rhythm following [1, 11]), and iii) unstressed (stress-adjacent). A distinction is made between secondary stressed and unstressed vowels to investigate the possibility that these may be subject to different types of variation (see Section 1.1), and because a distinction was not made in an earlier study looking at reduction [6]. Example words for all 4 types of prominence status are given in Table 1. Based on these target words, the corpus yielded a total of over 1 million initial low vowels for analysis (ca. 424k /a/ and 684k /ɑ/).

	tense /a/	lax /ɑ/
stressed monosyll.	/ˈχaf/	/ˈχɑf/
stressed polysyll.	/ˈpa.χi.na/	/ˈbɑk.la.va/
secondary stressed	/ˌka.bi.ˈnɛt/	/ˌkɑn.ta.ˈrɛl/
unstressed	/ma.ˈho.ni/	/ɑt.ˈtɛn.si/

Table 1: Example target words with /a/ and /ɑ/ as a function of prominence (stress status).

2.2. Statistics

Analysis was performed in R [12]. Linear-mixed regression models were fitted with *lme4* [13] on Lobanov-normalised F1 and F2 as a function of various predictors. Main effects were assessed through LRTs between full and null models for the predictors tested, and multiple comparisons (Tukey-corrected) are from *emmeans* [14]. R^2 values are generated with the package *MuMIN* [15]. Extracted data and scripts are available here: https://github.com/ambrug/Dutch_low_vowels.

3. RESULTS

3.1. Low vowels within the Dutch vowel space

Figure 1 shows the full vowel space for Netherlandic Dutch and Belgian Dutch, based on all monophthongs. Labelling is kept as it is in the CGN, with I E A O Y reflecting lax/short variants. For the tense mid vowels /e ø o/ (CGN labels: e 2 o), F1 and F2 are based on the measurement at 25% of the vowel duration as these are known to be realised as narrow closing diphthongs in Netherlandic Dutch [3] (see also method used in [16]). The Netherlands data are based on means from >2400 speakers and

>5 million vowel tokens, and the Belgium data on >1200 speakers and >3 million tokens.

These overall results show that /ɑ/ ('A' in Fig. 1) is realised further back and higher than /a/ ('a') in both varieties, in line with formant values reported in [2, 5, 16, 17, 18] (although cf. [19, 20] for some varieties spoken in Belgium). As the labels shown here represent a broad phonetic transcription, however, the apparent distinctiveness of the categories in part reflects the mere existence of acoustically different clusters, rather than differences as a function of phonological vowel status. In the following, the analysis will focus on the tense/lax distinction based on manually determined phonological status instead.

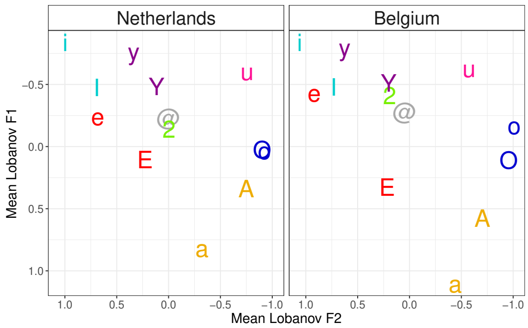

Figure 1: Vowel space showing (phonological) monophthongs for speakers from the Netherlands and Belgium. Labels reflect CGN annotations.

3.2. Realisation of low vowels as a function of stress status

Regression models were run for each formant and region separately, using mean values per speaker. Fixed effects were interacting `vowel` (ə, a, ɑ) and `stress` (4 levels, see Table 1). A random intercept was added for `speaker`. Conditional R^2 for these models was around 0.7 for the Netherlands, and around 0.75 for the Belgian data. Descriptive mean F1 and F2 for low vowels as a function of stress status are shown Figure 2, with schwa (>2 million tokens) plotted for reference as well.

For both Belgian and Netherlandic Dutch there were interactions between `vowel` and `stress` for both F1 and F2, with most pairwise comparisons, within- and between-vowel, significantly different from each other (at $p < 0.05$). Focussing on /a/, which shows to be most variable as a function of stress, the following comparisons are of particular interest for Netherlandic Dutch:

- secondary stressed /a/ is no different in F1 from unstressed /ɑ/ (est= 0.05, SE=0.05);
- secondary stressed /a/ is no different in F2 from /ɑ/ when it i) also carries secondary stress (est=0.10, SE=0.04) or ii) is unstressed (est=0.07, SE=0.03);
- unstressed /a/ is different from /ə/ in terms of both F1 (est=0.12, SE=0.01, p<0.0001) and F2 (est=-0.25, SE=0.01, p<0.0001).

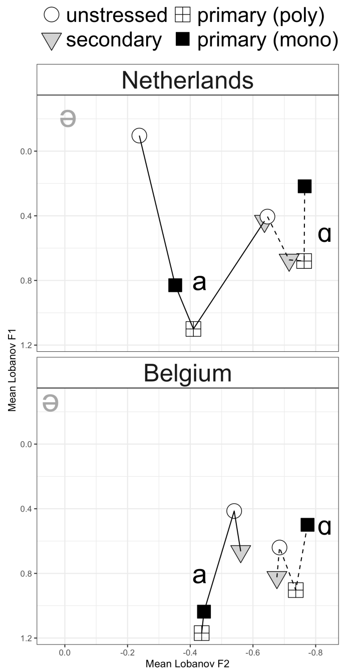

Figure 2: Mean F1 and F2 (Lob-normalised) of low vowels and schwa as a function of stress.

In sum, secondary stressed /a/ is retracted relative to its own stressed and unstressed counterparts, being realised with F2 similar to that of /ɑ/ (although not quite as far back as stressed /ɑ/ in monosyllables). When F1 and F2 are taken into account together, secondary stressed /a/ in words like /ˌka.bi.ˈnɛt/ is indistinguishable from /ɑ/ when it is unstressed in words like /ɑt.ˈtɛn.si/. Unstressed /a/ on the other hand is realised more centrally, although it remains distinct from /ə/.

For Belgian Dutch, the following tense/lax comparisons are most relevant:

- secondary stressed /a/ is no different in F1 from /ɑ/ when it is i) primary stressed and monosyllabic (est=0.13, SE=0.06) ii) secondary stressed (est=-0.21, SE=0.08) and iii) unstressed (est=0.02, SE=0.06);
- secondary stressed /a/ does not differ in F2 from secondary stressed or unstressed /ɑ/ (in both cases est=0.13, SE=0.05), nor from polysyllabic stressed /ɑ/ (est=0.17, SE=0.05);

Belgian Dutch thus exhibits similar retraction patterns as Netherlandic Dutch: secondary stressed /a/ overlaps in values with most cases of /ɑ/.

3.3. Antwerp vowels

To investigate claims about a merger in the Antwerp area, all low vowels spoken by Antwerp speakers (defined here as those who received their education in the Antwerp area, with *eduPlace* codes B-201–206 in the CGN) are considered separately (N=55 speakers and N=216 tokens). Figure 3 shows the mean values for /a/ and /ɑ/ ([ə] plotted for reference).

Regression results predicting F1 and F2 for /a/ and /ɑ/ reveal that F1 differs between `vowel`, but only for several comparisons involving primary stressed vowels. F2, however, is distinct only for the comparison between the most prominent lax vowel and the least prominent tense vowel: primary stressed monosyllabic /ɑ/ and unstressed /a/ (est=-0.32, SE=0.07, p<0.001). The latter, tense vowel can be seen to be realised more centrally, although not as much so as its Netherlandic counterpart. In short, this confirms [2, 5]'s observation that, at least in terms of F2, /ɑ/ and /a/ in Antwerp are to a large extent overlapping.

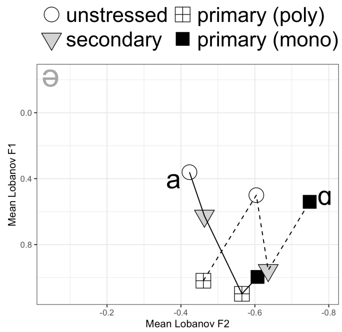

Figure 3: Mean F1 and F2 (Lob-normalised) of low vowels and schwa for speakers from Antwerp.

3.4. Other factors affecting F2 of tense /a/

Beyond prominence, many other factors may of course play a role in determining formant values. In order to assess what else may affect F2 for /a/, an exploratory random forest was run on all Lobanov-normalised F2 values for this vowel, using word-specific speaker means (package *ranger* [21], *mtry*=3, 2000 trees). The variable importance of the predictors is shown in Figure 4 and suggests that there is much speaker-dependent variation, beyond even more categorical speaker characteristics (such as place of education, year of birth). The variable *CGN folder* reflects different speech styles in the CGN, suggesting that there is considerable context-dependent variation. Most interestingly, usage-based factors such as word frequency (*Lg10WF*,

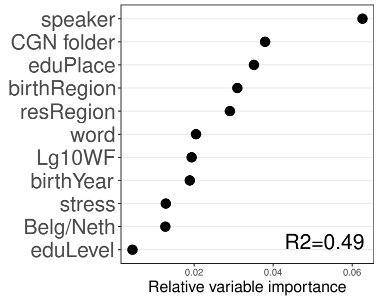

Figure 4: Variable importance for random forest on F2 for tense /a/.

based on the SUBTLEX corpus [22]) or other word-specific effects (*word*) do not rank highly here, counter to the general expectations about greater variation for more frequently used items [1, 23, 24]. The low ranking of *stress* (the 4 levels used in this study) might reflect that it makes a small contribution on its own, and rather derives its effect from interaction with other factors. Future work could look into this in more detail.

4. SUMMARY AND DISCUSSION

The above results show that vowel quality of Dutch low vowels indeed varies as a function of prominence. Especially tense /a/ was affected: when secondary stressed, it is retracted, occupying a region of the vowel space also used by /ɑ/.

The present data also bear on several other claims in the literature. For Netherlandic Dutch, data are in line with the observation that "[v]owels in open syllables …reduce easier than vowels in closed syllables" [1]: unstressed tense /a/, which always occurs in an open syllable (in contrast to /ɑ/), was realised toward the centre of the vowel space. These results are highly suggestive of the possibility that unstressed and secondary stressed /a/ are subject to variation of a different nature, at least in Netherlandic Dutch, with the former exhibiting patterns in line with reduction/centralisation, and the latter towards a merger with /ɑ/, also observed in Belgium. In Antwerp, /a/ and /ɑ/ generally exhibited similar F2 values, corroborating results by [5].

Finally, results presented here only describe averaged production patterns, and no claims are made with respect to perceptual distinctiveness of low vowels. While there is considerable overlap in formant values for low vowels, leading to non-distinct distributions under some prominence conditions, low vowels might well remain distinct in terms of duration, cf. [3, 16, 25].

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