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Reconstructing the diffusion of Middle English schwa deletion

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This paper presents a method for assessing whether schwas in Middle and Early Modern English final unstressed syllables were pronounced or not. This is a difficult problem as schwas were represented by <e> in writing even after they had long disappeared in speech. We approach the issue by using models of logistic growth calibrated to phonologically interpretable poetry data in order to extrapolate time-dependent frequency estimates for the realisation of final-syllable schwas also in prose corpus data. Our models produce estimates that conform to accounts in the phonological literature and can at the same time be used to estimate the probability of schwa realisation at specific points during the long period of its gradual loss.

KEYWORDS: schwa loss, linguistic spread, Middle English, poetry, rhythm, metre, logistic spread.

1. Introduction

Historical phonologists often need to work with written evidence, which is a challenge as spelling never straightforwardly reflects speech. A Middle English (**ME**) sound change that is particularly difficult to reconstruct from written data is the loss of schwa in unstressed final syllables. This began in the Late Old English period and was completed by the 18th century, changing words such as ME /ˈma(ː)kə/ 'make' or /ˈseːməd/ 'seemed' into /maːk/ 'make' and /seːmd/ 'seemed'. In spelling, schwa loss has never been reflected consistently, however, and Modern English still has <e> but no [ə] in words like *make* and *seemed*. In any text written between the 11th and the 18th century, it is therefore difficult to determine if the letter <e>[1] in an unstressed syllable represented a spoken schwa or not (see different proposals in Luick 1914-1921, Dobson 1957, Fisiak 1968, Jordan 1968, Erdmann 1972, Brunner 1984, Wright & Wright 1984, Mossé 1991 and Minkova 1991).

The fact that written data do not reflect schwa loss well also complicates the study of other phonological developments. This is particularly true of changes that may have been fed or triggered by schwa loss. An example is Middle English open syllable lengthening (as in ME /makə/

> /maːk(ə)/ or ME /ˈhopə/, 'hope' > /hɔːp(ə)/, or /bevər/ 'beaver' > /bɛːv(ə)r/). One hypothesis is that it compensated for schwa loss in final syllables (Minkova 1982; Bermudez-Otero 1998), so it would be desirable to reconstruct the chronology of schwa loss as precisely as possible. Various other issues also depend on the chronology of schwa loss too and indeed our own interest in this question was motivated by the question of whether English word forms in different periods of the history of the language ended in consonant clusters or not. This would clarify other problems: for example, the simplification of the final cluster in *sing* (ModE /sɪŋ/< ME /ˈsingən/), as opposed to its retention in *finger* (ModE /ˈfɪŋgə/ < ME /ˈfingər/, depended on whether /ŋg/ was final or not. Similarly, the answer to the question of when words like *mind* and *mined* started to be homophones depends on when the past tense suffix began to be pronounced as [d] rather than [əd].

In this paper, we demonstrate a method for estimating the probability of schwa realisation by combining models from quantitative ecology with the philological analysis of verse data. First, we use verse texts in regular iambic metres from the 12th to the 18th century and estimate the proportion of final schwas realised in them. Then, we model the spread of schwa loss on the assumption that it described a logistic S-shaped curve. Subsequently, we fit the logistic curves to the results gained from the verse analysis, and thereby derive probability estimates for the realisation of schwa at different periods. Finally, we compare our results to estimates found in the extant literature, which are mostly based on philological arguments, and show that they converge in a way that we consider encouraging.

2. Preliminaries: on the nature of Middle English schwa loss

Schwa is a mid-central vowel represented by the symbol /ə/ (Minkova 1991; Lass 1986). In Middle English, it could occur in any unstressed syllable, but this paper focuses on two possible conditions:

(i) Schwa in open word-final syllables, as in *ende* [en.də] 'end'
(ii) Schwa in closed word-final syllables, as in *houndes* [huːn.dəs] 'hounds'.

Modern English has lost most schwas in both of these contexts. The loss occurred in two phases: in the first phase, speakers dropped [ə] in open final syllables, and in the second phase, they dropped it in closed syllables as well (Jordan 1968; Brunner 1960: 348; Dobson 1957: 879;

Wright & Wright 1984: 69; Minkova 1991). Schwa loss in final syllables resulted from a combination of phonological and morphological factors. When schwa in open final syllables occurred before words beginning with vowels, the resulting hiatus was (first optionally and then regularly) resolved by schwa deletion (Luick 1914-1921: §452). Furthermore, since English stress was root-initial, final syllables were generally reduced in pronunciation. Schwa itself had resulted from the reduction of full vowels (such as /u/, /a/, /o/, etc.), which had often represented different inflectional suffixes. After these vowels had merged in schwa, many suffixes became ambiguous and lost their morphological function. This contributed to a radical restructuring of inflectional morphology, which was also promoted by contact with Scandinavian. Eventually, Late Old English and Early Middle English lost most inflections, and the schwas in final syllables became morphologically redundant and were eventually lost altogether (Minkova 1991, 2013).

While it is evident that schwa has not survived in final syllables, the precise chronology of its loss remains a challenge, and there is little consensus in the literature. The following short summary is based on Luick (1914-1921), Dobson (1957), Fisiak (1968), Jordan (1968), Erdmann (1972), Brunner (1984), Wright & Wright (1984), Mossé (1991) and Minkova (1991).[2]

In final open syllables, schwa loss started first in Northern dialects. There, speakers started to drop schwa roughly in the 12th century and the loss was completed in the 13th century. In the Southern and Midlands dialects, schwa loss in open final syllables occurred approximately one century later and was completed only by the end of the 14th century. In closed final syllables, on the other hand, schwa loss progressed roughly in the same way in the North and the South. During the 13th century, schwa was lost in the plural and in the 3rd singular present tense suffix {-es}, especially if the reduced vowel was preceded by /l/ or /n/. However, in the North the precursor of the 3rd singular present tense suffix, {-eth} retained schwa until it was fully substituted by {-es} (Dobson 1957: 880). In closed syllables, schwa loss was completed in all areas by the 18th century, when it was finally dropped also in past tense forms. Not all schwas in final syllables have been lost, however. Some have survived as /ɪ/ in the nominal plural and verbal 3SG present allomorph /ɪz/ after sibilants (as in *wishes,* N.PL or V.3SGPRES), and in the past tense and past participle allomorph /ɪd/ after coronal stops (as in *ousted*). Also the superlative suffix {-est} did not lose its vowel (Wright & Wright 1984: 73), and in derived adjectives such as *naked* or *learned* it has been preserved as well.

3. Estimating the chronology of schwa loss diffusion

As indicated, we estimate the diffusion of schwa loss by combining a quantitative analysis of verse data with general theories about the way in which phonological changes spread. We proceed in three steps. (i) We use rhythm and metre to establish which schwas in verse texts were actually realised. (ii) We measure how factors such as morphological boundaries, morphosyntactic category, or phonological context correlate with the likelihood of schwa loss. (iii) We use the results of that statistical analysis to model the logistic spread of schwa loss in open and in closed final syllables. This yields an estimate of the probability with which the two types of schwa were pronounced in each century of our observation period.

3.1. Inferring schwa loss from verse data

For our study, we divided the ME period into seven sub-periods, each covering one century from the 12th to the 18th. For each sub-period we chose a sample of verse texts in a regular, strictly alternating metre. Most of them employ iambic metres, mostly pentameters, or tetrameters. Only the 12th century *Ormulum* employs the septenarius. From the texts, we sampled items with <e> in the final syllable. This yielded 1206 items (Table 1) and 1211 datapoints (Table 2). There were more datapoints than items as some words (such as <heuede> ‘head’) included more than one <e>.

Period	Text	Items
12th c.	*The Ormulum*	148
13th c.	*Soul's Ward**	9
	*English Version of Genesis and Exodus**	26
	*A Bestiary**	26
	*Metrical English Psalter***	28
	Havelok the Dane	22
	The Fox and the Wolf	31
	The Owl and the Nightingale	36
14th c.	*De Baptismo***	22
	Le Morthe Arthur	22

	Sir Eglamour of Artois	24
	Sir Orfeo	22
	Sir Perceval of Gales	34
	*The Bruce (Book VII)***	20
	The Pearl	15
	The Pricke of Conscience	17
	*The Tale of Pers the Usurer***	26
15th c.	*Amis and Amiloun*	28
	De Regimine Principum (Lament for Chaucer)	15
	The Flower and the Leaf	37
	*The Kingis Quair****	34
	*Wallace (Book I)****	31
16th c.	*A Most Lamentable and Tragicall Historie (Didaco and Uiolenta)*	27
	A New Treatise in Three Parts	30
	Hero and Leander	27
	The Banquett of Dainties	29
	The Brevyate and Short Tragycall Hystorie of the Fayre Custance	23
	The Mylner of Abyngton	29
	*The Nut-Brown Maid****	23
17th c.	*Cupid and Psiche*	15
	Maggots (On a Maggot)	22
	Paradise Lost	32
	The Anatomie of Basenesse (Of the Flatterer)	32
	The Mirror of New Reformation (To the Protestant Reader)	32
	The Muses Welcome	32
18th c.	*A Miscellany of Poems (Harvest; or the Bashful Shepherd)*	29
	Friendship and Love	12
	Hardyknute	15
	Hobbinol	12
	Poems on Several Occasions (Commerce)	23

	The British General	25
	The Priest Dissected	31
	The Progress of Love	15
	The Seasons (An Imitation of Spenser)	18

Table 1. List of verse texts examined for schwa loss for each of the seven ME sub-periods.[3]

Period	*Final Schwa*	*Checked Schwa*	*Overall*
12th c.	76	72	148
13th c.	110	72	182
14th c.	103	100	203
15th c.	73	72	145
16th c.	92	96	188
17th c.	77	88	165
18th c.	93	87	180
Total	624	587	1211

Table 2. Number of data points for each sub-period.

In order to determine if orthographic <e> was realised as a schwa or not, we assumed that the texts were metrically well-formed iambic tetrameters or pentameters. In iambic verse, a line consists of four (tetrameter) or five (pentameter) iambic feet which start with a rhythmic dip (a syllable that is less prominent than its neighbours) and end in a rhythmic lift (a syllable more prominent than its neighbours) (1a-b). Dips are indicated by '↓', lifts by '↑'. Typically, the stressed syllables of content words such as nouns or verbs coincide with lifts, while grammatical words such as pronouns or prepositions often align with dips.

(1) a. Iambic pentameter

↓	↑	↓	↑	↓	↑	↓	↑	↓	↑
The	*cap*	*tain*	*of*	*the*	*team*	*is*	*strong*	*and*	*smart.*

b. Iambic tetrameter

↓	↑	↓	↑	↓	↑	↓	↑
A	*no*	*ther*	*wai*	*ter*	*was*	*dis*	*missed.*

In our analysis, we exploited the fact that the rhythmic well-formedness of our verse data depended on the realisation or the elision of schwas. Following fairly well-established practice (cf. McCully & Anderson 1996), we selected lines that were metrically well-formed when given a natural reading. By 'natural reading' we mean, for example, that lifts should not fall on inflectional endings. That is, we ruled out readings such as **wickˈed* as opposed to natural *ˈwicked*. Similarly, we considered scansions in which lifts fall on function words and dips on content words unnatural as well. Thus, we ruled out scansions like **ˈThe team ˈis strong* as unnatural. To minimise arbitrariness, we excluded lines in which more than a single natural reading seemed possible.

These principles made it possible to infer which schwas in a specific line had to be realised. This process is illustrated in example (2a-d), an iambic tetrameter from *The Fox and the Wolf*.

(2) a. No schwa loss

↓	**↑**	↓	**↑**	↓	**↑**	↓	**↑**	↓	**↑**
Ac	*cour*	*sed*	*be*	*thou*	*of*	*Go*	*des*	*mou*	*the.*

b. Schwa loss in *Godes*

↓	**↑**	↓	**↑**	↓	**↑**	↓	**↑**	↓
Ac	*cour*	*sed*	*be*	*thou*	*of*	*God(e)s*	*mou*	*the.*

c. Total schwa loss

↓	**↑**	↓	**↑**	↓	**↑**	↓	**↑**
Ac	*cours(e)d*	*be*	*thou*	*of*	*God(e)s*	*mouth*	*(e).*

d. Schwa loss in *Accoursed* (PREFERRED SCANSION)

↓	**↑**	↓	**↑**	↓	**↑**	↓	**↑**	↓
Ac	*cours(e)d*	*be*	*thou*	*of*	*God*	*es*	*mouth*	*e*

(*The Fox and the Wolf*, line 62)

Realising all schwas (as in (2a)) does not yield a tetrameter at all. Also, it forces one to stress the final syllables in *Godes* and in *mouthe*, as well as the preposition *of*. This is evidently unnatural. Interpreting only the <e> in *Godes* as silent (as in (2b)) does not yield a better verse either. It still forces one to realise the preposition *of* more prominently than the first syllable of *Godes*. Interpreting all <e>s as silent (as in (2c)) produces a different problem: either one produces a stress clash between *God(e)s* and *mouth(e)*, or one demotes *mouth(e)* into a dip, which leaves the line with only three lifts rather than the required four. Thus, the only natural reading that yields a well-formed iambic tetrameter is (2d), where the <e> is silent in *accoursed*, but realised as a schwa in *Godes*.

For our final sample, we excluded lines for which there was more than one plausible reading, as in example (3). For the line to be metrically well-formed, *louede* 'loved' must be read as disyllabic with a lift on the root. However, we found it impossible to decide whether it should be read as /ˈluvdə/ or as /ˈluvəd/.

(3) a. Final schwa loss in *louede*

↓	↑	↓	↑	↓	↑	↓	↑
He	lo	ued(e)	god	with	al	his	micth.

b. Checked schwa loss in *louede*

↓	↑	↓	↑	↓	↑	↓	↑
He	lou(e)	de	god	with	al	his	micth.

(*Havelok the Dane*, line 35)

In the end, we had 1206 items of which we could say with sufficient confidence whether <e> graphemes in their final syllables were silent or not.[4] We divided them into two sets: with schwas in open and closed final syllables. For all items, we then determined (a) their part-of-speech, (b) their length in letters, (c) the morphological status of their final syllable (stem or suffix), as well as (d) whether the following word began with a consonant or a vowel.

3.2. Determinants of schwa loss: a preliminary analysis

Next, we investigated which factors determined the realisation of <e> as schwa. We considered the following potential predictors: TIME, presence of a morpheme boundary in the syllable with the schwa (BOUNDARY: YES *vs* NO), the beginning of the following word (RIGHT ONSET: V *vs* C), and GRAPHEME COUNT (as a proxy for word length). Two independent variables were defined: SCHWA IN AN OPEN SYLLABLE (ABSENT *vs* PRESENT) and SCHWA IN A CLOSED SYLLABLE (ABSENT *vs* PRESENT). The following exemplifies our modelling procedure with the predictors of schwas in open syllables. The procedure for schwas in closed syllables was similar.

We used generalised linear models and multimodel-inference techniques to test which of the predictors showed a substantial effect on the (phonological) presence of schwa. So, we first defined a global binomial model (with logit link) of the way in which the realisation of schwa in open syllables depended on each and all of the abovementioned predictors, i.e. TIME, BOUNDARY (default: NO), RIGHT ONSET (default: C), GRAPHEME COUNT.

From a statistical perspective, this global model is not ideal and potentially over-specified (Grueber *et al.* 2011), so we had to find the best trade-off between the goodness-of-fit and the model complexity.

One standard procedure for dealing with overspecification is model optimisation, for instance driven by the Akaike information criterion (**AIC**) (West *et al.* 2015). A model's AIC approximates loss of information in the model relative to reality (Burnham *et al.* 2011). In the case of small samples, a corrected version of AIC (**AICc**) can be computed. By subsequently removing predictors from a model one can determine in which submodel least information is lost.

In our case, there are 32 candidate subtypes of the global model (five predictors yielding $2^5 = 32$ possible combinations). Simply relying on the optimal model is problematic since it might ignore relevant information contained in some of the remaining candidates. We therefore employed techniques from multimodel inference (Grueber *et al.* 2011; Burnham & Anderson 2016; Burnham *et al.* 2011; Johnson & Omland 2004). The basic idea is to combine multiple models to yield a single average model. This average model differs from the optimal model (the one with the lowest AICc) in that it also includes information from the second-best model, third-best model etc.

In multimodel inference, candidate models are assigned an Akaike weight (which is computed from AICc). For a given model, this weight can be interpreted as the probability of the model given the data and the set of candidate models. Thus, models are conceptualised as hypotheses, and Akaike weights give probabilities of the respective hypotheses (very much like Bayesian posterior probabilities).

In our analysis, for example, the model with the lowest AICc has an Akaike weight of 0.44 (see Table 3). It features GRAPHEME COUNT, BOUNDARY, RIGHT ONSET and TIME as predictors. It suggests that the realisation of final schwas at different times depended on the following factors: (a) the longer a word was, the more easily the schwa was deleted; (b) schwas were deleted less easily in suffixes than stem-internally; (c) schwas were more easily deleted before vowel-initial words than before consonant-initial words; (d) the likelihood of schwa deletion increased over time.

However, the second-best model, which lacks the predictor BOUNDARY does very little worse. Its Akaike weight is 0.414. It therefore counts as almost equally likely, and attributes no relevance to the morphological status of the syllable with the schwa. This factor may therefore have been less important than word length, and the sound following the word-final schwa.[5]

We ranked all models by their Akaike weights and compiled a confidence set. It included the four best models, listed in Table 3. Their Akaike weights added up to 0.95, which means that they defined a 95%-confidence set.

intercept	grapheme count	boundary	right onset	time	AICc	Akaike weight
+	+	+	+	+	186.6	0.444
+	+		+	+	186.7	0.414
+			+	+	189.8	0.089
+		+	+	+	190.9	0.053

Table 3. 95% confidence set for final schwa resulting from multimodel inference (binomial GLMs with logit link); '+' indicates that a predictor is present in the model.

From this model set, we computed an average model by calculating the weighted average for each regression coefficient.[6] In our case, each average coefficient was computed from the weighted average of four regression coefficients (one for each model in the confidence set). In a similar way, averaged standard errors were computed for each coefficient. Finally, Akaike weights were used to compute the relative variable importance (**RVI**) of a predictor (Burnham & Anderson 2002). The RVI expresses the probability that a certain predictor is relevant given the data.[7] Table 4 shows coefficients, standard errors, and p-values of the averaged model as well as RVI scores.

variable	coefficient estimate	SE	p-value	RVI
intercept	16.96	2.37	<0.001	–
grapheme count	-0.28	0.17	0.11	0.86
boundary (yes)	0.31	0.44	0.48	0.50
right onset (V)	-3.96	0.69	<0.001	1.00
time	-0.01	0.00	<0.001	1.00

Table 4. Averaged model of final schwa depending on grapheme count, boundary and right onset computed from the 95% confidence set given in Table 3.

As can be seen from Table 4, only the effects of RIGHT ONSET and TIME are not trivial ($p < 0.05$), while those of GRAPHEME COUNT and BOUNDARY are. This means that the probability of schwa deletion was significantly affected only by the presence of a vowel at the beginning of the next word, and that probability increased over time. As the RVI indicate, also the word length was likely to have increased the probability of schwa deletion, but the high p-value suggests that it is a relatively unreliable predictor.

We applied the same modelling procedure to schwas in closed final syllables. Here, eight models made it into the 95% confidence set. They are listed in Table 5 below.

intercept	grapheme count	boundary	right onset	time	AICc	Akaike weight
+				+	585.9	0.337
+		+		+	587.4	0.159
+			+	+	587.5	0.154
+	+			+	587.8	0.130
+		+	+	+	589.0	0.072
+	+	+		+	589.4	0.060
+	+		+	+	589.4	0.059
+	+	+	+	+	590.9	0.027

Table 5. 95% confidence set for checked schwa resulting from multimodel inference (binomial GLMs with logit link); '+' indicates that a predictor is present in the model.

Interestingly, for schwas in closed final syllables only time occurs in the optimal model. However, this model is only supported at 34% by the data, given all candidate models. The averaged model computed from the set in Table 5 results in the coefficients shown in Table 6 below:

variable	coefficient estimate	SE	p-value	RVI
intercept	10.09	1.11	< 0.001	–
time	-0.01	0.00	< 0.001	1.00
boundary (yes)	0.21	0.61	0.72	0.32
right onset (V)	3.83	300.5	0.99	0.31
grapheme count	-0.01	0.04	0.87	0.28

Table 6. Averaged model of checked schwa depending on grapheme count, boundary and right onset computed from the 95% confidence set given in Table 5.

Table 6 shows that the only robust predictor for the probability schwa loss in closed final syllables is time, which predicts schwa loss in open final syllables as well. In fact, the only difference between schwa loss in closed syllables and in open syllables is that in open syllables its probability is also predicted by the beginning of the following word: if it is vocalic the probability of schwa loss increases. While this result is not spectacular, it crucially reduces the number of scenarios to consider when modelling the interaction of time and schwa deletion. Specifically, it means that only three different cases need to be distinguished, namely (a) the case of schwas in open final syllables before vowels, i.e. CCə#V, (b) the case of schwas in open final syllables before consonants, i.e. CCə#C; and (c) the case of schwas in closed final syllables, i.e. CəC#. The next section shows what this means for modelling schwa loss diffusion.

3.3. Calibrating logistic models

The diffusion of linguistic changes is often described as an S-shaped curve (Denison 2010; Blythe & Croft 2012; Kroch 1989). Mathematically, this can be modelled by the logistic function. Here, the growth of a phenomenon (like schwa loss) depends multiplicatively on the amount of items (a) affected and (b) not yet affected by a change (Hofbauer & Sigmund 1998; Nowak 2006; Solé 2011; Wang & Minett 2005). The frequency of affected items *f* at time *t* is given by the following equation:

(4) $$f(t) = K \cdot \frac{1}{1+\exp(-rKt-C)}$$

Here, K is referred to as the carrying capacity, i.e. the maximum frequency in the population, and r denotes the rate of change and determines the steepness of the curve. If r is high, the curve is steep, while it is flat if $r = 0$. Finally, C is a constant parameter. When K is set to 1, f denotes the fraction of affected items. Then, for any single item, $f(t)$ can be interpreted as probability *pr(y)* of being affected by the change at time *t*. In that case, the formula reduces to

(5) $$pr(t) = f(t) = \frac{1}{1+\exp(-rt-t_0)}$$

where the constant t_0 denotes the inflection point of the S-shaped curve, which is the point in time at which exactly one half of all items are affected. This parameter determines the horizontal position of the curve: if

t_0 is increased, the curve shifts to the right (meaning later onset and offset of the change); if t_0 is decreased, the curve shifts to the left (corresponding to earlier onset and offset). In our case, time t is measured in centuries, going up from 1 (12^{th} century) to 7 (18^{th} century). Note that although motivated by an ecological application, the function defined in (5) is equivalent with the logistic function used in logistic regression.

We attempted to identify S-curves that best describe the diffusion of schwa loss in different phonological environments. For that purpose, we first divided the verse data into the three subsets: (i) CCə#V (schwas in open final syllables followed by vowels), (ii) CCə#C (schwas in open final syllables followed by consonants), (iii) CəC# (schwas in closed final syllables). In addition, we consider the category of final schwas (iv) CCə# (i.e. a super-category of (i) and (ii)). Next, each dataset was divided into seven further subsets, one for each century (from 12^{th} to 18^{th}). For each century and for each subset (CCə#V, CCə#C, and CəC) we then computed the proportion of realised schwas as determined by the verse analysis, together with their standard errors. This gave us trajectories consisting of seven data points for each category (i-iv).[8] Third, we employed weighted non-linear least-squares regression (**NLS**) to fit the logistic curve defined in (4) to each of the three trajectories. NLS is an extension of linear least-squares regression in which a specified function, in this case (4), is fitted to given data points in such a way that the distance between scores predicted by the function and the data is minimal. The only major difference between NLS and linear regression is that the former allows functions to be curved whereas the latter is restricted to linear functions. In addition, reciprocal standard errors were used to weight the data points, as not to lose information about the precision of the century-wise estimates. We used the nls() function in R to do so.[9]

For each category (i-iv) we obtained estimates for r and t_0. These are shown in Table 7.

Category	r	t_0
CCə#V	-0.44 (0.31)	-4.62 (4.55)
CCə#C	-1.21 (0.37)	2.80 (0.35)
CəC#	-0.86 (0.19)	3.76 (0.37)
CCə#	-0.92 (0.13)	1.98 (0.35)

Table 7. Parameters of logistic models (together with their standard errors).

Using the parameters in Table 7 together with formula (4), we computed probabilities of schwa realisation for the three types and for any year. Figure 1 shows the probability estimates for the different periods together with the corresponding logistic curves.

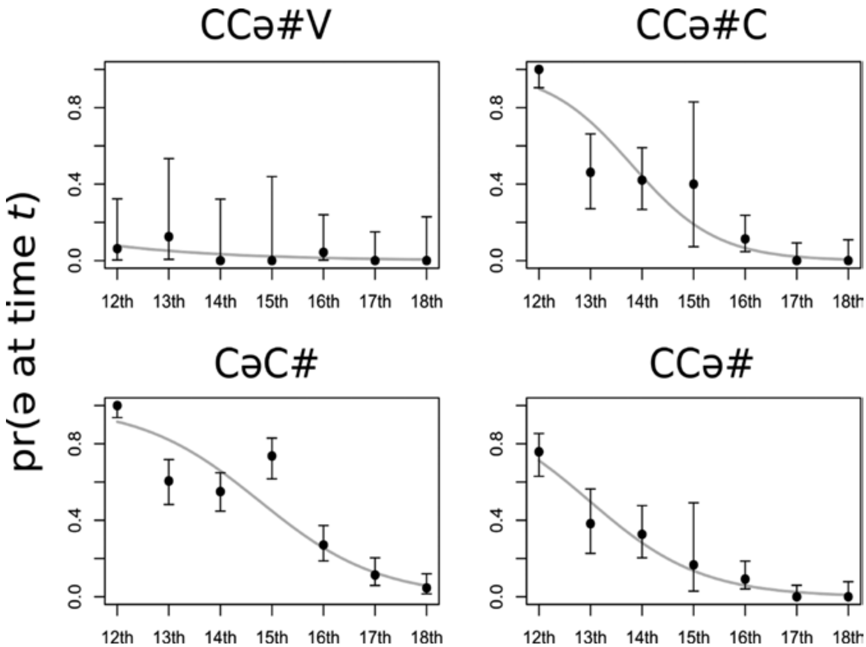

Figure 1. The decreasing probability of schwa realisation in three different environments. The curves are uniquely determined by the respective coefficients in Table 7. Dots denote estimates of schwa loss probabilities obtained from the analysis of the verse data (see 3.1). Error bars denote 95% confidence intervals.

In Figure 1, the probability with which schwas were realised can be read off for any point in time from the 12th to the 18th century. This can be done separately for each of the three contexts in which the diffusion of the schwa loss proceeded at its own rate. Reassuringly, the findings of our study are generally quite compatible with the un-quantified proposals in extant literature. Figure 2 compares our statistically derived estimates with those in the literature.

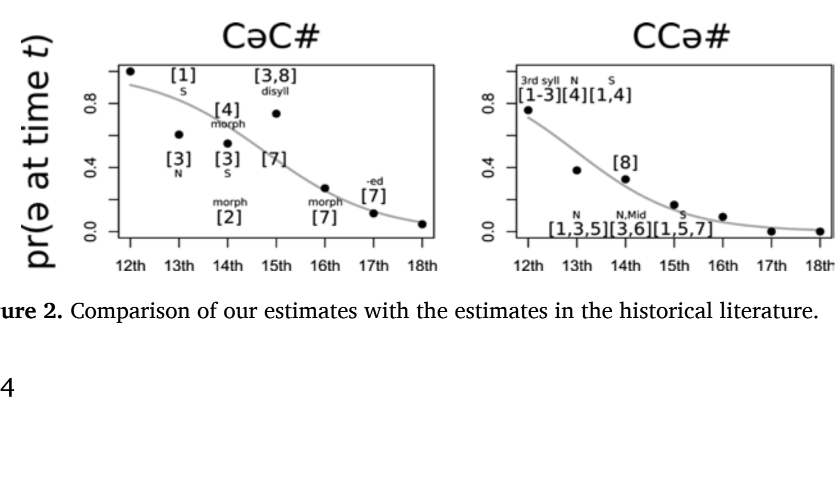

Figure 2. Comparison of our estimates with the estimates in the historical literature.

Dots are estimates per century drawn from the poetry analysis (cf. 3.1-2), and gray curves are model-based estimates (cf. 3.3). Rough estimates from the literature are shown in square brackets with additional linguistic or geographic information. Sources: [1] Jordan (1968), [2] Mossé (1991), [3] Brunner (1984), [4] Fisiak (1968), [5] Wright & Wright (1984), [6] Minkova (1991), [7] Dobson (1957), [8] Erdmann (1972). Abbreviations: N (North), S (South), Mid (Midlands), morph (schwa at a morpheme boundary), disyll (schwa in disyllabic words), -ed (schwa in past tense or participle forms).

In the case of schwas in closed final syllables, our estimates fit those from the literature remarkably well, if only roughly. The worst fit is with Mossé's estimate of schwa loss in inflectional syllables. On the other hand, the left plot in Figure 2, which describes the progress of the schwa loss in open final syllables, reveals a limitation of our study, namely that we did not take regional differences into account. For that purpose, we would have needed a larger and regionally more differentiated database.

Of course, estimates are always probabilistic and do not allow one to say with any certainty whether a specific schwa in a specific word token in a specific text would have been pronounced by its author or readers. However, they do make it possible to say, with some confidence, how many of the schwas in large text samples from different periods are likely to have been realised, and how many of them would have been deleted. Particularly for corpus-based studies, in which frequency matters and which are based on large and diverse text samples, this can be useful.

4. Conclusion

We have shown that formal models of phonological change can be calibrated with phonologically interpretable data from verse texts and allow one to infer plausible estimates about the diffusion of a sound change that is badly represented in written data. We have, therefore, proposed a method for dealing with one of the main problems in diachronic phonological research: a lack of audio data combined with a lack of one-to-one correspondences between graphemic and phonological representations. While the idea of using verse data for assessing the stage of a sound change at a given time is not new, our method adds quantitative rigour to it and helps to put generalisations drawn from specific philological studies on more solid ground. Well-informed and established formal models of linguistic change allow one to derive more phonological information from historical corpus data than has for far been acknowledged. For that purpose, they must be used as what they actually are, namely, as functions that describe diachronic trajectories, rather than just diagnostic tools for the delivery of potentially significant statistical effects.

As far as the diffusion of schwa loss is concerned, our findings have mostly corroborated extant accounts. They have shown that the factor which had the greatest impact on the speed with which schwas were lost was their immediate phonological right-hand context. They were lost first when they were word-final and followed by vowel-initial words, and last when they were followed by consonants within the same word. In comparison, the impact of other factors, such as word length, or the morphological status of the syllable in which schwa occurred, was much smaller. Although we have not revised established views on schwa loss, we have shown how quantifiable estimates about the progress of schwa loss can be produced for any point during the long period it took to unfold.

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Notes

1 In Middle English texts also alternative spellings such as <y>, <o>, <u>, <i> etc. are found.

2 See also the survey in the Appendix.

3 As a source, we used the *Chadwyck-Healey Literature Collections, English Poetry* (Barnard *et al.* 1996). For the poems marked '*', we used Morris (1848), for those marked '**' Morris & Skeat (1873), and for those marked '***' Skeat (1887).

4 We are aware that our argument hinges on the assumption that the poetic language we looked at was at least roughly representative of contemporary everyday language. In many respects, this is unlikely to have been the case. Everyday language obviously does not follow a regular metre, for example. What we will see, however, is that the trajectory of schwa loss diffusion that emerges from our verse data does describe the type of S-curve associated with the diffusion of changes in 'normal' language. At least with respect to schwa loss, this suggests a systematic correlation between the development of poetic and non-poetic language, although it clearly does not rule out that poetry may have preserved archaic features, or made deliberate use of innovative ones.

5 This difference would have been missed if only the best model had been considered.

[6] Weights in the average model are given by the Akaike weights in the last column in Table 3, and coefficients that do not figure in the model are treated as zero.
[7] Note that this differs from the information given by p-values, which measure the probability of the data given the hypothesis that the relevance of an assumed predictor is zero (i.e. the null-hypothesis is wrong).
[8] The number of data points per century was determined beforehand to make sure that the proportions can be estimated with a margin of error of ±10%.
[9] This way of estimating the logistic function for the given data differs from how logistic functions are usually fitted in generalised linear models. Instead of considering data points separately (which might be spread unevenly across a given century) and assigning numerical values 0 *vs* 1 (schwa absent *vs* present), we collect the data points for each century and estimate the fraction of present schwas together with its standard error. The latter encodes the precision of the estimate and is used as weight in the NLS estimation.

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Appendix. The diffusion of schwa loss as represented in extant literature

<table>
<tr><th></th><th>North</th><th>Midlands and South</th></tr>
<tr><td>Late OE</td><td colspan="2">• Elision of final [ə] in hiatus (Luick 1914-1921: §452)
• Fluctuations in proper nouns and place names (Minkova 1991)</td></tr>
<tr><td>12th c.</td><td>• Regular loss of final [ə], particularly in unstressed words like thanne or bute (Brunner 1984: 348), (although Fisiak 1968: 36 suggests the 13th c.)
• Final [ə] was lost in trisyllabic items after a long first syllable (Jordan 1968: 129)</td><td></td></tr>
<tr><td rowspan="2">13th c.</td><td>• Loss of final [ə] was complete (Wright & Wright 1984: 69), (although Minkova 1991 assumes completion only in the 14th c.)
• Loss of final [ə] in all trisyllabic items (Jordan 1968: 130)</td><td>• Loss of checked schwa in the third syllable regardless of the quality of the first syllable (began earlier in the North) (Jordan 1968: 130)</td></tr>
<tr><td colspan="2">• <-es> lost schwa after /l/ and /n/ (Jordan 1968: 142)</td></tr>
<tr><td rowspan="2">14th c.</td><td>• Start of syncope in verbal and nominal <-es>, completed by 1400 (Mossé 1991: 35)
• Schwa loss in hiatus also in past participle forms (Jordan 1968: 131)</td><td>• Complete loss of final [ə] (Wright & Wright 1984: 69; Jordan 1968; Brunner 1960: 348; maybe only by 1450 (Dobson 1957: 879)
• Loss of final [ə] in trisyllabic items after a short first syllable, except for syncope (Jordan 1968: 130)
Loss of schwa in <-eth> after heavy root syllables (Mossé 1991: 36)
• In Kent, final schwa was still pronounced (Jordan 1968)</td></tr>
<tr><td colspan="2">• Probable syncope in plural forms in trisyllabic items except after stops (Brunner 1984: 349)
• Schwa loss started in the endings of auxiliary verbs (Jordan 1968: 141)</td></tr>
</table>

<table>
<tr><td>15th c.</td><td colspan="2">• Start of schwa loss in inflectional endings (Erdmann 1972: 228) (although Fisiak 1968: 36 suggests that it began already in the 14th c.)
• Schwa loss in inflectional endings in disyllabic words (Brunner 1960: 349f)</td></tr>
<tr><td>16th c.</td><td colspan="2">• Loss in nominal and verbal [-əs] (substituting [-əθ]) is complete (Dobson 1957: 880)
• Syncope in [-əst] in verbs especially after V or C [+voice] (Dobson 1957: 886)</td></tr>
<tr><td>17th c.</td><td></td><td>• Nominal plural [-əs] is maintained in vulgar or dialectal speech (Dobson 1957: 883)</td></tr>
<tr><td>18th c.</td><td colspan="2">• Loss of [ə] in verbal past tense forms is complete (Dobson 1957: 880)</td></tr>
</table>