Vowel Reduction in Dutch as Metrical Variation
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1. Introduction

The phenomenon of vowel reduction is a well-known problem in Dutch phonology (cf. Martin 1968, Kager 1989, Booij 1995, van Oostendorp 1997a, Geerts 2008), which, at first glance, seems very simple and straightforward (unstressed vowels are pronounced as schwa in informal style), but is quite complex in reality. It can be described as a process with an extremely simple, categorical structural change (full vowel → schwa), but an extremely complicated set of conditioning factors - both tendencies and categorical constraints - at various levels: segmental, syllabic, word-prosodic, lexical, and stylistic (pragmatic).

Although the various analyses of the problem (see above) are quite different, there is one fundamental assumption which they all share - the assumption that the prosodic structure of a word is constant, and vowel reduction is a (variable) process operating on certain positions in that prosodic structure. The current paper (based on Nazarov 2008) challenges this assumption and presents a different perspective on the problem: the prosodic structure of a word is claimed to be variable, while vowel reduction is an automatic consequence of a vowel’s being in a certain prosodic position. Although perhaps a bit exotic at first sight, this proposal has interesting implications, and is in some ways better as an explanatory model. Section 2 will present the main empirical details of the contexts in which vowel reduction applies; after that, Section 3 will explain the theoretical idea proposed here, and Section 4 will present an analysis in OT which makes this theoretical idea compatible with stress assignment, and which explains the correlation between reduction and style levels. Finally, Section 5 will provide some concluding remarks.

2. Descriptive overview of vowel reduction

In the grammar of (Standard) Dutch, the term ‘vowel reduction’ stands for optional realization of full vowels as schwa (cf. (1a)). There are other phonological phenomena in Dutch which could, in principle, also be subsumed under vowel reduction; these include laxing of unstressed vowels (cf. (1b)) and vowel deletion (cf. (1c)). All three phenomena share the notion that a vowel is somehow not fully realized, and that the non-full realization is associated with a rather informal and colloquial speech style. However, it is not clear whether laxing and vowel deletion are ultimately part of the same synchronic process as vowel reduction in the narrow sense\(^1\), and therefore, we will use ‘vowel reduction’ in the narrow sense only (as defined above).

(1) a. true reduction: [fonolo’yi ~ fonolo’yi ~ fono’lo’yi]\(^2\) ‘phonology’
    b. laxing: [ba’n’an ~ b’a’n’an] ‘banana’
    c. vowel deletion: [lokomo’tif ~ lokmo’tif] ‘locomotive’, [va’lerijo ~ ‘vlerijo] ‘Valerio (proper name)’

The data described in this section are primarily taken from Kager (1989) and Booij (1995), supplemented with data from a preliminary empirical investigation described in Nazarov (2008). The latter research consisted of collecting judgments from 6 native speakers

\(^1\) Geerts (2008) does treat vowel reduction and vowel deletion as extensions of the same process, but this approach is not uncontroversial.

\(^2\) All Dutch data will be given in a variant of the IPA-based phonemic transcription conventionally used to transcribe Standard Dutch.
The most important conditioning factor for vowel reduction is its status as a lexically conditioned process. In the data from Nazarov (2008), on average only 41% of the words in the word list, which all satisfied the phonological criteria for reduction, were judged as acceptable with reduction (with individual speakers’ rates ranging from 28% to 57%). However, there are enough regularities, both categorical and gradient, that guarantee the status of vowel reduction as a synchronic phonological process. The phonological regularities concern the segmental identity of the vowel itself and its surrounding segments, and also syllable structure and word prosody. In addition, there are two factors of language use that are normally identified as influencing vowel reducibility: the token frequency of a word and the style level used.

Concerning segmental identity of the vowel itself, the only categorical condition is that phonologically diphthongal vowels (ei, øy, au) are barred from reduction. However, in addition to this, the identity of a monophthongal vowel influences its susceptibility to reduction. The primary data for the relative reducibility of vowels come from patterns in the lexical distribution of reduction, but they seem to be confirmed by what we can recover from data on synchronic variation (i.e., the relative reducibility of different vowels in the same phonological grammar variant)\(^3\).

There are two proposals in the literature as to the nature of this reducibility hierarchy. The first is proposed in Kager (1989), and the second comes from Booij (1995):

\[
\begin{array}{c|c|c}
\text{Kager (1989)} & \text{Booij (1995)} \\
\hline
\text{most reducible} & \text{least reducible} & \hline
/e/ & /e, y/ & /e/ \\
/a/ & /a, α/ & /a/ \\
/o/, /ø/ & /o, ω/ & /o, y, ω/ \\
/i/ & /i/ & /i/ \\
/u, y/ & /y, u, ø/ & /u/ \\
\end{array}
\]

As can be seen above, the two hierarchies only differ in the place of /ø/, and the inclusion of lax vowels /ɪ, ɑ, ɔ/. The data gathered in the research for Nazarov (2008) confirm the hierarchy of tense vowels given in Kager (1989), and disprove the automatic connection between tense and lax vowels that is made in Booij’s (1995) hierarchy. The table below gives the percentages of words in the survey in Nazarov (2008) containing each of the tense vowels in a position theoretically eligible for reduction, in which the vowel in question was actually judged to be reducible.

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\(^3\) We do not know of any research which has systematically compared the reducibility of vowels in the same position within one word, which would be necessary to derive a scale of reducibility of vowels (research of this type is not easy to implement, in part because of the paucity of words that have the length that such an investigation requires) - comparing reducibility of vowels in the same position in different words is not valid because there is no way of guaranteeing that both words are judged/pronounced at the same style level. However, Kager (1989) does find a pattern in the relative reducibility of vowels in different positions within the same word, which supports the hierarchy found in lexical distributions.
The reducibility percentages of lax vowels in the survey in Nazarov (2008) are given below.

<table>
<thead>
<tr>
<th>vowel</th>
<th>percentage of reducibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>e</td>
<td>71%</td>
</tr>
<tr>
<td>a</td>
<td>58%</td>
</tr>
<tr>
<td>o</td>
<td>38%</td>
</tr>
<tr>
<td>ø</td>
<td>33%</td>
</tr>
<tr>
<td>i</td>
<td>30%</td>
</tr>
<tr>
<td>u</td>
<td>19%</td>
</tr>
<tr>
<td>y</td>
<td>17%</td>
</tr>
</tbody>
</table>

The reducibility percentages of lax vowels in the survey in Nazarov (2008) are given below.

<table>
<thead>
<tr>
<th>vowel</th>
<th>percentage of reducibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>ε</td>
<td>69%</td>
</tr>
<tr>
<td>i</td>
<td>47%</td>
</tr>
<tr>
<td>ø</td>
<td>42%</td>
</tr>
<tr>
<td>θ</td>
<td>39%</td>
</tr>
<tr>
<td>α</td>
<td>23%</td>
</tr>
</tbody>
</table>

Given the following vowel pairs as differing only in the feature [lax]: {e, i}, {a, α}, {o, ø}, {ø, θ} (cf., e.g., van Oostendorp 1995) - there is no simple and automatic relation between the reducibility of both members of these pairs. There is a generalization to make that the unrounded lax vowels /i, α/ are significantly less reducible than their tense counterparts, while the rounded lax vowels /ø, θ/ are marginally more reducible than the corresponding tense vowels. However, it is puzzling that lax vowels can be more reducible than tense vowels, because lax vowels always occur in (structurally) closed syllables, while tense vowels occur in open syllables: as mentioned by Kager (1989) and Booij (1995), closed syllables are less preferable for reduction, so that one would expect lax vowels to be automatically less reducible than their tense counterparts. All in all, the place of lax vowels in the reducibility hierarchy should be considered in further research, taking into account all additional factors (e.g., the influence of syllable codas).

Next to conditions on the vowel itself, there are conditions on the surrounding segments. These include a ban on reduction of vowels that are not preceded by a syllable onset, or vowels that are adjacent to [h]. There are also gradient preferences: for example, as mentioned above, most closed syllables are less preferred as targets of vowel reduction than open syllables. Also, some conditions on surrounding segments are only valid in certain prosodic positions (see below). Conditions on surrounding segments are described in detail in Kager (1989) and Booij (1995), but will not be discussed here, as they are not crucial for this paper.

Concerning word prosody, vowel reduction can occur in all syllables that do not carry (main or secondary) stress, except word-final syllables\(^4\). This class of unstressed, non-word final

\(^4\) Booij (1995) and Ernestus (2000) mention a handful of forms where they claim that vowel reduction does apply in final syllables; only very few of these forms cannot be explained by some other phenomenon. If it turns out that these forms are really governed by the same process as all the other cases of vowel reduction, then we can at least say that word-final vowel reduction is extremely rare.
positions can be divided into three subclasses, which will henceforth be called Position 1, 2 and 3, respectively. The definition of these Positions is as follows:

- **Position 1**: word-initial syllables directly preceding a syllable that carries (main or secondary) stress
- **Position 2**: syllables directly following a syllable that carries (main or secondary) stress
- **Position 3**: unstressed syllables directly following Position 2

Examples of these Positions identified in Dutch lexical words are given below:

(5)  
   a. Position 1: to mát ‘tomato’, ba nà látsi ‘banalization’
   b. Position 2: fò ko lá ‘chocolate’, fôn o lo yí ‘phonology’
   c. Position 3: fôn o lo yí ‘phonology’

The three Positions are identified because they are different in their relative reducibility. Evidence for such differences can be found both by between-word comparisons and by within-word comparisons.

The patterns in lexical distributions, as found for the word list in Nazarov (2008), are as follows:

- Of all words with a target vowel in Position 1, 34% allowed reduction of that vowel.
- For Position 2: 55%.
- For Position 3: 33%.

From these data, we can see that vowels in Position 2 are, overall, much more prone to reduction than Position 1 and 3, which, in turn, seem to have the same degree of reducibility (schematically: Pos 2 > [Pos 1, Pos 3]). This is the same as has been assumed in Kager (1995) and Booij (1995).

In contrast to this, Geerts (2008), using data from the CGN (Corpus Gesproken Nederlands/Corpus of Spoken Dutch), finds evidence for an equal reducibility status for Position 1 and 2, while he assumes Position 3 to be less reducible (schematically: [Pos 1, Pos 2] > Pos 3). Geerts’ methodology is somewhat different: he searches for corpus attestations of words that fit a set of prosodic patterns, and then determines for a target syllable - fixed for each prosodic pattern - whether it is reduced or not. The figures that he uses to compare Position 1 and 2 are percentages of corpus attestations that show vowel reduction (i.e., percentages of instances of vowels in Position 1 or Position 2, respectively, that undergo reduction). It is possible that the different findings in Geerts (2008) and in other research have been triggered by this methodological difference. However, the only safe conclusion is that the relation between Position 1 and Positions 2 and 3 cannot be unequivocally established, based on the data we have.

Data from within-word comparisons offer support for the ranking between Positions 2 and 3 as established in between-word comparisons: Position 2 is more susceptible to reduction than Position 3. This support comes mainly from words where Positions 2 and 3 are filled by the same underlying vowel, especially cases where this is a vowel relatively low on the reducibility scale. In words of this form, reduction of Position 3 can only occur if Position 2 also undergoes reduction. In other words, reduction of Position 3 only is banned, while the
other two reduction possibilities (Position 2 only, both Position 2 and 3) are allowed. This is illustrated below:

<table>
<thead>
<tr>
<th></th>
<th>No reduction in Pos 2</th>
<th>Reduction in Pos 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>No reduction in Pos 3</td>
<td>(fòno(lo)yì ‘phonology’ *(indìvi)dý ‘individual (noun)’</td>
<td>(fòna(lo)yì *(indìvi)dý</td>
</tr>
<tr>
<td>Reduction in Pos 3</td>
<td>N/A</td>
<td>*(fòna(lo)yì, *(indìvi)dý</td>
</tr>
</tbody>
</table>

According to Kager (1989), words where Positions 2 and 3 are both filled by vowels high on the reducibility scale, such as /e/ and /a/, can have reduction in Position 3 without reduction in Position 2 and vice versa; in other words, the restriction for other words with identical vowels does not seem to hold in these cases.

The generalization that can be stated about words with different vowels in Positions 2 and 3 is the following:

- If the vowel occupying Position 2 is more reducible than the one occupying Position 3, reduction in Position 3 is only possible if Position 2 is reduced (i.e., the same situation as with identical vowels: a reduced Position 3 without a reduced Position 2 is banned).
- If the vowel occupying Position 2 is less reducible than the one occupying Position 3, reduction in Position 3 and reduction in Position 2 are possible independently.

This can be illustrated by the following examples:

(7)  
a. Position 2 more reducible than Position 3:  
pàranomí ~ pàranomí ~ pàranomí, *pàranomí ‘paranomia’  
b. Position 2 less reducible than Position 3:  
χrònometérór ~ χrònometérór ~ χrònometérór χrònometérór ‘to time’

It must be emphasized, however, that the generalizations presented here do not seem to cover all data. An informal survey of our own judgments on a list of words containing both Position 2 and Position 3 revealed that the patterns are far from clear. Future investigations should provide better insight into these patterns. In the meantime, we will make one simplifying assumption, viz. that identically filled Positions 2 and 3 uniformly obey the constraint against reduction of Position 3 without reduction of Position 2, even if they are highly reducible vowels, which are (as stated above) claimed by Kager (1989) to behave differently.

Within-word comparisons of other pairs of Positions are more difficult because of the inherent properties of Dutch. A comparison between Position 1 and 3 is very difficult because of the constraints of the Dutch metrical system, which make Position 1 and 3 mutually exclusive in

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5 Kager (1989) claims that words of this type where Position 3 is occupied by /e/ cannot have reduction of Position 2 without reduction in Position 3; however, this is contradicted by the word χrònometérór ‘to time (with a timer)’, which can have (according to our intuitions) the reduced realizations (χrònometérór ~ (χrònometérór ~ (χrònometérór.

6 If the secondary-stressed syllable preceding Position 2 (and 3) contains /a/, this vowel must be laxed in order for reduction to occur. Sadly, this process has known very little phonological investigation (to our knowledge).
the default case \(^7\). A string with 5 syllables before main stress can only be parsed in the following three ways, of which only the first is unmarked (cf. Kager 1989):

\[(8) \quad \sigma_\text{Y} \sigma_2 \sigma_3 \sigma_2 \sigma_3(\sigma) \]
\[\sigma_1 \sigma_2 \sigma_2 \sigma_3 \sigma_2(\sigma) \]
\[\sigma_2 \sigma_3 \sigma_2 \sigma_3 \sigma_2(\sigma) \]

The only possibility for Position 1 and 3 to co-occur is in certain Graeco-Roman compounds, where the original stress of the first member is preserved:

\[(9) \quad \text{ko}'r\text{o}na \rightarrow \text{ko}r\text{onolo}'\text{gyi} \quad \text{‘coronology’} \]

This is the only potential ground for testing hypotheses on the relation between Positions 1 and 3 based on within-word comparisons; however, there has been no research in this direction yet (to our knowledge).

The co-occurrence of Positions 1 and 2 is less rare - these two positions co-occur:

- in some words with an odd number of syllables before main stress, where the regular option of a word-initial sequence of a stressed syllable and two unstressed syllables does not apply (\(\sigma_1 \sigma_2 \sigma_2 \sigma_3 \sigma_2(\sigma)\) instead of \(\sigma_2 \sigma_3 \sigma_2 \sigma_2(\sigma)\))
- in quadrisyllabic words that have antepenultimate stress

The problem with testing the relation between both positions systematically is the paucity of both types of words. Examples of members of this narrow class include:

\[(10) \quad \begin{align*}
\text{a. } & \text{e'lekto}'\text{rat} \quad \text{‘electorate’} \quad \text{(cf. also the second example in (5a))} \\
\text{b. } & \text{nau'sikaa} \quad \text{‘Nausicaa’} 
\end{align*} \]

In order to compensate for this, we attempted to test the relation between Position 1 and Position 2 by constructing a nonsense word list based on the second pattern, quadrisyllabic words with antepenultimate stress. The details of this survey will be reported in van Oostendorp & Nazarov (in preparation). The results are quite mixed, and in general do not warrant any conclusions, so that we can conclude that the relation between Position 1 and Positions 2 and 3 cannot be established with certainty at the moment.

Finally, as has been mentioned, there are factors of language use that influence vowel reduction. The tendency for more frequent words to allow reduction more often is noted by Kager (1989) and Booij (1995). However, this tendency is not very strong when interpreted as a crude statistical correlation, as evidenced by Martin (1968) and Nazarov (2008); it seems that frequency effects interact with the other factors that influence reduction (e.g., an /i/ in a word with frequency X is not necessarily allowed to reduce, if an /a/ in a word with a frequency lower than X is allowed to reduce). In any case, since frequency effects do not have a direct correlate in the model of synchronic grammar used here, this factor will not be taken into account in the formal analysis.

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\(^7\) This mutual exclusivity does not hold for words with native prefixes, e.g., \(\text{ya}\text{polit}\text{i}z\text{er}d\) ‘ politicized’, but prefixes are never eligible for reduction (e.g., \(\text{vorzeyd}, *\text{vorzeyd} \quad \text{‘foretold’} \)); also, prefixes in Dutch are generally assumed to be non-cohering (e.g., not to be part of the Phonological Word).
Stylistic marking of vowel reduction, however, is a factor that will play an important role in our formal analysis. Kager (1989) and Booij (1995) note that the amount of reduction increases when formality of style decreases; Geerts (2008) confirms this basic notion with data from the Corpus of Spoken Dutch (Corpus Gesproken Nederlands/CGN). In our OT analysis, we will make the common assumption that different styles correspond with different grammars, and, furthermore, we will assume that the correspondence between style and grammar is determined by the relative height of Faithfulness constraints; see section 4 for more on this.

3. Theoretical proposal: vowel reduction is metrical variation in disguise

In the theoretical analyses of Dutch vowel reduction known to date (amongst others, van Oostendorp (1997a), Geerts (2008)), different degrees of vowel reduction are linked to different style levels (cf. section 3), and style levels, in turn, are systematically linked to differences between grammars. In Optimality Theory (OT), the difference can be made by linking different constraint rankings to style levels, which consequently means that each style level has its own grammar (cf. section 4).

The assumption of a correlation between style levels and variants of OT grammars is maintained in the current analysis, but the locus of variation is claimed to be different. In previous analyses, the metrical structure of reduced and non-reduced versions of a single word has been kept constant, while the occurrence of the process of reduction was said to be optional. Kager (1989) even states that vowel reduction is ‘a window on metrical structure’, in the sense that comparing reduced and non-reduced versions of a word can help us discover ‘the’ metrical structure for that word.

In the current analysis, however, this conceptualization is turned upside down: the variation is localized in metrical structure. All style levels obligatorily require reduction in a well-defined class of prosodic positions, but the various style levels prefer different metrical structures, which may or may not parse a vowel into a position prosodic positions where reduction must apply.

There are at least two conceptual arguments for this change of perspective. First, the metrical pattern of Dutch words is underdetermined by the empirical data in a class of cases, namely, words that have an uneven amount of syllables preceding main stress. In these words, one of two situations applies:

- the first syllable directly precedes a stressed syllable (with main or secondary stress)
- there is a stretch of two contiguous unstressed syllables between the initial secondary stressed syllable and the next stressed syllable (main or sec. stress)

Such cases could be assigned different metrical structures in metrical ‘common practice’ (the examples used are to`mat ‘tomato’ and fono`lo`yi ‘phonology’):

(11) \( \sigma(\sigma...)\ldots \) : first syllable unfooted - e.g. to(mat)

(\( \sigma)(\sigma...)\ldots \) : first syllable parsed in subminimal foot - e.g. (to)(mat)

(12) \( (\sigma\sigma)(\sigma...)\ldots \) : binary foot + unfooted syllable - e.g. (fono)lo(yi)

\( (\sigma\sigma)(\sigma\sigma\sigma)(\sigma...)\ldots \) : ternary foot - e.g. (fonolo)(yi)
In order to resolve this indeterminacy, Geerts (2008) searches for experimental motivation in order to choose one correct metrical representation for each of these two problematic cases, but does not arrive at any conclusive findings. This means that, in principle, any of the structures in (11,12) should be possible for the types of words that they can parse. Thus, if one does not use conceptual arguments (e.g., prohibition of subminimal or ternary feet) to rule out all but one possibility in (11,12), it could be assumed that words with an uneven amount of syllables before main stress show variation between the metrical patterns in (11,12), perhaps conditioned by some factor. In other words, metrical variation is already in some sense inherent in the Dutch system of word prosody, so that it is realistic to invoke such a phenomenon.

Second, directly and uniquely linking vowel reduction to certain metrical positions opens up the possibility to represent lexical exceptions to reduction with underlyingly present metrical units: if a word exceptionally disallows reduction of a certain vowel, this word is stored with a metrical structure in which that vowel is unreduced. This is particularly interesting because underlying metrical units are also used in accounts of exceptional stress patterns in Dutch (cf. section 4). In other words, the current account of vowel reduction makes it possible to represent exceptions to reduction by an independently motivated mechanism of lexical exceptions, instead of an ad hoc exceptionality mark. It is difficult to conceive of a non ad hoc way of accounting for exceptionality in other formal accounts of vowel reduction, where a non-reducing vowel must be treated as exceptionally not undergoing a rule or process of vowel reduction.

In order to construct an account of metrically conditioned vowel reduction, we must assume a Prosodic Hierarchy which is slightly less standard. The hierarchical interval between the prosodic word and the foot, which is filled by the level of the Foot in ‘common practice’ (cf. (13A)), is split into two levels in the current approach: the Superfoot (Σ or SFt) level and the Foot (Ft) level (cf. (13B)). The division of this domain into Superfeet and Feet has been introduced for Dutch by van der Hulst & Moortgat (1980), and has been used in, amongst others, van Oostendorp (1995).

(13)

<table>
<thead>
<tr>
<th>A. (‘common practice’)</th>
<th>B.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prosodic Word (ω)</td>
<td>Prosodic Word (ω)</td>
</tr>
<tr>
<td>Foot (Ft)</td>
<td>Superfoot (Σ/SFt)</td>
</tr>
<tr>
<td>Syllable (σ)</td>
<td>Foot (Ft)</td>
</tr>
</tbody>
</table>

In the remainder of this text, ‘flat’ (non-arboreal) representations of metrical structure will indicate Superfeet with square brackets [ ], and Feet with parentheses ( ).

The assumptions on the nature of Superfeet and Feet made here are the following. Superfeet and Feet are both structures that are headed on one side (left or right), and which preferably contain two syllables. This means that the ideal Superfoot + Foot combination

8 It is also interesting to note that underlying feet used for exceptional stress and those used for marking certain vowels as non-reducible are in a complementary distribution (viz., exceptional stress feet are always word-final, while anti-reduction feet always come before main stress); cf. section 4.

9 This appears to be a rather curious assumption, because it seems more logical that a binarity requirement for Superfeet should mean that the Superfoot should contain two Feet rather than two syllables. However, since it seems that a preference of binarity is not observed in languages at the level of the prosodic word (i.e., every
would be one where the Superfoot and Foot coincide: \([\sigma \sigma] \) or \([\sigma \sigma]^{10}\). The difference between both units is that only heads of superfeet can bear (main or secondary) stress\(^11\), and, naturally, that superfeet dominate feet and not vice versa.

Given these assumptions about metrical structure, we further assume the crucial proposition that in Dutch, every Foot (Ft) contains exactly one full vowel. This allows for feet that consist of either one single syllable with a full vowel, or a head syllable with a full vowel and dependent syllables with schwa as their nucleus. Assuming that both feet and superfeet are left-headed in Dutch (which is the most natural assumption, since Dutch stress facts are most easily analyzed when main or secondary stress comes leftmost in every accentual unit), this means that syllables always start with their only full-vowel syllable, and optionally contain schwa syllables after that. A selection of foot structures possible and impossible under these constraints is shown below (where \(V\) stands for a full vowel):

\[
(14) \quad \text{(CV), (CVC\(\sigma\)), (CVC\(\sigma\)C\(\sigma\)), *(CVCV), *(C\(\sigma\)C\(\sigma\)), *(CVC\(\sigma\)C\(\sigma\)), *(CVC\(\sigma\)CV)}
\]

To illustrate the structures generated under such an approach, we present some examples of metrical parsings of Dutch words below:

\[
(15) \quad \begin{align*}
\text{a. } & [(\text{k\(\alpha\)})(\text{n\(\alpha\)})] \ 'canoe' \\
\text{b. } & [(\text{k\(\alpha\)d\(\alpha\)})] \ 'quay' \\
\text{c. } & [(\text{k\(o\)d\(o\)})][\text{(n\(a\))(t\(a\))}] \ 'coronation' \\
\text{d. } & [(\text{h\(i\)d\(a\)})][\text{(l\(o\)p\(a\))}] \ 'Hindeloopen (toponym)' \\
\text{e. } & (\text{f\(\sigma\)r})[(\text{m\(\alpha\)l\(\alpha\)})] \ 'formula' \\
\text{f. } & b\(\sigma\)[(\text{p\(a\)l\(\alpha\)})] \ 'to determine'
\end{align*}
\]

Examples (15a-d) show how vowel identity dictates metrical structure: in \(\text{k\(\alpha\)n\(\alpha\)}\), the second syllable cannot be parsed into the same foot as the first syllable, since it contains a full vowel, which forces two monosyllabic feet to be created within the superfoot; in contrast, the second syllable in \(\text{k\(\alpha\)d\(\alpha\)}\) contains a schwa, which means that it must be a non-head member of the foot headed by the preceding syllable; the same comparison holds for (15c,d), but now for two feet in the same word. Examples (15e,f) both feature an initial syllable which directly precedes a superfoot boundary; such syllables do not carry secondary stress (according to our judgments), and therefore are not parsed into superfeet. The difference between (15e) and (15f) is that the first syllable in (15e) has a full vowel and therefore can still form a foot on its own, while (15f) has a first syllable which cannot form a foot within the word because it can only occupy a non-head, non-first position in the foot, while there is no preceding syllable available.

The examples above illustrate how the metrical representation of a word systematically varies with vowel quality (full vowel vs. schwa). But the same principles governing this systematic
variation between words also assign different metrical structures to reduced and unreduced versions of the same word, as can be seen below:

(16)  a1. (to)[(mat)] ‘tomato’
a2. tɔ[(mat)]

b1. [(par)(ti)][(zan)] ‘partisan’
b2. [(par.ta)][(zan)]

c1. [(fo)(no)(lo)][(yǐ)] ‘phonology’
c2. [(fo.nə)(lo)][(yǐ)]
c3. [(fo.nə.lə)][(yǐ)]

The situation in (16a) is analogical to (15e,f), while (16b) is analogical to (15a,b). (16c) is somewhat different from the examples in (15), because the first superfoot is ternary rather than binary; however, the principle behind the parsings is the same: syllables containing schwa are parsed in a foot together with the preceding syllable, while syllables with a full vowel are always foot heads.

This consequence of the assumptions made (viz., that reduction variants of words can be uniquely distinguished by metrical structure) can be used to develop a theory of vowel reduction in which it is the choice between several metrical structures that determines where vowel reduction occurs or not. However, before we embark on this adventure, we will first justify our untraditional version of the Prosodic Hierarchy by providing independent motivation for it.

We know of at least three phenomena which motivate a Prosodic Hierarchy with feet and superfeet as presented here: restrictions on the shape of Germanic stems in Dutch; the so-called Germanic foot in Old English; and stress assignment in Nishnaabemwin.

In Dutch, word stems of the Germanic (inherited) stratum tend to conform to a template where the first syllable contains a full vowel, and may only be followed by syllables with schwa. Inflectional suffixes ‘conspire’ with this template: these are all vowelless or contain a schwa only (i.e., forms of the stems inflected by suffixes also conform to the template). There is one type of Germanic stems which categorically conforms to the template: (non-denominal) verb stems.

(17)  kop- ‘buy’ (ko.p-ə(n) ‘buy-Inf’)
      vandaːl- ‘stroll’ (va.n.də.l-ə(n) ‘stroll-Inf’)
      tekən- ‘draw’ (te.kə.n-ə(n) ‘stroll-Inf’)

Don & Erkelens (2006) provide experimental evidence which suggests that this templatic requirement is not only a distributional fact, but is also synchronically active. If the latter is the case, it is most elegant to describe this template as a domain which the verb stems (and their suffixed forms) have to match. It is precisely the foot as defined in this text that provides the appropriate domain; in other words, non-denominal, non-complex Germanic verb stems (and their (unprefixed) inflected forms) must be exactly the size of one single foot.

(18)  ‘[(ko.pən)]
      [(va.n.də.lən)]
The proposal of the ‘Germanic Foot’ for Old English (Dresher & Lahiri 1991) features a complex template to which ‘Germanic feet’ must correspond. A Germanic foot consists of either a heavy syllable, optionally followed by a light syllable; or a sequence of two syllables of which the first member is light, again optionally followed by a light syllable, cf. (19). The equivalence of a heavy syllable with a sequence of two syllables (L + L or L + H) within this structure calls for an extra node in the hierarchical structure, which could be ‘rewritten’ to either one heavy syllable, or a light syllable and another syllable. In other words, there must be a level on which the equivalence of H(eavy) and L(ight)+X holds, which means that there must be two levels between Prosodic Word and the syllable. This division is precisely what is advocated in this paper. An analysis of the Germanic Foot pattern in terms of Superfeet and Feet is provided in (20).

(19) or

(20)

Finally, there seems to be evidence for two layers of structure between the Prosodic Word and the syllable in Nishnaabemwin, an Algonquian language spoken in southern Ontario (Valentine 2001). According to Valentine (2001:55-7), who takes this particular analysis from Kaye (1973), quantity-sensitive iambics are built left-to-right in the word, and vowels in a weak foot position are either reduced or deleted; given this footing, main stress is assigned to the third foot from the end. The latter rule is suspicious from a conceptual point of view, because it is very unattractive to allow stress rules to count syllables or feet (especially given the metrical framework). In order to avoid ‘counting rules’, one could postulate binary head-final superfeet that organize the feet in a word, and say that main stress falls on the head of the non-final superfoot:\footnote{12 This analysis was suggested by Grażyna Rowicka (p.c.).}

(21) \[ [(n\text{i}\.w\text{á}a)][(b\text{a}\.m\text{i})(g\text{o}\.n\text{aa})] \text{ ‘ANsg sees us (excl.)’} \] (adapted from Valentine 2001:56; cursive script signifies that a vowel is reduced or deleted)

Given this reanalysis, there is also an interesting parallel with the situation in Dutch: in both cases, the Foot proper is a domain of vowel reduction. It remains to be seen in future research how much of this is due to coincidence. In any case, the data from Nishnaabemwin provide independent evidence for Superfeet and Feet as separate levels of metrical structure.

4. An analysis in OT

This section assumes the general framework of Optimality Theory. Because vowel reduction is a variable process (i.e., multiple outputs are linked to one input), the classic OT model must be enriched in order to explain the data (since classic OT can only effectuate the linking of one input to one output). There are several models in existence which serve this purpose (cf. Anttila 2002); the model used here is a hybrid of two different models: Stratified Grammar and Floating Constraints. Both of these models use variable constraint ranking within certain boundaries to allow several variants of one ‘mother grammar’.\footnotetext{12 This analysis was suggested by Grażyna Rowicka (p.c.).}
In the Stratified Grammar model (cf. Anttila 2002), the grammar consists of a ranking of ‘strata’, each of which contains one or more constraints. The constraints within each stratum can be ranked freely with respect to each other, but the ranking between strata is fixed. Thus, the grammar in (22a) may only surface as the subrankings shown in (22b), but never as (22c):

(22)  
a. A >> {B, C} >> D  
b. A >> B >> C >> D  
A >> C >> B >> D  
c. *A >> B >> D >> C (because {B, C} >> D)

The Floating Constraints model (cf., for instance, Nagy & Reynolds 1997) achieves variable ranking by assuming a fixed constraint hierarchy and one ‘floating’ constraint which can be inserted in any place in (a designated segment of) the hierarchy. This means that the grammar in (23a) can take the form of the options in (23b), but not that of (23c):

(23)  
a. A >> B >> C + D (floating)  
b. A >> B >> C >> D  
A >> C >> D >> C  
A >> D >> B >> C  
D >> A >> B >> C  
c. * A >> D >> C >> B (because B >> C)

The model which we will use (and which is very similar to the model implicitly assumed by van Oostendorp 1997a) could be called Floating Hierarchies. This model assumes that there are strata, as in Stratified Grammar, but these strata do not consist of a set of constraints, but rather of a set of constraint hierarchies; each hierarchy may have one or more members. For example, a stratum may have the form {A, B}, {P, [Q >> R]}, or {{W >> X}, [Y >> Z]}. Each of the constraints within a stratum may be ordered in any way that is faithful to any partial ordering present in the ‘mother grammar’. In other words, the hierarchies ‘slide into place’ in any way that does not break their inner ‘chains’ (and that does not violate the boundaries of the stratum), in the same way in which a floating constraint ‘slides into place’, integrating itself into a pre-existing hierarchy. This process is illustrated in (24): the grammar in (24a) can occur as the variants in (24b), but not as the variants in (24c).

(24)  
a. A >> {B >> C, D >> E} >> F  
b. A >> B >> C >> D >> E >> F  
A >> B >> D >> C >> E >> F  
A >> B >> D >> E >> C >> F  
A >> D >> B >> C >> E >> F  
A >> D >> E >> B >> C >> F  
c. * A >> B >> C >> D >> F >> E (because {B >> C, D >> E} >> F)  
* A >> B >> C >> E >> D >> F (because D >> E)

Together with this model of variable constraint ranking, we adopt the following principle from van Oostendorp (1997a) which evaluates the relative formality of grammar variants:

(25) The more formal the style level, the higher ranked the faithfulness constraints.  
(= van Oostendorp 1997a:209 (1))
This principle, motivated by the general idea of formal registers’ increasing ‘communicative effort’ on the part of the speaker, makes it redundant to specify style levels for each grammar variant in a variable grammar: if there are variants, the principle in (25) will automatically assign relative formality to each variant. The principle also constrains the analysis, because there are many conceivable ways to account for (stylistically conditioned) variable phenomena in OT that do not involve changing the place of faithfulness constraints only.

The constraints that are to be ranked variably in the current analysis are constraints on the form of feet and superfeet (Markedness constraints) on the one side, and constraints that favor the retention of vowel features (Faithfulness constraints) on the other side. In accordance with the principle in (25), higher ranking of the vowel retention constraints results in less or no vowel reduction and a more formal style, whereas lower ranking of these constraints ensues in more vowel reduction and a less formal style.

Before the interaction of these constraints can be shown, however, we must first introduce the context for these. This context consists of the following two constraints, which represent absolute conditions for reduction to occur:

\[
\text{Connect}(V,Ft) = \text{Project}(V,Ft) \& \text{Project}(Ft,V)\]

13 = the head of a syllable contains vowel features iff the syllable is the head of a foot

\[
\text{Max}(\text{LastV}) = \text{retain the last vowel of a lexical word}
\]

The formulation of Connect(V,Ft) is based on an theory of unary vowel features, specifically the set of representations for Dutch vowels proposed by van Oostendorp (1995) (these representations will be shown in a later section); in this proposal, schwa is a segment devoid of vowel features, and formally consists only of a root node which itself contains the binary specification [+sonorant, +vocalic]. Connect(V,Ft) has the effect of a one-to-one correspondence of foot heads and syllables with full vowels, and of dependent positions in a foot and syllables with schwa (i.e., in other words, this constraint sets up the foot as a reduction domain).

The descriptive constraint Max(LastV) could possibly be reformulated in a more interesting way; however, since the focus of this paper is not on the lack of reduction in the last syllable, we will use high-ranked Max(LastV) as a shorthand for any more elegant mechanism enforcing this phenomenon.

Furthermore, before we can formalize the variable parsing at the level of feet, as introduced in section 3, we must first provide an account of Dutch main stress in the non-standard system of superfeet.

Main stress assignment in Dutch (cf., e.g., Nouveau 1994) consists of one default pattern and two exceptional patterns. The default pattern is characterized by the following descriptive generalizations:

\[\text{(26)}\]

1. If the last syllable is not heavy (where heavy = bimoraic, and both tense and lax vowels project one mora), main stress is on the penultimate syllable.

Examples: \text{mà.kà.ro.nì} ‘macaroni’, \text{òò.to.mà.tì} ‘machine’

13 The constraint family Project (and related Connect) is taken from van Oostendorp (1995).

14 We follow, amongst others, Zonneveld (1993) and Nouveau (1994) in assuming that word-final sequences of a tense vowel and a consonant or group of consonants represent a disyllabic complex rather than a superheavy syllable.
2. If the last syllable is heavy, and the penultimate syllable is light, main stress is on the antepenultimate syllable (with secondary stress on the final syllable).
   Example: leóni.das ‘Leonidas’
3. If both the last and the penultimate syllable are heavy, main stress is on the penultimate syllable.
   Example: da.más.kos ‘Damascus’
4. Bisyllabic words are stressed on the penultimate syllable.
   Example: tú.kan ‘toucan’

The two exceptional patterns are the following:

(27) a. words with a light final syllable that have antepenultimate stress
   Example: mó.ni.kà ‘Monica’
   b. words that are stressed on their final syllable
   Example: fó.ko.lá ‘chocolate’

The analysis of main stress presented here is based on the proposal in van Oostendorp (1997b). The default stress pattern is accounted for by the following constraints:

NoClash = heads of Superfeet are not adjacent.
Non-Finality = the syllable carrying main stress is not final in the word.
Edgemost(R) = Align(PWd, R, σ, R) = the right edge of every Prosodic Word coincides with that of the syllable carrying main stress.
WSP(σ→Σ) = Weight-to-Stress Principle (from syllables to superfeet) = If a syllable is heavy and part of a Superfoot, this syllable is in the head position of the Superfoot.
Parse-syllable = every syllable is part of a Superfoot.
*[(µ)] = a superfoot does not consist of 1 mora only.

These constraints are ranked as follows:

NoClash, Non-Finality, *[(µ)] >> WSP(σ→Σ) >> Edgemost(R) >> Parse-syllable

The mechanism of this ranking can be seen in the table below.

<table>
<thead>
<tr>
<th></th>
<th>NoClash</th>
<th>N-Fin</th>
<th>*[(µ)]</th>
<th>WSP(σ→Σ)</th>
<th>Edgemost</th>
<th>Parse-syll</th>
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<tbody>
<tr>
<td>/impala/ ‘impala’</td>
<td></td>
<td></td>
<td>*!</td>
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<td>σσ!</td>
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<td>σσ!</td>
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15 We omit constraints on the headedness of feet and superfeet, which, of course, are unviolated and thus high-ranked; we will restrict ourselves to considering candidates that have left-headed structures on both levels, in order not to complicate the presentation of the analysis.
For the first word, *impala* (which represents the words that end in a light syllable), final stress is excluded by its violation of Non-Final, and antepenultimate stress (and stress earlier in the word) is excluded by excessive violations of Edgemost; thus, penultimate stress remains as the optimal option. Superfooting of syllables in word-initial pretonic syllables is excluded by NoClash\(^{16}\).

For the second word, *pyrmaliexion* (which represents the words ending in a light-heavy sequence), final stress is again excluded by violation of Non-Finality, and stress on the pre-antepenultimate syllable is excluded by excessive violations of Edgemost, but penultimate stress is no longer optimal, because the penultimate-stressed candidate violates the (syllable-to-superfoot) Weight-to-Stress principle - it contains a [LH] superfoot. Therefore, antepenultimate stress remains as the optimal candidate. The contrast between the last two candidates for this word provides the argument for the ranking WSP(σ→Σ) >> Edgemost. Also, the fact that the three violations of Edgemost in '[(pIV)(ma)(li)]Æ[(O)n]' are worse than two violations of Edgemost and a violation of Parse-syllable in the winning candidate '[(pIV)(ma)(li)]Æ[(O)n]' entails the ranking Edgemost >> Parse-syllable.

For the third word, *palɛmbɑŋ* (which represents words ending in two heavy syllables), final stress is again excluded by Non-Finality. Antepenultimate stress can be created by building one bisyllabic and one monosyllabic superfoot; this candidate is excluded by Edgemost. However, an alternative possibility for creating antepenultimate stress is not parsing the penultimate heavy syllable, which prevents violation of WSP(σ→Σ). The fact that penultimate stress is preferred to this candidate is explained by establishing the ranking *[(µ)]>> WSP(σ→Σ).

One could construct different parsings that yield penultimate main stress for this class of words: one where the two last syllables each occupy their own superfoot (which is possible, since they are heavy, bimoraic syllables), entailing secondary stress on the final syllable, and one where the two last syllables are parsed together in one superfoot (which is also possible when binarity is counted on the syllabic level). The fact that the latter possibility is the attested one establishes the ranking NoClash >> WSP(σ→Σ).

Finally, the fourth word, *tukan* (which represents bisyllabic words ending in a heavy syllable), can be parsed into a superfoot in its entirety, violating WSP(σ→Σ), or one can parse only its last syllable into a superfoot, violating Non-Finality. The fact that the first option is chosen provides the argument for the ranking Non-Finality >> WSP(σ→Σ). In this fashion, we have justified all subrankings of the main stress constraints proposed.

In order to account for the two exceptional stress patterns, we take a representational solution (this approach has been taken in many works on Dutch stress; it has been formalized in OT in \(^{16}\) Note that *(im)*'[(pa)(la)] does not violate WSP(σ→Σ), because the syllable *im* is not in a superfoot.)
van Oostendorp 1997b): words that have one of the exceptional stress patterns have underlying prosodic material which distinguishes them from other words. For the first exceptional pattern (exceptional antepenultimate stress), we assume that the last syllable of words that follow this pattern has an additional empty mora, and there is an underlying foot over this last syllable: CVCV(CV+µ). For the second pattern (exceptional antepenultimate stress), we assume that the last syllable is followed by an additional empty (catalectic) syllable, and there is, again, an underlying foot over the last segmental syllable and the empty prosodic unit: CVCV(CV.σ). This yields the following representations:

(29) a. /moni(ka+µ)/ [mónikà]
b. /foko(la.σ)/ [fôkolá]

In order to incorporate this account of exceptional stress into the current analysis, we must add additional constraints to the existing hierarchy:

Max(Ft) = the position, structure, and weight\(^{17}\) of a foot in the input may not be changed in the output.
Max(µ/σ) = retain (underlying) morae and syllables.
*Empty = there are no prosodic units without segmental content.

The ranking of these constraints must be Max(Ft) >> *Empty >> Max(µ/σ), which expresses the proposition that empty morae are disallowed unless they contribute to the structure of an underlying foot (cf. van Oostendorp 1997a). Regarding the integration of these three constraints in the ranking established above, Max(Ft) must be above Edgemost, but the ranking of *Empty and Max(µ/σ) with respect to Edgemost and Parse5syllable cannot be determined, since these two sets of constraints never come into direct conflict\(^{18}\). In this fashion, we arrive at the following constraint ranking:

[NoCl, NFin, *[µ] >> WSP(σ→Σ), Max(Ft) >> Edgemost >> Parse5syll] &
[Max(Ft) >> *Empty >> Max(µ/σ)]\(^{19}\)

See the tableau below for the effects and mechanism of this ranking:

\[
\begin{array}{|c|c|c|c|c|c|c|c|}
\hline
\hline
\text{word/phonetic form} & \text{NoCl} & \text{NFin} & *[µ] & \text{WSP} & \text{Max} & \text{Edgemost} & \text{Par}
\text{s5yll} & *\text{Empty} & \text{Max} \\
\hline
\text{‘Monica’} & & & & & & & & \text{σ} & & \text{σ} & \\
\hline
\text{‘chocolate’} & & & \text{σσ} & & \sigma & & & & & \text{σσ} \text{σ} \text{σσ} & \\
\hline
\end{array}
\]

\(^{17}\) The concept of ‘foot weight’ will be introduced below.

\(^{18}\) Naturally, Max(µ/σ) does come into conflict with Edgemost and Parse5syllable when syllables are deleted in order to satisfy the latter constraints; however, the fact that this situation does not occur can more plausibly be attributed to higher-ranked constraints against deletion of segments. Thus, it is not clear whether Max(µ/σ) is active here.

\(^{19}\) We will represent the discontinuous ranking of *Empty and Max(µ/σ) on the one side, and Edgemost and Parse-syllable on the other side, in the tableau as if it were Edgemost, *Empty >> Parse-syllable, Max(µ/σ).
For the first word, **monika**, we can see that final stress is excluded by Non-Finality. Penultimate stress is excluded by WSP(σ→Σ), as with any other word with a heavy final syllable. When the empty mora is deleted in order to make penultimate stress possible, this results in a violation of Max(Ft), because the ‘weight’ of the foot (its bimoraicity) has been altered. The fact that to violate Max(Ft) is worse than to have an additional violation of Edgemost (as in the winning candidate) establishes the ranking Max(Ft) >> Edgemost.

For the second word, **fokola**, we can see that deleting the empty syllable results in an unacceptable violation of Max(Ft) (because the structure of the foot is altered: the branching structure is changed to a non-branching structure). Antepenultimate stress (in segmental terms) is excluded by excessive violations of Edgemost. The remaining candidate is one with final stress (in terms of segmentally filled syllables), which behaves as if it had regular penultimate stress because of its segmentally empty final syllable.

We have seen that it is Max(Ft) which reacts against deletion of the exceptionality mark (empty syllable or mora) in these words. In other words, the presence of an underlying foot over the metrically enhanced final word-boundary is essential in this account: a mora or syllable suffixed to the underlying sequence of segments alone would not suffice, because the constraint Max(µ/σ) is ranked too low to have any effect on the stress pattern.

Having discussed the apparatus for accounting for main stress, we will now introduce the mechanism that makes possible the metrical variation that ensues in vowel reduction. This mechanism consists of constraints on the form of feet and superfeet, and constraints against the deletion of vowel features.

The foot and superfoot constraints, and their ranking, are shown below. The reasons for the ranking that is assumed will be explained at a later stage.

<table>
<thead>
<tr>
<th>(jo)(ko)(la)</th>
<th></th>
<th></th>
<th>*!</th>
<th>σ</th>
<th></th>
<th>*</th>
<th>*</th>
</tr>
</thead>
<tbody>
<tr>
<td>[(jo)(ko)][(la.σ)]</td>
<td></td>
<td></td>
<td>σσ!</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[F] [(jo)(ko)][(la.σ)]</td>
<td></td>
<td></td>
<td>σ</td>
<td>*</td>
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</tbody>
</table>

Ft-Binarity = feet contain exactly two morae or two syllables.
WSP(Ft→Σ) = if a foot is ‘heavy’\(^{20}\) (i.e., at least binary at the moraic or syllabic level), this foot is the head of a superfoot.
Strong(Ft→Σ) = any foot is the head of a superfoot.

Ft-Binarity >> WSP(Ft→Σ) >> Strong(Ft→Σ)

The constraints against vowel features, all members of the Maximality family, constitute the following hierarchy:

Max([high]) >> Max([labial]) >> Max([dorsal]) >> Max([coronal])

This hierarchy has been proposed in van Oostendorp (1997a), and is based on the representations of Dutch vowels proposed in van Oostendorp (1995) (only tense vowels and schwa are shown):

---

\(^{20}\) The idea that a foot can be heavy seems exotic, but because the foot is defined here as a level between the domain of stress (the superfoot) and the syllable, it is not unreasonable to assume that feet as defined in this text can have features of syllables (e.g., weight) as well as traditional feet (e.g., binarity).
This means that, if features are rewritten as the natural classes that they represent, the hierarchy shown above has the following appearance:

\[
\text{Max}\{\{i, y, u\}\} >> \text{Max}\{\{o, o, u, y\}\} >> \text{Max}\{\{a, o, u\}\} >> \text{Max}\{\{e, o, i, y\}\}
\]

Since reduction is only motivated if it is full (i.e., if all features are deleted to yield schwa), the highest Max-constraint that applies to a vowel is decisive: if this highest Max-constraint dominates a certain Markedness constraint, that constraint will have no effect on the vowel, whatever the place of any other Max-constraints that target the vowel in question; conversely, if the highest Max-constraint is dominated by a Markedness constraint, that Markedness constraint will always exert its effect on the vowel, no matter the configuration of the other Max-constraints. If we take this into consideration, we find that the four constraints above give us the following ranking of vowels, from least reducible to most reducible:

\[
i, y, u < o, \emptyset < a < e
\]

If we compare this ranking to (2) in section 2, it can be seen that the ranking presented here is almost identical to Kager’s (1989) reduction hierarchy — the only difference is lack of separation between \(i\) and \(\{y, u\}\) in the hierarchy on this page\(^{21}\). Thus, the ranking of the four vocalic Max-constraint is motivated by Kager’s vowel reduction hierarchy.

We further assume that the two hierarchies together (the foot form constraints and the vowel Max-constraints) form a stratum in the grammar, in the sense explained at the beginning of this section — any ranking of the constraints within the stratum may occur, as long as the partial ordering in the ‘mother grammar’ is maintained:

\[
\{\text{Ft-Binarity} >> \text{WSP(Ft→Σ)} >> \text{Strong(Ft→Σ)}, \text{Max(high)} >> \text{Max(labial)} >> \text{Max(dorsal)} >> \text{Max(coronal)}\}
\]

When all potentially reducing prosodic positions contain the same vowel, the various patterns of reduction are obtained by different rankings of Ft-Binarity, Strong(Ft→Σ), and the relevant Max-constraint (as has been said above, only the highest constraint that applies to a vowel is relevant for that vowel, because partial vowel reduction is not motivated in the current analysis). If the Max-constraint is above the two other constraints, there is no reduction. When the Max-constraint is ‘sandwiched’ between the two other constraints, there is reduction in Positions 1 and 2, but not in Position 3; finally, when the Max-constraint is dominated by both Markedness constraints, all three Positions undergo reduction. This is illustrated by the following tableaux:

\[
\text{(33)}
\]

\(^{21}\) Explaining the different degrees of reducibility between \(i\) and \(\{y, u\}\) would require different vowel representations, e.g., an Element Theory-based model, where \(y\) and \(u\) share an element \([U]\), which \(i\) lacks. Unfortunately, however, a revision of the feature specifications of Dutch vowels is beyond the scope of this paper.
It can be seen that in the first tableau, the high-ranked Max-constraint expels all footings that do not allow full vowels in all superfoot positions, thus forcing every syllable into a separate foot. In the second tableau, the high-ranked constraint on foot binarity excludes the division of a ternary superfoot into three feet, but for the remaining two candidates, which have the same amount of violations of Ft-Binariness, the Max-constraint chooses the candidate which loses the least vowel features (resulting in vowel reduction in Position 2, but not 3); high-ranking Ft-Binariness also chooses unfooted Position 1 over footed Position 1 (since there is not enough space for a binary foot). In the third tableau, high-ranking Ft-Binariness has the same effects as in the second tableau (excluding the structure [(σ)(σ)(σ)] and the structure (σ)[... ]), but now, Strong(Ft→Σ) chooses the ternary superfoot without divisions over the ternary superfoot with a division into a binary and a unary foot.

Note that the relative height of the relevant Max-constraint (Max(labial)) is directly correlated with the relative formality of variants: the highest position for Max(labial) yields the formal *fonoloyi*; an intermediate position of Max(labial) yields the quasi-formal *fonloyi*; and, finally, the lowest position for Max(labial) yields the informal pronunciation *fonlo*.

When Positions 2 and 3 are occupied by different vowels, the constraint WSP(Ft→Σ) becomes important as well. This constraint is violated by configurations where a heavy (= bisyllabic or bimoraic) foot in a superfoot is not the head of the foot, notably the structure [(σ)(σ)(σ)], which entails reduction of Position 3 but not Position 2. Indeed, this structure is
(assumed to be) excluded in every word where Positions 2 and 3 have the same vowels or where Position 2 has a more reducible vowel than Position 3. However, in words where Position 2 has a less reducible vowel than Position 3, the structure \([\sigma](\sigma\sigma)\) seems to coexist with the structure \([(\sigma\sigma)\sigma]\).

In the present analysis, the configuration \([\sigma](\sigma\sigma)\) only surfaces when the highest Max-constraint relevant for the (less reducible) vowel in Position 2 is above WSP(Ft→Σ) (the place of the Max-constraint relevant for the vowel in Position 3 is unimportant; it may be at any position under the higher Max-constraint). This is illustrated below for the word γρόνομετρέραν ‘to time’, and contrasted with the words ψόνολογι ‘phonology’ and γυναικολογίς ‘gynaecological’, where the vowel in Position 2 is not less reducible than the vowel in Position 3; the position of Max(cor) shown here is more or less arbitrary.

\[
\begin{array}{|c|c|c|c|c|c|}
\hline
\text{Word} & \text{Ft-Bin} & \text{Max(labial)} & \text{Max(coronal)} & \text{WSP(Ft→Σ)} & \text{Strong(Ft→Σ)} \\
\hline
\text{γρόνομετρέραν} & & & & & \\
\hline
\text{fόνολογι} & & & & & \\
\hline
\text{γυναικολογίς} & & & & & \\
\hline
\end{array}
\]

We can see that high-ranked Ft-Binariness excludes all candidates with a superfoot of the structure \([\sigma](\sigma\sigma\sigma)\) (only shown for the first word), while Max(labial) excludes candidates with a superfoot of the structure \([(\sigma\sigma\sigma)\sigma]\) (which has otherwise the same violations of Ft-Binarity as the candidates which divide the trisyllabic superfoot into two feet). For the words with different vowels it is Max(labial) which makes a further selection: the form where /o/ is reduced is excluded, which means different forms for different inputs; for γρόνομετρέραν, this means excluding the form with \([(\sigma\sigma\sigma)\sigma]\), while the form with \([(\sigma\sigma\sigma)\sigma]\) is excluded for γυναικολογίς. If Positions 2 and 3 are filled by the same vowel, as in ψόνολογι, the decision between \([(\sigma\sigma\sigma)\sigma]\) and \([(\sigma\sigma\sigma)\sigma]\) is made by WSP(Ft→Σ), which is always in favor of \([(\sigma\sigma\sigma)\sigma]\).

In the grammar variant where both Max(labial) and Max(coronal) are lower than WSP(Ft→Σ), but higher than Strong(Ft→Σ), all three words come out with the pattern \([(\sigma\sigma\sigma)\sigma]\); the tableau below shows how this is effectuated for γρόνομετρέραν:

\[
\begin{array}{|c|c|c|c|c|c|}
\hline
\text{Word} & \text{Ft-Bin} & \text{WSP(Ft→Σ)} & \text{Max(labial)} & \text{Max(coronal)} & \text{Strong(Ft→Σ)} \\
\hline
\text{γρόνομετρέραν} & & & & & \\
\hline
\text{fόνολογι} & & & & & \\
\hline
\text{γυναικολογίς} & & & & & \\
\hline
\end{array}
\]

The main stress pattern of this word is different due to morphological factors; the representation as showed here is simplified, and we are aware that the last syllable violates the representational assumptions made before (i.e., that a sequence of a tense vowel and a consonant is always heterosyllabic).
In this tableau, Ft-Binariness still excludes the candidate that contains the structure [(σ)(σ)(σ)]. However, the candidate with the structure [(σ)(σ)] is now excluded by the higher-ranked WSP(Ft→Σ), while the candidate with [(σσ)] is discarded because of its violation of Max(coronal).

Having shown the mechanism above, we can now present the arguments for the hierarchy of the set of foot and superfoot constraints - Ft-Binariness >> WSP(Ft→Σ) >> Strong(Ft→Σ). The subranking WSP(Ft→Σ) >> Strong(Ft→Σ) is needed to account for reduction in Position 2, but not Position 3 in words where Position 2 is filled by a less reducible vowel than Position 3 (as shown directly above). Compare the tableau in (35) to that in (36) below, where the position of WSP(Ft→Σ) and Strong(Ft→Σ) has been reversed:

(36)

<table>
<thead>
<tr>
<th>/χronometrerən/</th>
<th>Ft-Bin</th>
<th>Strong(Ft→Σ)</th>
<th>Max(labial)</th>
<th>Max(coronal)</th>
<th>WSP(Ft→Σ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>[(ɣro)(no)(me)][(tre.ən)]</td>
<td>*<strong>!</strong></td>
<td>**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>☉ [(ɣronə)(me)][(tre.ən)]</td>
<td>*</td>
<td>!</td>
<td>*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| [(ɣro)(nomə)][(tre.ən)] | * | ! | | * | *
| ♀ [(ɣronəmə)][(tre.ən)] | * | | | * | *

In tableau, Strong(Ft→Σ) excludes both candidates where the ternary superfoot is split into two feet, including the intended winning candidate. Since the ranking WSP(Ft→Σ) >> (relevant Max5constraints) >> Strong(Ft→Σ) is the only grammar where the (attested) [(σ)(σσ)] pattern can be obtained for words of this type, we must assume that WSP(Ft→Σ) is ranked above Strong(Ft→Σ).

For the argument in favor of the ranking Ft-Binariness >> WSP(Ft→Σ), we again turn to the same type of words (where Position 2 has a less reducible vowel than Position 3), but now to their realizations with reduction in Position 3 only. We have seen above that these realizations occur in all rankings for which [Ft-Binariness, (highest relevant Max-constraint) >> WSP(Ft→Σ)] is true. If we reverse the hierarchy of Ft-Binariness and WSP(Ft→Σ), there is no longer a grammar which has reduction in Position 3 as its outcome for the class of words under discussion. Compare the tableau in (34) to that in (37) below:

(37)

<table>
<thead>
<tr>
<th>/χronometrerən/</th>
<th>WSP(Ft→Σ)</th>
<th>Max(lab)</th>
<th>Max(cor)</th>
<th>Ft-Bin</th>
<th>Strong(Ft→Σ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>♀ [(ɣro)(no)(me)][(tre.ən)]</td>
<td>⋯</td>
<td>⋯</td>
<td>***</td>
<td>**</td>
<td></td>
</tr>
<tr>
<td>[(ɣronə)(me)][(tre.ən)]</td>
<td>⋯</td>
<td>*</td>
<td>!</td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>
| ☉ [(ɣro)(nomə)][(tre.ən)] | * | ! | | * | *
| [(ɣronəmə)][(tre.ən)] | * | ! | | * | *

In this tableau, high-ranked WSP(Ft→Σ) excludes the intended winning candidate, independent of the place of the Max-constraints. This means that we must assume that Ft-Binariness dominates WSP(Ft→Σ) in order to be able to derive the form [(ɣro)(nomə)][(tre.ən)].

Next, we must integrate the stratum of variably rankable constraints with the rest of the constraint hierarchy proposed. First, we must assume that the stratum is dominated by Parse-
syllable. This is because we do not see non-parsing of syllables as a solution to violation of any of the constraints within the stratum; this is illustrated in the tableau below:

<table>
<thead>
<tr>
<th>/fonolo(ɣi.σ)/</th>
<th>Parse-syll</th>
<th>Ft-Bin</th>
<th>WSP(Ft→Σ)</th>
<th>Max(lab)</th>
<th>Strong(Ft→Σ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>[(fo)(no)(lo)][(ɣi.σ)]</td>
<td>!!**</td>
<td><em>!</em></td>
<td>*</td>
<td>**</td>
<td>*</td>
</tr>
<tr>
<td>fo[(nola)][(ɣi.σ)]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>![fon(a)(lo)][(ɣi.σ)]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>![fon(a)][(ɣi.σ)]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In this tableau, it is the ranking of Parse-syllable above Ft-Binarity that prevents the candidate with an initial unfooted syllable from being chosen as the optimal candidate (since, if Parse-syllable were to be positioned lower than Ft-Binarity, then Ft-Binarity would eliminate all other candidates because only this candidate has perfectly binary feet). Therefore, we assume that Parse-syllable dominates the stratum.

Since the stratum is dominated by Parse-syllable, it is also dominated by Max(Ft), which makes it possible to explain lexical exceptions to reduction with underlying feet, as had already been announced in section 2. Max(Ft) demands that all feet in the input should be kept intact, which constrains the range of possibilities created by the variable stratum in the following ways.

Underlying unary feet over syllables which are eventually found in Position 1 or 3 have the effect of preserving exactly that syllable. A unary foot over a syllable which is eventually located in Position 2 means non-reduction of both that syllable and (if applicable) the adjacent Position 3 syllable. When an underlying unary foot is positioned over a syllable which eventually receives secondary stress, this means that the adjacent Position 2 must be unreduced, but the optional ‘homohyperpodial’ Position 3 may be reduced. These three situations are summarized below schematically (assuming words that end in two light syllables). Obviously, under the current representational assumptions, underlying feet which are larger than unary have the same output as representations with schwas: /CVCV/ = /CVCa/ → (CVCa), and will therefore not be considered here.

(39) Position 1: / (σ)σσ / → (σ)[σσ]; *σ[σσ]
Example: /(mo)tif/ → (mo)[tif], *mə'[tif] ‘motive’

Position 3: / σσ(σ)σσ / → [(σ)(σ)(σ)](σσ) ~ [([σσ][σσ])][σσ]; *[(σ)(σσ)][σσ], *[(σσ)][σσ]
Example: /Romanizerən/ → [(ro)(ma)(ni)][zerən] ~ [(romə)(ni)][zerən];
*romanəzerən, *romanəzerən ʻto romanize’

Position 2: / σσ(σ)σσ / → [(σ)(σ)(σ)][σσ]; *[σσ][σσ][σσ], *[(σ(σσ)][σσ], *[(σσ)][σσ]
Example: /konsoliderən/ → [(kən)(so)(li)][dərən]; *konsoliderən, *konsoliderən,
*konsoliderən ʻto consolidate’

stressed: / (σ)σσσσ / → [(σ)(σ)(σ)][σσ] ~ [(σ)(σσ)][σσ]; *[(σσ)][σσ], *[(σσ)][σσ]

---

23 As already mentioned before, there are words where the superfooting σ[σσ][σσ] is possible as an alternative to σσσσσσ, e.g., kalēidoskóp ~ kalēidoskóp; however, these are exceptions to the general rule.
24 Technically, Parse-syllable could be within the stratum dominating Ft-Binarity, because Parse-syllable never conflicts with any of the Max-constraints in the stratum; however, in order to minimize the number of grammar variants (since more constraints in the stratum means more ordering possibilities), we assume that Parse-syllable dominates all of the stratum.
25 Underlined syllables have a reduced vowel; the internal structure of the main foot is not shown.
Example: /diosezan/ → [(di)(jo)(se)][zan] ~ [(di)(joʊə)][zan];
*dijəse'zan, *dijəsə'zan ‘diocesan’

Finally, we must incorporate the constraints Connect(V,Ft) and Max(LastV), mentioned in the
beginning of this section, into the hierarchy assembled up until now. Max(LastV) must
minimally be above WSP(σ→Σ), in order to prevent a solution to problem of words that end
in a sequence two heavy syllables by reduction of the last syllable - we assume that schwa
does not project a mora, which makes closed syllables with schwa light. This is shown in the
first word in tableau (40) below (cf. also (28) above).

Also, we must minimally assume that Connect(V,Ft) is ranked above Max(Ft); this is because
we must exclude (non well-formed) underlying feet which only contain a schwa syllable from
surfacing as such (this is, of course, based on the Richness of the Base principle). This is
illustrated by the second, hypothetical, word in (41) below.

(40)

<table>
<thead>
<tr>
<th>kalimontan ‘Kalimantan (toponym)’</th>
<th>Max(LastV)</th>
<th>WSP(σ→Σ)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="http://placehold.it/50x50?text=Image1" alt="image" /></td>
<td><img src="http://placehold.it/50x50?text=Image2" alt="image" /></td>
<td><img src="http://placehold.it/50x50?text=Image3" alt="image" /></td>
</tr>
<tr>
<td><img src="http://placehold.it/50x50?text=Image4" alt="image" /></td>
<td><img src="http://placehold.it/50x50?text=Image5" alt="image" /></td>
<td><img src="http://placehold.it/50x50?text=Image6" alt="image" /></td>
</tr>
</tbody>
</table>

As we have seen in (28) above, the surface forms of words of this type (also including
palembang) always violate WSP(σ→Σ); however, a candidate where the last syllable is
reduced prevents violation of WSP(σ→Σ) because, as we have assumed above, schwa does
not project a mora, and, subsequently, the last syllable becomes light. Because these
candidates never surface (even not in informal registers), we must assume that they are
excluded by virtue of Max(LastV)’s dominating WSP(σ→Σ).

(41)

<table>
<thead>
<tr>
<th>/la(pɔ)nat/ (well-formed non-word)</th>
<th>Connect(V,Ft)</th>
<th>Max(Ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="http://placehold.it/50x50?text=Image1" alt="image" /></td>
<td><img src="http://placehold.it/50x50?text=Image2" alt="image" /></td>
<td><img src="http://placehold.it/50x50?text=Image3" alt="image" /></td>
</tr>
<tr>
<td><img src="http://placehold.it/50x50?text=Image4" alt="image" /></td>
<td><img src="http://placehold.it/50x50?text=Image5" alt="image" /></td>
<td><img src="http://placehold.it/50x50?text=Image6" alt="image" /></td>
</tr>
</tbody>
</table>

Here, we see that, in order to enforce our assumption that the principle expressed by
Connect(V,Ft) (viz., that schwa syllables are always and only in dependent foot positions) is
always maintained, we must assume that Connect(V,Ft) dominates Max(Ft) to exclude
idiosyncratic feet which violate the principle of the biunique mapping from foot heads to full
vowels and *vice versa*.

In conclusion, the eventual ranking of constraints is the following - presentation in the form of
a Hasse diagram is chosen for ease of exposition (the curly brackets designate a stratum
consisting of several subrankings):
5. Concluding remarks

In this paper, we have investigated the complex phenomenon of vowel reduction in Dutch by proposing a novel theoretical interpretation of it, which views vowel reduction as the result of an optimalization of metrical structure to the expense of neutralizing the identity of (certain) unstressed vowels. This analysis, of which the key feature is that full vowels are in complementary distribution with schwa regarding their position in metrical structure, makes certain assumptions, most notably an enriched Prosodic Hierarchy, with two tiers of structure between the Prosodic Word and the syllable. However, the gain is that the model allows formalizing vowel reduction and restrictions on the form of certain Germanic stems with the same representational mechanism; also, lexical exceptions to vowel reduction can now be represented with underlying metrical material, similarly to the representation of exceptional stress patterns.

As always is the case, more research on this phenomenon is needed, in particular empirical research, investigating the relative reducibility of the three prosodic Positions identified in this text, and the reducibility of lax vowels in relation to tense vowels. Also, the implications that vowel reduction has for the representations of vowels should be examined. Finally, it should be investigated whether it is possible to construct the same account as in this paper without assuming both Feet and Superfeet (one could, for instance, try to derive the same effects by assuming that feet do not always project grid marks, and derive alternations between gridmarks by feet-independent constraints). The latter would help eliminate extra levels of representation, and thus, make the current account more economical.
References


Martin, W. 1968. *De verdoffing van gedekte en ongedekte e in niet-hoofdtonige positie bij Romaanse leenwoorden in het Nederlands* [= Reduction of covered and uncovered e in unstressed position in Romance loan words in Dutch]. De Nieuwe Taalgids, 61, 162-181.


