Full title: Vowel reduction in verbs in King Alfred's Pastoral Care

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Abstract

An original unstressed vowel **ō* generally develops to *a* in Old English. In some categories, however, both *a* and *u* are found as reflexes. The traditional explanation for this phenomenon posits that **ō* developed to *u* when the following syllable also had a **u*. A statistical analysis of the distribution of *a* and *u* in such forms in an Old English text finds no support for this theory. Since shortened vowels tend to raise and unstressed vowels in medial syllables are shorter than in final syllables, I hypothesize in this paper that **ō* shortened and raised to *u* in medial syllables. A statistical analysis of the same text strongly supports this new hypothesis. This vowel raising process can be explained by neuromuscular and perceptual properties. Producing short low vowels increases the risk of undershooting the vowel target, which translates into vowel raising. At the same time, a shortened low vowel can be misperceived as a higher vowel, since high vowels are shorter than low vowels. With these explanations, a formal grammatical analysis is not needed to explain why vowel raising takes place.

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1. Introduction

The original Proto-West-Germanic long unstressed vowel **ō* generally develops to a short unstressed vowel *a* in Old English (Brunner 1965: 31, 128; Hogg 1992: 233; Luick 1921: 298).[1] This is illustrated in (1), in which the stressed vowel is marked by an acute accent ‹◌́› and vowel length by a macron ‹◌̄›. Since stress was located on the initial syllable in both Proto-West-Germanic and Old English, it will no longer be marked (cf. Campbell 1959: 30; Hogg 1992: 47–48).

(1)	Proto-West-Germanic		Old English	
	**glṓfōz*	>	*glṓfa*	“gloves”
	**mā́nōþiz*	>	*mṓnaþ*	“months”
	**wúndōþi*	>	*wúndaþ*	“woundeth”
	**túngōni*	>	*túngan*	“tongue”

In the past tense forms of *ō*-verbs, however, both *a* and *u* are found as reflexes of the original unstressed **ō*. The examples in (2) demonstrate that these two vowels are found in both the preterite (2a) and perfect (2b) category of the past tense. When comparing the Old English forms in (2) with their English glosses, it is also easy to see that the *ō*-verb conjugation is the chief origin of the weak verb conjugation in Modern English.

(2)	a)	Pret.	*andswar**a**de*	~	*andswar**u**de*	“answered”
		Pret.	*syng**a**de*	~	*syng**u**de*	“sinned”
	b)	Perf.	*wund**a**d*	~	*wund**u**d*	“wounded”
		Perf.	*bisg**a**d*	~	*bisg**u**d*	“busied”

The variation between Old English *a* and *u* in (2) versus the general development of Proto-West-Germanic **ō* to Old English *a* seen in (1) indicates that **ō* under some condition developed to Old English *u* rather than *a*. The aim of this paper is to determine what that condition is.

[1] This paper will for the most part limit its references to Old English grammars, handbooks, and reference manuals published in the 20th and 21st centuries. For entirely uncontroversial aspects of Old English diachronic and synchronic phonology, references will be limited to the most comprehensive grammars of Old English, i.e. Brunner (1965), Campbell (1959), Hogg (1992), Hogg & Fulk (2011), and Luick (1921, 1940).

The traditional and widely accepted explanation for the vowel *u* in forms of the kind seen in (2) is that the original **ō* assimilated in Proto-West-Germanic to a **u* in a following syllable (van Helten 1891: 460, 463–464). If that explanation is correct, one would expect to find *u* more often in Old English forms where a **u* originally followed in the subsequent syllable than in forms where no **u* followed. A statistical analysis of past tense forms of *ō*-verbs in King Alfred's Pastoral Care reveals, however, that no such tendency can be found.

The hypothesis put forward in this paper is that Proto-West-Germanic **ō*, after developing to **o* by the regular pre-Old English shortening of unstressed long vowels, reduces in medial syllables to a high vowel *u*. The rationale for this development rests on experimental evidence that vowels in medial syllables are shorter, and that shorter vowels tend to raise. If this is the right explanation, then *u* should be more common in Old English medial syllables than in final syllables. A statistical study of the *ō*-verbs in King Alfred's Pastoral Care shows that the *u* is indeed significantly more common in medial syllables. The traditional explanation is consequently rejected in favor of this new hypothesis.

The remaining question to be answered is why such shortened vowels tend to raise. It is suggested here that this connection between vowel duration and vowel raising is rooted in strictly physiological and perceptual conditions, and not caused by grammar. As the duration of a lower vowel decreases, the likelihood that the articulators will reach the intended target for that vowel in time drops accordingly. If the articulators do not reach the lower vowel target in time, they 'undershoot' their target and produce, strictly as a biomechanical consequence, a raised vowel.

This paper is organized as follows: Section 2 clarifies what is meant by 'Old English *u*'. Section 3 gives an account of the traditional explanation for the distribution of *a* and *u* in Old English, tests it against an Old English corpus, and finds that it has no support in the data. Section 4 then lays out the rationale behind the new hypothesis, that *u* is the result of vowel raising in shortened medial syllables. Section 5 fleshes out the details of this new hypothesis and tests it against the Old English corpus. Section 6 discusses the neuromuscular and perceptual properties that have caused the vowel raising to occur, and concludes that there is no reason to assume a grammatical component acting on top of that. Section 7 makes suggestions for further reasearch, before section 8 summarizes and concludes the paper.

2. *Old English* u

The earliest Old English texts, which date from the 8th century, have only two unstressed back vowels: *u* and *a* (Campbell 1959: 19, 153; Hogg 1992: 240; Pilch 1970: 74; Reszkiewicz 1973: 93). These two vowels are contrastive in unstressed syllables, as seen in word pairs such as *sunu* "son.NOM.SG" vs. *suna* "son.GEN.SG". During the course of the early Old English period, however, *u* shows a tendency to lower to *o* (Brunner 1965: 31, 124, 128; Campbell 1959: 19, 155–156; Hogg 1992: 245–246; Luick 1921: 302–303). In the 9th and early 10th century, then, *u* and *o* function as free variants of a phoneme /u/ in unstressed syllables. This lowering of unstressed *u* to *o* within the early Old English period is of no interest in this study. The central question here is what the conditions were that caused Proto-West-Germanic unstressed **ō* to develop to the *u* we find in the earliest Old English texts. Since we know that the unstressed vowels *u* and *o* in texts from the 9th and early 10th century both go back to the vowel *u* in the earlier stages of attested Old English, this paper will treat the unstressed vowels *u* and *o* in such texts as instances of the vowel *u*.

3. *Van Helten's rule*

3.1 The rule

The oscillation between *a* and *u* in the past tense forms of *ō*-verbs, as seen in (2), was recognized early (Rask 1817: 2), and the first proper attempt at explaining it was provided by van Helten 1891. He suggested that the Proto-West-Germanic unstressed **ō* was raised to **ū* by assimilating to a **u* in the following syllable (1891: 460, 463–464), as illustrated with the preterite forms of "wounded" in (3).

(3)		PROTO-WEST-GERMANIC				OLD ENGLISH
a)	3.sg.pret.ind.	**wundōdē*			>	*wundade*
b)	3.pl.pret.ind.	**wundōdun*	>	**wundūdun*	>	*wundudun*

In (3a) the Proto-West-Germanic **ō* in **wundōdē* is not followed by a **u* in the next syllable, hence the **ō* undergoes the regular development to Old English *a* and gives *wundade*. In (3b), on the other hand, the **ō* in **wundōdun* is followed by a **u*, and it assimilates therefore to this vowel and raises to **ū*, giving a later Proto-West-Germanic form **wundūdun*, ending up as Old English *wundudun*. The shortening of Proto-West-Germanic **ō* and **ū* is regular, since all unstressed long vowels are shortened in pre-Old English (Brunner 1965: 16, 31; Campbell 1959: 139, 147–148; Hogg 1992: 65, 233–234; Luick 1921: 288–289).

It is crucial to emphasize here that this is a Proto-West-Germanic rule, not an Old English rule. The fact that the unstressed vowel **u* that triggered the assimilation in Proto-West-Germanic is still present in the Old English form in (3b) is merely a coincidence. This is clearly illustrated in the perfect forms of "wounded" seen in (4).

(4)		PROTO-WEST-GERMANIC				OLD ENGLISH
a)	Perf.m.nom.sg.	**wundōdaz*			>	*wundad*
b)	Perf.f.nom.sg.	**wundōdu*	>	**wundūdu*	>	*wundud*

In (4a) the Proto-West-Germanic **ō* develops as in (3a), since it is not followed by a **u* in the next syllable. A final *-*z* and an unstressed **a* are both regularly lost in pre-Old English, thereby deleting the final Proto-West-Germanic syllable *-*az* (Brunner 1965: 123, 148; Campbell 1959: 138, 166; Hogg 1992: 65; Luick 1921: 273, 1940: 818). In (4b), on the other hand, the **ō* raises as in (3b) to a **ū* before the **u* in the next syllable. Since a final *-*u* is lost in pre-Old English after a long syllable, the form in (3b) also deletes its final syllable (Brunner 1965: 124; Campbell 1959: 144; Hogg 1992: 227; Luick 1921: 282). As the conditioning syllable for van Helten's rule has been lost in Old English, the Old English forms in (4) are by themselves not able to explain why one has the vowel *a* and the other the vowel *u*. Van Helten's rule implies, then, that there is nothing synchronic in Old English that will explain the distribution of *a* and *u*.

Nearly all grammars of Old English accept van Helten's rule as the explanation for the variation between *a* in *u* in the past tense forms of *ō*-verbs (Brunner 1965: 31–32, 128, 329; Bülbring 1902: 156–157; Campbell 1959: 139; Girvan 1931: 126; Hogg 1992: 66–67; Hogg & Fulk 2011: 283; Kieckers 1935: 36–37; Luick 1921: 269–270). It is safe to say, then, that van Helten's rule has become part of the 'canon' of diachronic Old English phonology.

3.2 Generalization

Van Helten's rule predicts that certain forms in the paradigm of *ō*-verbs should have *a* in Old English, whereas other forms should have *u*. As seen in (3) and (4), for example, the rule predicts that the 3.sg.pret.ind. and the perf.m.nom.sg. forms should have the vowel *a*, whereas the 3.pl.pret.ind. and the perf.f.nom.sg. should have the vowel *u*. In reality, however, the distribution is as seen in (2), in which any past tense form of the *ō*-verb category can display either *a* or *u*. Regardless what the phonologically regular distribution of *a* and *u* once was, or what it should have been, it is clear that the actually attested variation in (2) must be due to a generalization of both *a* and *u* beyond their original distribution within the paradigm (cf. Brunner 1965: 329; Campbell 1959: 139; Girvan 1931: 126; Hogg 1992: 67; Hogg & Fulk 2011: 283; Kieckers 1935: 184; Luick 1921: 270; Reszkiewicz 1973: 148).

3.3 Testing van Helten's rule against an Old English corpus

If the phonologically regular distribution of *a* and *u* in Old English is dictated by van Helten's rule, then it should be possible to trace this distribution in the Old English data, regardless of the paradigmatic generalization discussed in section 3.2 above. The vowel *u* should, in other words, be more commonly present in the paradigmatic forms where it originally belongs than in forms where it has subsequently been generalized to. If this is not the case, then there is no cogent reason to posit van Helten's rule in the first place, as any other postulated rule would explain the distribution equally well.

Despite the near universal acceptance of van Helten's rule as the explanation for the variation between *a* and *u* in Old English, this clear prediction made by the rule has to my knowledge never been tested against a corpus of Old English data. Such a corpus would necessarily need to exclude all texts from the 'classical Old English' period between the 10th and 11th century, since the unstressed vowels *a* and *u* began merging in the 10th century (Brunner 1965: 33; Campbell 1959: 19–20, 156–157; Hogg 1992: 246; Luick 1921: 320, 489–491). All the past tense forms of *ō*-verbs (n = 457) were therefore manually extracted from the manuscript Hatton 20 (text edition by Sweet 1871 with corrections by Kim 1973). This manuscript is a near complete version of King Alfred's translation of the Pastoral Care. It was written by three scribes in Old West Saxon and dates to c. 890 (Ker 1957: 384–385). It was chosen as the basis for an early Old English corpus here because it is with 67 835 words by far the largest text from this period.

@@ Insert Figure 1 here

Figure 1 displays the distribution of the unstressed vowel *u* in the past tense forms of *ō*-verbs in this corpus, with the two bars representing the two relevant categories according to van Helten's rule: the position before an original **u*, and the elsewhere condition. According to this rule, then (section 3.1), the *u* should be more common when a **u* originally followed than elsewhere. As Figure 1 shows, however, the distribution actually trends in the opposite direction; the *u* is *less* common before an original **u*.

This data was fitted to a logistic regression model with the *glmer()* function in R (Bates et al. 2014; R Core Team 2014). The random effects structure of this model was data-driven using a backward best-path algorithm with $\alpha = 0.2$ (Barr et al. 2013). The variance explained by the model is estimated with the R^2 measure suggested by Nakagawa & Schielzeth (2013) with the implementation by LaHuis et al. (2014). A summary of the model is given in Table 1.

@@ Insert Table 1 here

The explained variance of $R^2 = 0.019$ means that the model is correctly predicting only 2 % of the variation between the vowels *a* and *u* in the corpus. This is a good indication that van Helten's rule is unable to account for the distribution of the vowel *u* in this data set. A likelihood ratio test shows that the model with van Helten's rule as a predictor is not significantly different from a model without the rule: $\chi^2(1) = 1.007$, $p = 0.316$. This means that there is simply no significant correlation between van Helten's rule and the distribution of the vowel *u* in the data, neither a positive correlation (as expected by van Helten's rule), nor a negative correlation (as indicated by the actual data seen in Figure 1). Since van Helten's rule cannot explain the distribution of *a* and *u* as the reflexes of **ō* in this Old English corpus, the rule should as a result be rejected.

4. *Vowel reduction*

4.1 Vowel duration and position

An alternative to viewing the change from **ō* to Old English *u* as a phonotactically conditioned change (as in van Helten's rule) is to focus on the prosodic position of this unstressed vowel. Although it is well known that unstressed vowels generally are shorter than stressed vowels (Fry 1955), the central fact in this connection is that unstressed vowels in medial syllables are shorter than unstressed vowels in final syllables (Lindblom 1968; Oller 1973). All other things being equal, then, the unstressed vowel in a final syllable in a word of the type [ˈmakat] will be longer than the equivalent unstressed vowel in a medial syllable in a word like [ˈmakatan], as illustrated in (5).

(5)	Final syllable		Medial syllable
	[ˈmak**a̲**t]	>	[ˈmak**a̲**tan]

4.2 Vowel duration and vowel height

Duration is not only found to depend on the position of the vowel, as discussed above, but also on the quality of the vowel. In short, vowel length is inversely correlated with vowel height, such that the higher a vowel is, the shorter it is (Lehiste 1970: 18–19). This finding can plausibly be linked to the articulation of vowels in their most typical environment, which is next to an oral consonant. In order to produce a low vowel, the lower lip, the lower jaw, and the tongue (or simply 'the articulators') are lowered. The lower the vowel is, the more the articulators are lowered (Lindblom 1967: 2–3; Parmenter & Treviño 1932). An oral consonant, on the other hand, requires the articulators to be raised so that they create contact with one of the upper articulators (the upper lip, the teeth, or the palate). In the transition phase between an oral consonant and a vowel, then, the articulators need to move from the the raised position of the consonant to the lowered position of the vowel, and then back up again if another oral consonant follows. The lower this vowel is, the longer the distance the articulators need to travel to reach their targets. Covering this distance takes time, and it follows that the longer the articulators need to travel, the longer the duration of their movement will be, all other things being equal. It is quite expected, then, that low vowels will be durationally longer than high vowels (Jespersen 1913: 181; Lehiste 1970: 18–19; Lindblom 1967: 21, 23–24).

4.3 Vowel duration and vowel raising

A vowel can be considered as having an articulatory and auditory target (cf. Perkell 2012). Reaching these targets takes time, and as noted above it takes more time for some vowels than for others. When the available time frame for an articulatory movement is shortened, experiments show that there are direct correlations between vowel height, vowel raising, and duration, such that the lower a vowel is, the more it is raised, and the shorter the vowel is, the more it is raised (Lindblom 1963: 1777–1778). A shortened low vowel /ɔ/ is in other words raised more than a shortened mid vowel /o/ is, and a low vowel /ɔ/ is raised more when it is 100 ms long than when it is 150 ms long. A reasonable interpretation of these facts is that under constrained time conditions, the articulators run a higher risk of not being able to reach the targets for a low vowel before they need to move on to another phonological segment, since covering the articulatory distance for low vowels requires more time than for higher vowels. If the articulators 'undershoot' their low vowel targets in this fashion, the consequence will be that the articulators reach a position raised above their originally intended targets. The acoustic correlate of this undershoot is a raised vowel (1963: 1778–1779). A closer discussion of this effect is postponed until section 6.1.

This interconnection between vowel height and vowel length can be illustrated as in Figure 2. This illustration can be understood bidirectionally: (1) As one moves in the direction of the arrow, less time is devoted to the production of the vowel. The low vowel [ɑ] is thus produced with a longer duration than the vowel [ɔ], which in turn is produced with a longer duration than the vowel [o], etc. (2) When less time is being devoted to the production of a vowel, the vowel moves in the direction of the arrow. A shortened low [ɑ] moves in the direction of the vowel [ɔ], which moves in the direction of the mid vowel [o], etc.

@@ Insert Figure 2 here

4.4 Summary of vowel reduction patterns

We have seen in this section that unstressed vowels are shorter in medial syllables than in final syllables, and that shortened low vowels have a tendency to raise. When connecting these two observations, a readily available hypothesis is that unstressed vowels in medial syllables are more likely to raise than unstressed vowels in final syllables. Section 5 will apply that hypothesis to the Old English corpus from section 3.3.

5. New hypothesis: Vowel raising in medial syllables

5.1 The proposal

As discussed in section 3.1, all unstressed long vowels are shortened in pre-Old English. This process thus shortens the Proto-West-Germanic unstressed vowel **ō* to **o* (Kieckers 1935: 36; Luick 1921: 289). The hypothesis put forward here is that this **o* raises to *u* in unstressed medial syllables, since vowels in unstressed medial syllables are shorter than in final syllables, and shortened vowels tend to raise, as discussed in detail in section 4.

@@ Insert Figure 3 here

The raising of /o/ as a function of duration is illustrated in Figure 3, which is based directly on the data in Lindblom 1963. The acoustic correlate of vowel height is the first formant, F_1. The left column in Figure 3 displays the target F_1 value, F_{1t}, for the vowels /u/ and /o/ (1963: 1777). The solid horizontal line shows the observed F_1 value for the vowel /u/ as a function of duration. As the straight line indicates, reducing the duration of high vowels has no effect on their vowel height (1963: 1776–1777). The dotted horizontal curve tracks the observed F_1 value for the vowel /o/ as a function of duration between two coronal consonants /d_d/. Only this curve has been plotted in Figure 3, as this is the most relevant consonantal environment for the Old English corpus used in this study. All forms in this corpus have the reflex of the vowel **o* in the position *C_d*, with *C* representing any consonant. The curves for /o/ in labial and velar environments are, however, very similar. As the curve clearly indicates, the height of the vowel /o/ raises to close proximity to the height of the vowel /u/ as duration decreases. Two dashed vertical lines have been added to indicate the average duration of unstressed vowels in medial and final syllables, taken from Oller (1973: 1236). Based on these observations, there is good reason to hypothesize that the pre-Old English vowel **o* would show a greater tendency to raise to *u* in unstressed medial syllables than in unstressed final syllables.

Using the Proto-West-Germanic forms from (3) and (4), the concrete proposal made by this hypothesis can be seen in (6).

(6)	PROTO-WEST-GERMANIC		PRE-OLD ENGLISH		OLD ENGLISH
a)	**wundōdē*	>	**wundŏde*	>	*wundude*
b)	**wundōdu*	>	**wundod*	>	*wundad*

The Proto-West-Germanic 3.sg.pret.ind. **wundōdē* in (6a) undergoes the regular pre-Old English shortening of unstressed long vowels and gives **wundode*. Since the vowel **o* is in a medial unstressed syllable, it is significantly shorter than the corresponding unstressed **o* in the pre-Old English form **wundod* in (6b). This 'extra-short' **o* is indicated in (6a) with **ŏ*. The proposal made here is that this 'extra-short' **o* will raise to a high *u* in Old English. The Proto-West-Germanic perf.f.nom.sg. **wundōdu* in (6b) undergoes the same shortening of unstressed long vowels, but also loss of final *-*u* after a long syllable (cf. section 3.1). This comes out as pre-Old English **wundod*. The unstressed **o* in this form is in a final syllable and has a 'regular short' length, and undergoes the general development of pre-Old English **o* to *a*. Two things are worth noticing about the development outlined in (6).

The first thing to notice is that the proposed regular developments in (6) are the exact opposite of what van Helten's rule suggests in (3) and (4). The relevant forms from those two examples are repeated in (7) below. The Proto-West-Germanic form in (7a) is predicted by van Helten's rule to develop an *a* in Old English, as a direct result of not having a **u* in the third syllable in Proto-West-Germanic. The proposal made in this section, however, is that this form will develop an Old English *u* by virtue of having the pre-Old English vowel **o* in a medial syllable, seen in (6a) above. The Proto-West-Germanic form in (7b), on the other hand, has a **u* in the third syllable and is therefore predicted by van Helten's rule to give Old English *u*. The new proposal made here is that this vowel will become Old English *a* because it is in a final syllable (cf. 6b). The disagreement in predictions between (6) and (7) is therefore a good example of how different these two proposals are in both theory and practice.

(7)	Proto-West-Germanic				Old English
a)	**wundōdē*			>	*wundade*
b)	**wundōdu*	>	**wundūdu*	>	*wundud*

The second thing worth noticing about the new proposal in (6) is that the phenomenon that splits the Proto-West-Germanic **ō* into Old English *a* and *u* occurs after the loss of short unstressed vowels. That it occurs after the shortening of long unstressed vowels is a tautology, since the proposal itself is that the shortened **o* from **ō* raises to *u* in medial syllables. The loss of short unstressed vowels, however, necessarily predates the shortening of long unstressed vowels (cf. Campbell 1959: 161; Hogg 1992: 235; Luick 1921: 292), from which it follows that the split of Proto-West-Germanic **ō* into Old English *a* and *u* occurs after the loss of short unstressed vowels. The relative chronology of the loss of short unstressed vowels and the shortening of long unstressed vowels is illustrated in (8).

(8)

	Nom.sg.	Nom.pl
Proto-West-Germanic	**burstiz*	**burstīz*
Loss of final **-z*	**bursti*	**burstī*
i-umlaut	**byrsti*	**byrstī*
Loss of short unstressed vowels	**byrst*	
Shortening of long unstressed vowels		**byrsti*
Old English	*byrst*	*byrsti*

The list in (8) shows the phonological processes that affected the nominative forms of the Proto-West-Germanic noun **bursti-* "bristle" on its way to Old English.[2] If the shortening of long unstressed vowels had occurred before the loss of short unstressed vowels, then **burstīz* would simply merge with the outcome of **burstiz* and give Old English *byrst* in both forms.[3]

As can be seen in the examples given in this paper (cf. (1), (4), and (8)), the predominant reason for the reduction in the number of syllables between Proto-West-Germanic and Old English is the loss of unstressed short vowels. Since the proposed split of **ō* into *a* and *u* is set after this loss, then the number of syllables at the time of the split will be identical to the number of syllables in Old English. In other words, the medial syllable position in pre-Old English which triggered the raising of **o* to *u* will still be medial in Old English, and the final syllable position which triggered the general development of **o* to *a* will also be final in Old English. This allows us to state the generalization strictly in synchronic terms: The regular outcome of Proto-West-Germanic **ō* in Old English is *u* in a medial syllable and *a* in a final syllable. This is in stark contrast to van Helten's rule, by which the generalization must be stated diachronically – Old English itself cannot explain the distribution (cf. section 3.1).

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[2] The loss of final **-z* is treated in section 3.1. The change called *i*-umlaut is a process in which an unstressed **ī̆* fronts the root vowel **u* to *y* (Brunner 1965: 69, 76; Campbell 1959: 71, 78–79; Hogg 1992: 121–123; Luick 1921: 166–168). The rules for the loss of unstressed **i* follow those for loss of **u*, treated in section 3.1.

[3] The regular declination *byrst – byrsti* is faithfully preserved in some early Old English texts, as in the Erfurt glossary from c. 800 (Lindsay [1921]: 48; Pheifer 1974: 47).

5.2 Testing the new hypothesis against an Old English corpus

If the hypothesis made above is correct, then we would, following the logic outlined in section 3.3, expect to find the vowel *u* more often in medial syllables than in final syllables. Figure 4 displays the distribution of the vowel *u* in the past tense forms of *ō*-verbs in the Hatton 20 manuscript (see section 3.3 for details) according to syllable type. The left bar represents how often *u* is found in unstressed medial syllables, and the right bar how often it is found in final syllables. The distribution in Figure 4 conforms well to the hypothesis made above in section 5.1, as the vowel *u* is indeed more common in medial syllables where it is posited to be the regular outcome of **ō*.

@@ Insert Figure 4 here

This data was fitted to a logistic regression model according to the procedure explained in section 3.3. A summary of the model is given in Table 2. The model accounts for 83 % of the variation between the vowels *a* and *u*, thereby demonstrating a good fit between the predictions of the model and the actual variation in the data. A likelihood ratio test shows that the model with syllable position as a predictor is significantly better than a model without it: $\chi^2(1) = 25.41$, $p < 0.000001$. This means that the vowel *u* is significantly more common in unstressed medial syllables than in unstressed final syllables, just as posited by this new hypothesis.

@@ Insert Table 2 here

6. Discussion

6.1 Vowel raising by articulatory error

As indicated in section 4.3, it is suggested here that the articulators risk not reaching the targets of a shortened low vowel, and as a result undershoot their targets and produce a raised vowel. This section addresses this proposal in more detail, and ties these assumptions to general properties of human movement.

Shortening the duration of a speech segment requires the articulators to move faster towards the target of that segment, all else being equal (cf. Ostry & Munhall 1985). Increasing the speed of a movement will, however, result in a higher error rate in hitting the intended target (Fitts 1954: 383; Schmidt et al. 1979: 419–420, 424; Woodworth 1899: 27–53). This fact alone indicates that the misses will be evenly distributed among undershoots, in which the movement does not reach the target, and overshoots, in which the movement goes beyond the target. Human motion is, on the other hand, biased towards undershooting a target, which leads us to expect significantly more undershoots than overshoots (Elliott et al. 2004: 343–344). A related finding about human motion is that the degree of undershoot correlates with the dispersion of target misses (Worringham 1991: 82–83). This means that as the number and spread of target misses increase, the average miss moves further and further away from the target. When relating these findings to the articulation of vowels, it is important to emphasize that the dispersion of target misses increases with the speed and distance of the movement (Schmidt et al. 1979: 422–424). Since shortened vowels have an increased speed of the articulators, and since low vowels have both an increased speed of the articulators (Ostry & Munhall 1985) and require the articulators to travel a longer distance, the expected result is that shortened low vowels suffer from more articulatory undershoot than longer and higher vowels. As reviewed in section 4.3, this is indeed the finding in Lindblom's articulatory experiment.

In the many motion experiments referred to above, it is always the intention of the subject to hit the target. To explain the observed articulatory undershoot of shortened low vowels, there is in other words no need to assume that the speakers have shifted their targets (Lindblom 1963: 1778–1779). The undershoot is not intentional, it is an error caused by the neurological and biomechanical properties of motion.

6.2 The role of perception

The discussion has so far focused on the role played by articulation, primarily based on the fact that vowel raising as a function of duration is an observed effect in articulatory experiments. This is not to deny, however, that there could also be an additional role played by perception. As outlined in section 4.2, vowel height correlates with vowel duration, such that lower vowels are longer than higher vowels. Although this effect probably has an articulatory origin, it turns out that listeners are aware of this correlation, such that a high vowel [u] which is 15 ms shorter than a mid-low vowel [ɔ] will be perceived to be of equal length (Gussenhoven 2004). This means that listeners expect lower vowels to be longer than higher vowels. If a low vowel is shortened, then, listeners could misperceive it as being a raised vowel. Perceptual experiments have indeed demonstrated this effect (Daniloff et al. 1968; Hillenbrand et al. 2000; Stevens 1959). Note that in this case, too, the listener does not intend to perceive a raised vowel. It is rather an error caused by the listener's perceptual expectation that lower vowels will be above a certain durational threshold.

As there are both articulatory and perceptual reasons to expect a shortened low vowel to raise to a higher vowel, we have no cogent incentive to envision a scenario of 'either articulation or perception' as the cause of this effect. Since the properties of these two domains are converging on the same result, they are rather working in tandem and thereby enforcing the effect already present in the other domain.

6.3 From error to grammar

The articulatory and perceptual properties discussed in section 6.1 and 6.2 above are meant to explain how vowel raising in unstressed medial syllables is initiated. At a certain point, however, the raised vowel in this position has become part of the speaker's grammar. There are several ways in which this might occur. I will sketch three scenarios here.

1. Although the speaker intends to produce an [o], he frequently produces a raised [ʊ] instead, by the process explained in section 6.1. The listener fails to compensate for the biomechanical properties causing this raised vowel, and therefore interprets [ʊ] as the intended output by the speaker. The listener thus assumes [ʊ] is the target vowel in that position, or even that it is the unstressed variant of /u/. When the listener turns speaker, his target vowel is no longer [o], but [ʊ] (or [u]), cf. Ohala 1981. For the

connection between listeners' perception and their own production, cf. Perkell 2012.

2. The speaker produces [o], but it is extra short in an unstressed medial syllable (cf. section 4.1). Since the listener is aware of the correlation between vowel length and vowel height, he misinterprets this extra short [ŏ] as a higher vowel [ʊ] or [u], as outlined in section 6.2. When the listener turns speaker, the target vowel has thus shifted from [o] to [ʊ]/[u], as explained under scenario 1 above.

3. The speaker produces a raised [ʊ] for reasons explained under scenario 1 above. Through articulatory and auditory self-feedback, the speaker updates his own linguistic representations to reflect this pronunciation, cf. Perkell 2012.

As with articulation and perception both being the causes of vowel raising (cf. section 6.2), there is no need to assume that the grammaticalization of this vowel raising is due to either scenario 1, 2, or 3. These forces are rather working together to yield the same result. Whether or not this grammaticalized product is accepted by other speakers of the language and propagated throughout the community depends on sociolinguistic factors which will not be discussed here.

What is important to stress here is that the original biomechanical, neurological, and perceptual motivations behind the vowel raising process are both irrelevant and unknown to a synchronic speaker of Old English. This speaker produces *u* in unstressed medial syllables of *ō*-verbs for no other reason than that this is simply the Old English grammatical distribution as he learned it. That the original target vowel in this position for a speaker of pre-Old English was **o* has no relevance anymore – the target vowel in Old English is *u*.

6.4 Vowel raising by grammar

The discussion in this section has so far attributed the origin of the vowel raising effect to non-grammatical properties, such as articulatory error due to the speed and distance of the movement involved in producing short low vowels (section 6.1), and misperception due to listeners' experience with the correlation between duration and vowel quality (section 6.2). A substantially different approach is taken by Flemming 2004, in which the process is entirely triggered by the grammar itself. According to this view, the increased articulatory speed necessary to produce short low vowels means that these segments are more "effortful" (2004: 245), and vowel raising occurs when the grammar prioritizes less effortful articulations over vowel distinctions. The language therefore loses a potential contrast between unstressed [o] and [u], since the grammar decrees that too much effort is required to produce a vowel [o] distinct from the less effortful vowel [u].

This proposal is, unlike the one sketched in section 6.3, strictly a synchronic account. The vowel raising is generated instantaneously and repeatedly as a speaker of Old English produces past tense forms of *ō*-verbs. Such a speaker produces a high [u] in unstressed medial syllables because both a low [ɑ] and a mid [o] require too much effort to articulate. Although the only other available back unstressed vowel in Old English is *a* (cf. section 2), a mid [o] is nevertheless repeatedly evaluated as a possible candidate.

The main problem with this approach is that the principle to minimize the expenditure of motor energy, or in short 'effort', has been incorporated into the grammar. The principle of effort minimization is, however, a general neuromuscular property (cf. Todorov 2004). If effort minimization is specified uniquely in the grammar, then this principle is either independently stated in every cognitive domain related to movement (e.g. speech, vision, gait, pointing, lifting, etc.), or the domain-general principle has been duplicated and restated inside the grammar. No one has to my knowledge proposed that the principle of effort minimization is independently stated in all these domains, but Flemming has proposed that this principle has been duplicated and restated inside the grammar (2001: 26, 2004: 236).[4] Since the domain-general principle of effort minimization will apply to the movements of speech production, it is not clear what effect it has to also specify this principle inside the grammar. Put differently, if the grammar did not have

[4] Other phonologists have argued that principles of effort minimization in phonetics need to be incorporated into the grammar (Boersma 1998: 145; Kirchner 2001: 4), but Flemming is the only one to my knowledge who explicitly acknowledges that these principles are domain-general yet assumes they are duplicated in the grammar.

such a principle within its domain, effort minimization would still exert its effect on the grammatical output simply by virtue of being domain-general. Stating the principle twice (both inside and outside of the grammar) is therefore redundant, since stating it once predicts the same effect to take place anyway.

It is of course possible that a grammatical principle of effort minimization is fundamentally different from the domain-general principle. If this were the case, then positing its presence in the grammar makes a different prediction from positing its absence (exactly what the prediction is will depend on what the content of the grammatical principle of effort minimization is), but no one has to my knowledge succeeded in finding such an effect. Although differences in movements between speech and non-speech gestures have been demonstrated, there is nothing to indicate that this difference has anything to do with the minimization of effort (Bunton 2008; Nelson et al. 1984; Perkell & Zandipour 2002). The guiding assumption should therefore be that effort minimization in phonetics is due to the same principle as effort minimization elsewhere (Lindblom 1983: 232, 243). Until it has been established that a unique principle of effort minimization exists inside the grammar, the methodologically correct procedure would be to prefer the simpler of the two theories and dispense with the idea that the principle of effort minimization is stated both inside and outside of the grammar.

7. *Further research*

The Old English data presented in this paper quite clearly shows that there is solid empirical and statistical support for the hypothesis that the Proto-West-Germanic vowel **ō* shortened and raised to *u* in medial syllables. It would nevertheless be of great value to demonstrate, especially when viewing the Old English language as a whole, that this change occurs not only in other morphological classes than the *ō*-verbs, but also in Old English dialects outside of West Saxon. This paper can therefore be taken as a preliminary report on the support for the vowel raising hypothesis until a complete corpus of early Old English texts has been compiled and probed statistically for additional support.

8. *Conclusion*

The Proto-West-Germanic unstressed vowel **ō* generally develops to *a* in Old English. It nevertheless often shows up as *u* in past tense forms of *ō*-verbs. The traditional explanation for this, called 'van Helten's rule', is that Proto-West-Germanic **ō* raised to **ū* by an assimilation process when a **u* followed in the next syllable. Although this rule is almost universally accepted, its prediction that Old English *u* should be more common when an original **u* followed in the next syllable in Proto-West-Germanic has never been tested. By performing a statistical analysis on the past tense forms of *ō*-verbs in the largest text from the early Old English period it is revealed that no connection can be found between van Helten's rule and the distribution of Old English *a* and *u*. This rule should therefore be rejected as the correct explanation for this phonological feature of the Old English language.

This paper has put forward a new hypothesis for the distribution of Old English *a* and *u*. Since shortened vowels tend to raise, and unstressed vowels are shorter in medial syllables than in final syllables, it is hypothesized that the outcome of Proto-West-Germanic **ō* was raised to a high vowel *u* in Old English medial syllables. A statistical analysis of the past tense forms of *ō*-verbs in the above mentioned text gives strong support for this hypothesis. We can therefore add this descriptive rule to our knowledge of diachronic Old English phonology: Proto-West-Germanic unstressed **ō* develops to Old English *u* in medial syllables, and to *a* in final syllables.

The raising of **ō* to *u* in shortened medial syllables can be understood as a consequence of general human neuromuscular and perceptual properties. The distance the articulators need to travel in order to produce a low vowel is longer than for a high vowel, and shortening a vowel requires the articulators to move more quickly in order to reach their targets. An increase in speed and distance also increases the risk of undershooting the target. Since undershooting the height target of a vowel translates into raising the vowel, a contributing explanation is found for the observation that the shorter (= higher speed) and lower (= longer distance) a vowel is, the more it is affected by vowel raising (= target undershoot). Another contributing factor to the raising of shortened vowels lies in perception. Lower vowels are longer than higher vowels, and it has been demonstrated that listeners know this. Listeners will therefore expect a low vowel to be somewhat long, and if such a vowel is sufficiently shortened, it can be misperceived as being a higher vowel, since higher vowels are intrinsically shorter.

Given these 'natural' explanations for the origin of vowel raising in this position, a purely formal and grammatical explanation for the same phenomenon seems unwarranted. Such explanations have nevertheless been provided for this vowel raising process, in which it has been assumed that domain-general properties of the neuromuscular and biomechanical system have been duplicated and restated inside the grammar. In lieu of being domain-general, however, the principles of these systems will exert their effect on the output of grammar anyway, hence it is not clear what the benefit is of stating those principles a second time inside a more specific domain. Unless evidence can be provided that this duplication has in fact taken place, it should be considered a redundant assumption which can be discarded with no apparent loss in explanatory power.

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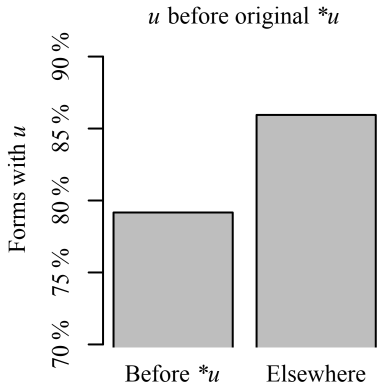

Figure 1: Distribution of *u* by van Helten's rule

$\xrightarrow{\text{Less time}}$

[ɑ] > [ɔ] > [o] > [u]

Figure 2: Correlation between vowel height, length, and raising

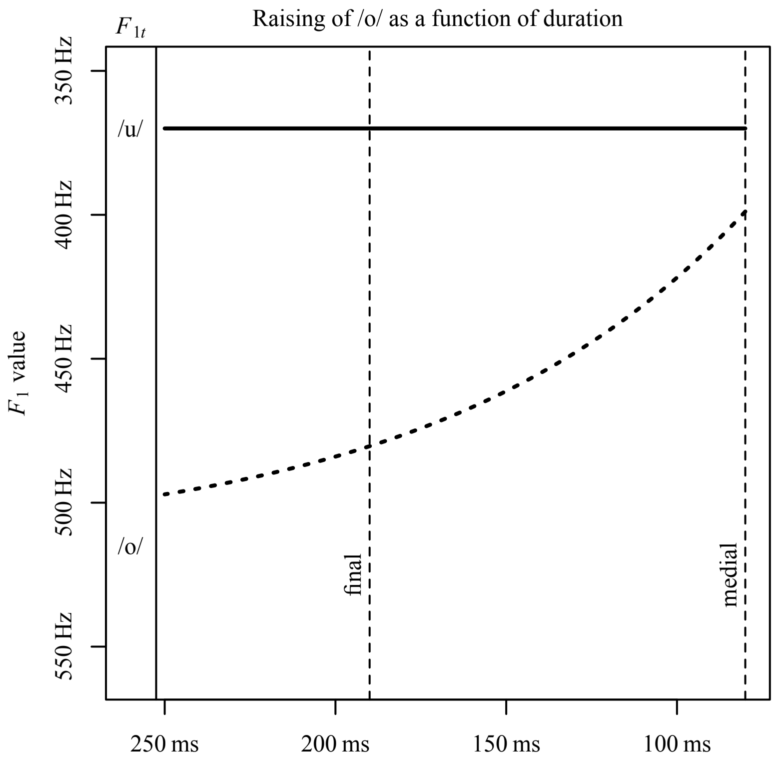

Figure 3: Vowel raising as a function of duration

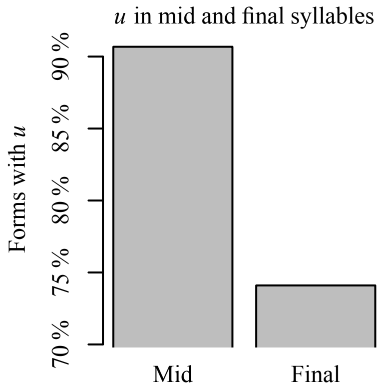

Figure 4: Distribution of *u* by syllable position

List of Tables

Random effects:

Groups	Name	Variance	Standard deviation	Correlation
Word	(Intercept)	1.879	1.371	
	Before *u	3.862	1.965	−1

Fixed effects:

	Estimate	Standard error	*z* value
(Intercept)	2.346	0.352	6.657
Before *u	−0.788	0.667	−1.181

Explained variance: $R^2 = 0.019$

Table 1: Summary of logistic regression model for van Helten's rule

Random effects:			
Groups	Name	Variance	Standard deviation
Word	(Intercept)	1.574	1.255
Word	Mid syllable	37.74	6.143
Fixed effects:			
	Estimate	Standard error	*z* value
(Intercept)	1.332	0.344	3.871
Mid syllable	5.364	1.563	3.433
Explained variance: $R^2 = 0.827$			

Table 2: Summary of logistic regression model for new hypothesis