Phonological Data & Analysis Volume 4, Article 5: 1–31 (2022)
https://doi.org/10.3765/pda.v4art5.67

Received 31 July 2021; Revised 01 July 2022; accepted 01 August 2022. © 2022 Dorota Krajewska et al.
Published by the Linguistic Society of America with permission of the authors under a CC BY 3.0 license.

Sibilant mergers in 18th-century Basque: A quantitative study

Dorota Krajewska[a], Eneko Zuloaga[b] & Ander Egurtzegi[c*]

[a]University of the Basque Country UPV/EHU – dorota.krajewska@ehu.eus
[b]University of the Basque Country UPV/EHU – eneko.zuloaga@ehu.eus
[c]Centre National de la Recherche Scientifique – IKER (UMR5478) – ander.egurtzegi@iker.cnrs.fr

Conservative Basque dialects distinguish apical (/s̻/ and /t͡s̻/) and laminal (/s̺/ and /t͡s̺/) alveolar sibilants in the fricative and affricate series. This paper analyses the changes this system was undergoing in the Central Basque variety of San Sebastián in the 18th century: (1) the "Western merger": neutralisation of the laminal and apical fricative sibilants in favour of the latter and the neutralisation of the laminal and apical alveolar affricates in favour of the former, which started in Western Basque and spread to some Central varieties, and (2) the "Central merger", a more recent development, limited to some central dialects, where both fricative and affricate alveolar sibilants are realised as laminals. A generalised linear mixed-effects model was fitted to the data extracted from an early-18th-century manuscript which shows evidence of both mergers. We propose that sibilant mergers were still in progress in the variety and time period under study and that they are interrelated processes. The Western merger started as a phonetically-conditioned sound change due to coarticulation to a following consonant. As this neutralisation extended to other positions, a hypercorrective change was initiated in some Central varieties, which eventually resulted in a mirror-image process, namely a change from apical to laminal fricatives.

Keywords: sibilants; Basque; merger; corpus study

1 Introduction

In Basque historical phonology, the study of consonants has prevailed over that of vowels (Michelena 1990; Lakarra 1995; Lakarra 2013; Trask 1997; Egurtzegi 2013). Among processes affecting consonants, the changes that have altered the phonological opposition between pairs of fricative and affricate sibilants with different places of articulation have aroused considerable interest, with renewed discussion in recent times (Muxika-Loitzate 2017; Egurtzegi & Carignan 2020; Beristain 2021). The interest of the Basque sibilant system lies in its relative complexity: it includes voiceless fricative-affricate pairs with three contrasting places of articulation – lamino-alveolar (/s̺/ and /t͡s̺/), apico-alveolar (/s̻/ and /t͡s̻/) and postalveolar (/ʃ/ and /t͡ʃ/) – and voiced counterparts of these in some eastern varieties (cf. Michelena 1990; Hualde 2003; Egurtzegi & Carignan 2020).

The best-understood development in the evolution of the phonological contrasts involving sibilants in Basque is what we call here the "Western merger" (Figure 1). This merger dates back to the 17th century

* The research reported in this paper was funded by the following projects: "Monumenta Linguae Vasconum VI" (PID2020-118445GB-I00), "Modern approaches to diachronic phonology applied to Basque (MADPAB)" (ANR-20-CE27-0007) and "Diachronic Linguistics, Typology and the History of Basque" (IT1534-22). Data and code used in this paper as well as supplementary materials are available at https://osf.io/t6a7w/.

https://doi.org/10.3765/pda.v4art5.67 Published online by Cambridge University Press

and has been proposed as the main consonantal development differentiating the Western dialect of Basque from the rest (Zuloaga 2020: 273). It involves the neutralisation of the laminal and apical alveolar fricative sibilants in favour of the latter and the neutralisation of the laminal and apical alveolar affricates in favour of the former.

Though geographically less widespread and more recent, other sibilant neutralisation processes also occurred in different Basque varieties (see Hualde 2010 for an overview). In addition to the Western merger, we also analyse the "Central merger" (Figure 2), an innovation which developed during the 17th-19th centuries in some central varieties. In this merger, fricative and affricate alveolar sibilants are realised as fricative and affricate laminals (see Beristain 2018; Beristain 2019; Beristain 2021 for analyses of modern data).

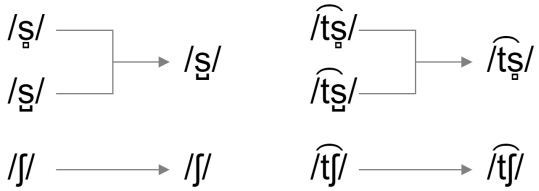


Figure 1: The Western merger

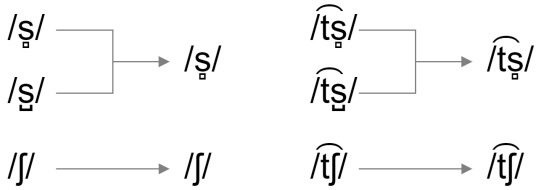


Figure 2: The Central merger

This paper presents two main novelties. First, it focuses on the intermediate phase of the Central merger, which has barely been analysed. Second, it involves a quantitative approach. Research on the history of sibilant neutralisation in Basque has generally been qualitative, mainly because the Basque pre-19th-century corpus does not always allow quantitative analyses due its limited size. In this paper, we take advantage of the recent discovery of a relatively extensive manuscript: "Lubieta's dictionary", dated 1728. It represents the variety of the town of San Sebastián (located in the province of Guipuscoa, in the centre of the Basque Country). The text shows evidence of two patterns of merger, namely the Western and Central mergers.

We intend to specify the degree of development of the Western and Central mergers in the variety of San Sebastián in the middle of the 18th century, whether a potential connection between the two mergers may have existed, and the details of the process that led to the generalisation of the Central merger in that area. We also explore a number of general issues, such as how to establish whether a phonemic opposition was lost in quantitative diachronic data, how to study a merger in progress, and how quantitative data analysis can inform qualitative diachronic phonological studies. Most importantly, this study is particularly interesting for general theories of sound change because 18th century San Sebastián Basque provides an excellent example of two competing sound changes at an early stage of development.

The paper is structured as follows: In Section 2, we present the background of the present research: (a) the definition of a merger and problems related to the study of mergers in diachrony, (b) an overview of the Basque sibilants, and (c) a description of our source, Lubieta's dictionary. We conclude Section 2 by presenting the objectives of our study. Section 3 presents our methodology with an introduction to the statistical model we constructed. This is followed by Section 4, with descriptive statistics of the data, and Section 5, detailing the model's results, diagnostics and effects. We conclude the paper with a general discussion of our results in Section 6.

https://doi.org/10.3765/pda.v4art5.67 Published online by Cambridge University Press

2 Background and objectives

2.1 The concept and study of mergers

A merger is usually understood as the identification (and gradual equation) of all instances of one (or more) phoneme(s) A with those of a different phoneme B, with a concomitant loss of the phonological features distinguishing them (and thus their phonemic contrast), such that A, B > A. When the loss of a phonemic contrast is underway or when it is limited to a particular phonological context, we speak of neutralisation instead.

Three types of mergers are distinguished in the literature. In a "merger by approximation", the phonetic targets of two phonemes gradually converge and the outcome might be an intermediate sound (Labov 1994: 321). A "merger by transfer", as explained by Labov (1994: 321), is a unidirectional process in which one phoneme is replaced with another in a word-by-word manner. Finally, in a "merger by extension", first described by Herold (1990), "the lexical constraints on the distribution of the two former phonemes are removed, and the range that was previously divided between the two phonemes is used for the new phoneme, with allophonic distributions in appropriate areas of the new range" (Labov 1994: 323–324).

Several procedures can be used to study an ongoing merger, the simplest being producing and perceiving contrasts in minimal pairs (Gordon 2015). Acoustic analysis might also be used. The situation is different for diachronic data (Minkova 2015), where the analysis depends mainly on spelling and its interpretation (though "indirect" evidence, such as poetry, can be used (cf. Minkova 2015)). The analysis of the gradual neutralisation requires a detailed study of the spelling in testimonies, since pronunciation is not the only criterion for the establishment of orthography (Martínez Alcaide 2010: 14).[1]

The study of the neutralisation of Basque sibilants poses two general problems. First, the brevity of most texts does not allow for extensive quantitative analysis. Traditionally (see Michelena 1990; Hualde 2010; Zuloaga 2020), a sufficiently consistent graphic distinction, even if there is some deviation, has been taken as a reflection of a phonological contrast. Thus, graphic confusion is considered a reflection of the loss of contrast, especially when it occurs repeatedly in the same positions in different texts of the same period and area. One of the objectives of the present study is to apply a more quantitatively oriented methodology to study merger phenomena in longer texts.

The second problem is the lack of a univocal orthographic rule for pre-20th-century Basque, which makes it difficult to distinguish between the sibilants (both between fricatives and affricates and between laminals and apicals). Basque writers had to resort to the spelling systems of other languages, and in the Peninsular Basque Country, Spanish orthography was used (Echenique 2013: 71). As a result, authors had to work with defective spelling, since they had to express sounds that did not exist in Spanish by means of the Spanish spelling.

The situation in Basque bears certain similarity with that of Middle English before the standardisation of English orthography (Stenroos 2002): during that period, there was not a single model for spelling, and thus it is not easy to distinguish between phenomena which reflect different aspects of phonology from those related to clashes between various models (see also Oyosa 2015 for a discussion of the situation in Romance languages). Thus, even though our study is concerned with Basque, the methodology we apply might be useful to study other languages as well.

2.2 Sibilants in Basque

The "moderately complex" (Igartua & Zabaltza 2012: 11) sibilant system reconstructed for Proto-Basque (Michelena 1990; Hualde 2010) remained stable in all Basque dialects until the Archaic Basque period, i.e.

[1] A distinction should be made between spelling and orthography: "Spelling involves the graphic realisations of all spoken items, whereas orthography is limited to a more or less binding norm that can lead to criticism in case of non-compliance" (Rutkowska & Rössler 2012: 214).

https://doi.org/10.3765/pda.v4art5.67 Published online by Cambridge University Press

ca. 1400-1600 (Mounole & Lakarra 2018: 418).[2] The system is still preserved in some central-eastern dialects. It includes three fricative consonants (lamino-alveolar /s̻/, apico-alveolar /s̺/ and postalveolar /ʃ/, nowadays expressed by the graphemes <z>, <s> and <x>), and three affricates with analogous place of articulation (lamino-alveolar /t͡s̻/, apico-alveolar /t͡s̺/ and postalveolar /t͡ʃ/, nowadays expressed by the digraphs <tz>, <ts> and <tx>).[3]

Regarding their phonotactic distribution, alveolar fricative sibilants occur word-initially (*zu* 'you (sg.)', *sagu* 'mouse'), medially – both intervocalically (*hezi* 'to educate', *hesi* 'fence') and preconsonantally (*gazte* 'young', *asko* 'a lot') –, as well as in post-vocalic word-final position (*ez* 'no', *ados* 'OK'). Alveolar affricates are absent from word-initial position –where only the postalveolar /t͡ʃ/ is possible (*txakur* 'dog') – and only occur in medial position – intervocalically (*atzo* 'yesterday', *atso* 'elderly woman') or after a sonorant (*mintzatu* 'to talk', *hartza* 'the bear') – or final position (*hotz* 'cold', *hots* 'sound'), either after a vowel or after a sonorant. Affricates are found in word-final coda clusters (*beltz* 'black', *hortz* 'tooth'), while fricatives occur in non-final coda clusters (*belztu* 'to become black', *horzkari* 'dental'). Almost all such tautosyllabic coda clusters show the laminal sibilant. No sibilant can appear in tautosyllabic onset clusters.

The most important change in this system is the Western merger, initiated in the Western Basque (see Figure 3). It has led to the loss of the distinction between the laminal and apical alveolar fricatives in favour of the latter (Michelena 1990; Hualde 2010; Zuloaga 2020). Conversely, in the series of affricates, neutralisation occurred in favour of the laminal (see Figure 1).[4]

Zuloaga (2020) shows that initially (between Archaic and Old Basque) the neutralisation of laminal to apical fricatives was sporadic and limited to the preconsonantal (especially before stops, e.g. *guzti* 'all' or *zazpi* 'seven') and word-final position (e.g. with the instrumental suffix *-z*). It was not systematic in any phonological context, nor did it extend to any prevocalic position (i.e., intervocalic or word-initial). Examples are found in most varieties attested at that time. Zuloaga does not specify whether the process could be explained as assimilatory or dissimilatory. Here, we will argue that the preconsonantal position was crucial: the merger could have started due to coarticulation to the following consonant, especially before /t/. During the Old Basque period, the neutralisation became more systematic in preconsonantal and word-final positions in the Central and Western varieties. Moreover, neutralisation started to extend to new contexts, i.e. to word-initial and intervocalic position. As regards affricates, the first examples of apical to laminal neutralisation are attested in the early Old Basque period. From the 18th century, the Western neutralisation in fricatives and affricates extended to all possible phonological contexts in the Western area (Biscay, Alava and western Guipuscoa). Moreover, throughout the 18th and 19th centuries, it spread to the whole peninsular Basque coast and was even attested in some coastal villages in Labourd (Zuloaga 2020).

[2] The history of Basque is commonly divided into the following periods: Old Proto-Basque, Modern Proto-Basque (last cent. BC), Aquitanian (first cent. BC), Old Common Basque (6–9th cent.), Medieval Basque (10–15th cent.), Archaic Basque (1400–1600), Old Basque (1600–1745), Early Modern Basque (1745–1890), Late Modern Basque (1891–1968) and Unified Basque (1968–) (Lakarra, Manterola & Segurola 2019).

[3] For the sake of simplicity, we will use *apical* and *laminal* to refer to these sounds, focusing on the shape of the tongue, but note that the main constriction occurs in the alveolar region for these segments.

[4] Postalveolar sibilants have a special status in Basque, often patterning with palatal sounds, which have affective connotations in the language. These will be left out of our analysis, given that they remained unchanged in most varieties and show no obvious variation in our data.

https://doi.org/10.3765/pda.v4art5.67 Published online by Cambridge University Press

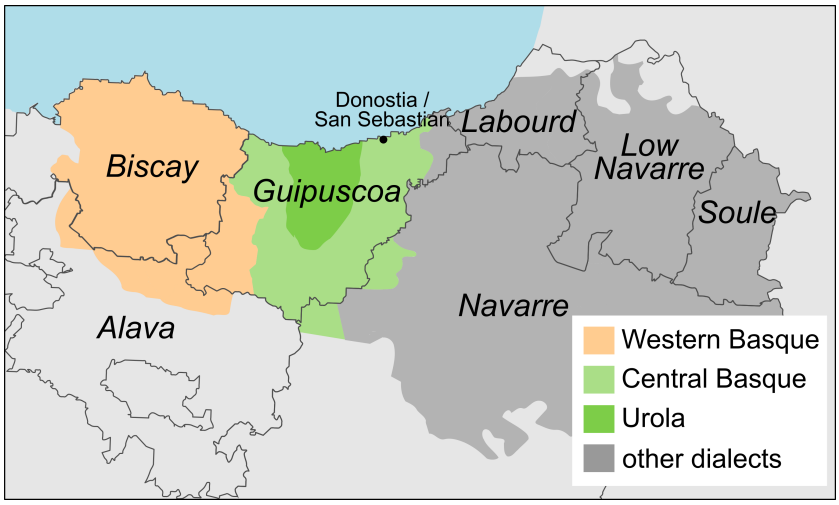


Figure 3: Varieties of Basque

The second change relevant for this paper emerged in Central Basque, and it involved the neutralisation of alveolar fricative and affricate sibilants in favour of the laminal (Figure 2). It is first attested between the Archaic and Old Basque periods, especially in intervocalic and word-initial position (though there are a few examples in preconsonantal position as well). In the 18th and 19th centuries, it is always documented alongside the Western neutralisation, i.e. in the fricative series, and both patterns co-occur in the same text. From the 19th century onwards, the Central merger became the prevailing pattern in the Guipuscoan coastal areas and in the Urola valley (see, e.g. Camino 2000; Sagarzazu 2005; Beristain 2018; Beristain 2019).

Finally, it is worth mentioning that in the affricate series no variety shows a laminal to apical merger. Though unusual, some examples of an apical realisation of the laminal affricate, best understood as hypercorrection, are found in texts and in eastern coastal villages of Guipuscoa nowadays, such as Hondarribia (see Sagarzazu 2005: 67).

This paper aims to reassess and build on the descriptions and proposals by Zuloaga (2020) from a quantitative and qualitative point of view. In particular, we would like to evaluate Zuloaga's hypothesis that the Central merger developed through generalised hypercorrection.

The concept of "hypercorrection" has been widely used in sociolinguistics since Labov (1972), where it is usually defined as a "process and result of an exaggerated attempt on the part of a speaker to adopt or imitate linguistic forms or a linguistic variety that he/she considers to be particularly prestigious" (Bussmann, Kazzazi & Trauth 1998: 525). In this paper, however, we follow a more general definition: "A pronunciation or grammatical construction often arising from a mistaken analogy with standard usage and produced out of the wish to be 'correct', but usually resulting in incorrect or stilted forms" (Brown & Miller 2013).

2.3 Lubieta's dictionary

Diccionario en Castellano y Basquenze que Sirve para la Enseñanza de la Vascongada, commonly known as "Lubieta's dictionary", is a bilingual Spanish-Basque manuscript written by Joseph Domingo Lubieta, dated from 1728 and preserved in the private library of the Sociedad Bilbaina. The existence of the manuscript went practically unnoticed until 2006 (see Bilbao 2012 for more details).

At least two features make Lubieta's dictionary particularly interesting. Firstly, it is one of the most extensive texts in the Central dialect preceding the 19th century. It is also one of the few texts documenting the Basque of San Sebastián (*Donostia* in Basque), an important coastal town that became the capital of Guipuscoa in the early 19th century. Lubieta has 6316 instances of sibilants, which allows for a quantitative analysis.

https://doi.org/10.3765/pda.v4art5.67 Published online by Cambridge University Press

Secondly, the textual genre is worth mentioning. The text was prepared for Juan Francisco de Lullier, a merchant from San Sebastián, so that he could learn Basque. The text includes, as was customary in the manuals of the time, general notions of grammar, lists of words and a series of practical examples, such as dialogues, verses, sayings and parts of the Christian doctrine. The data's reliability is to some extent limited due to the genre and to the fact that it is based on materials written in other languages. At the same time, however, the text offers an interesting advantage: it contains a much wider range of vocabulary than religious texts, which prevail in the Basque historical corpus.

The preliminary analysis in Zuloaga (2020), based on a fragment of the text, has shown that Lubieta's dictionary exhibits a pervasive graphic confusion in the representation of alveolar sibilants: <s>, expected to represent apical sibilants, is found in words with an etymological laminal, and <z> and <c>, used to represent laminals at that time, are used with etymologically apical sibilants. There are also instances of confusion in the affricate alveolar sibilants: what is expected to be an apical affricate in other varieties is often represented by means of <z>, and there are a few instances etymologically laminal sibilants spelled with <s>.[5] Thus, the text shows both patterns of sibilant merger presented in Section 2.2.

2.4 Research questions

The main objective of this paper is to answer the following questions:

Q1. Was the contrast between apical and laminal alveolar sibilants already lost in 18th-century Basque of San Sebastián, either in the fricative or affricate class (or in both)? Or was the neutralising change still in progress?

Q2. What was the role of the phonological context on one hand, and lexical and frequency effects on the other hand, in the observed changes? Which had a bigger effect?

Q3. How can we account for the observed distribution of innovative spellings?

3 Methodology

3.1 Generalised linear mixed-effects models

Logistic regression models quantify the effects of predictors on a binary dependent variable. Generalised linear mixed-effects models, apart from the usual predictors ("fixed effects"), also include "random effects", which allow models to better deal with unbalanced and hierarchically organised data by taking into account the variation related to author, speaker or specific item. Thus, these models are particularly adequate for the analysis of various topics in linguistics (Coupé 2018; Winter 2020), e.g. in corpus studies (Gries & Hilpert 2010; Gries 2015a; Gries 2015b). They have proven fruitful in diachronic corpus studies, especially in the morphosyntax (see, for example, Gries & Hilpert 2010; Wolk et al. 2013; De Smet & Van de Velde 2020), and have also been used to study changes in spelling in German (Barteld, Hartmann & Szczepaniak 2016; Dücker, Hartmann & Szczepaniak 2020).

We use the top-down model selection strategy to construct our model (Zuur et al. 2009: 121–122; Gries 2013: 259–261). First we fit a "beyond optimal" model, with all independent variables and as many interactions as possible, inasmuch as they are theoretically justified. The next step is to evaluate whether the model should be simplified. The decision on whether to discard a predictor, an interaction, or a random effect will be based on significance testing (in that an element should be discarded if the deletion does not make the model significantly worse). The effect of this procedure is the minimal adequate model.

We use R (R Core Team 2021) for our statistical analyses as well as the libraries *lme4* (Bates et al. 2015) and *ggeffects* (Lüdecke 2018). For plotting, we use *ggplot2* (Wickham 2016), *sjPlot* (Lüdecke 2020) and *ggstatsplot* (Patil 2018).

[5] Note that, as usual at that time, fricative and affricate sibilants are not graphically distinguished in the text.

https://doi.org/10.3765/pda.v4art5.67 Published online by Cambridge University Press

3.2 Variables

The dependent variable is SPELLING with two levels, *ConSpell* (conservative spelling) or *InnSpell* (innovative spelling). We use the label ConSpell when an etymologically laminal sibilant is spelled with <z> or <c> or when an apical sibilant is spelled with <s>. Conversely, InnSpell is used when a laminal sibilant is written with <s> or an apical one with <z> or <c>.[6] As far as the interpretation of spelling is concerned, we infer the place of articulation of a given segment by directly translating the spelling conventions to their phonological equivalent, under the assumption that variation would reflect the merger in progress.

Independent variables are the following:

(1) Etymological place of articulation (PLACE_ETYM): *apical* vs *laminal*.
(2) Manner of articulation (MANNER): *fricative* vs *affricate*.
(3) CONTEXT: prevocalic word-medial position (*_V*),[7] word-initial position (#_), word-final position (_#) and preceding a consonant (_*C*).
(4) LOAN: *yes* / *old* (loanwords showing historical sound change) / *no*.
(5) CATEGORY: *grammatical* (affixes + function words) vs *content*.
(6) FREQUENCY_CLASS of the lexeme: *high* / *mid* / *low*.

Thus, we take into account the sibilant's features (variables 1 and 2), the phonological context in which it appears (variable 3) and a number of factors related to lexical diffusion and frequency effects (variables 4-6).

The variable MANNER is mainly used to evaluate potential differences in the direction of the change in fricative and affricate series, given that, unlike in the case of fricatives, both mergers result in a laminal affricate. The value was established on the basis of the written tradition and modern data, as fricatives and affricates are not graphically distinguished in the text. Most Basque sibilants are unambiguously fricative or affricate. Nonetheless, Basque shows a systematic process of post-sonorant affrication (Michelena 1990: sec. 14.6), but the fact that sibilant manner of articulation was rarely reflected in spelling until later times makes dating the affrication process challenging. Given that recent research suggests that post-sonorant affrication developed during the preceding Old Basque period (Mounole & Lakarra 2018: 498; Mujika 2002: 221; Zuloaga 2020: 471–472), we decided to treat sibilants following a sonorant as affricates.

Lexemes' frequency values have been extrapolated from modern data and only approximate the language at the time of our text. Lubieta's dictionary, because of its nature, cannot be used to establish frequencies, and there are no other adequate texts for the time period and language variety under study. Thus, we used the Goenkale Corpus (Euskara Institutua 2011), a corpus of 13.3 million words which contains scripts of the Basque soap opera "Goenkale", broadcasted in the Basque television from 1994 to 2015. Currently, this is the only readily available source of frequency data from (nearly-)conversational language. Our working assumption is that the frequency of a word as used in the oral language (and not in a literary register) could condition a sound change in progress.

The number of occurrences per 10,000 words for each lexeme was extracted from the corpus. The data was available for 499 lexemes out of 873 (57%). Most of the lexemes for which frequency data was not available are unadapted loanwords (339/373), which are not common in the modern language. To avoid undefined values, the lexemes not found in the reference corpus were given the lowest value found for other lexemes, which is 0.01. The values were then log transformed (Gries 2010; Baayen 2001: 32), scaled and centred (using the *scale* function in R). We then binned the data into three classes: high, mid and low as

[6] The etymological place of articulation was determined by taking into account data from older texts from the same variety or from dialects that do not show any evidence of merger. Innovations are only considered with regard to place of articulation. Potential innovative spellings related to manner of articulation are not expected.

[7] Fricatives are intervocalic and affricates can follow a vowel or a sonorant consonant (see 2.2 for an overview of phonotactics).

https://doi.org/10.3765/pda.v4art5.67 Published online by Cambridge University Press

shown in Figure 4.[8] The cuts are -1.3 and 0.2 (which correspond to 0.06 and 27 per 10.000 words), and they are meant to respect the form of the distribution and allow apical sounds to have items in all three frequency levels. Although data-driven, this decision is necessarily arbitrary given the lack of comparable studies on Basque.[9]

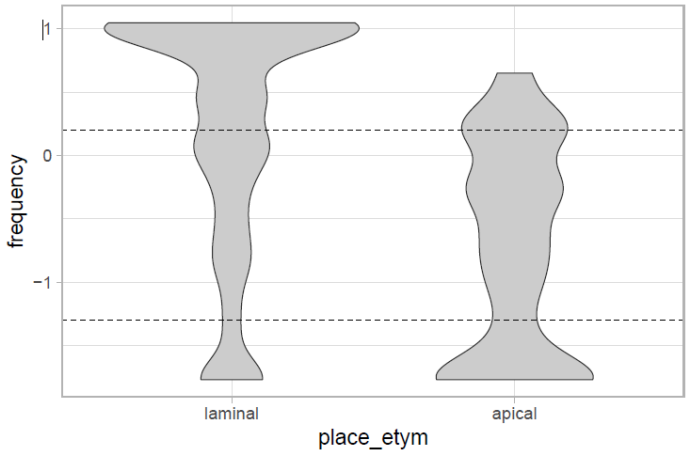


Figure 4: Violin plot for logged frequency and etymological place of articulation. Dashed lines represent the thresholds used for binning the data

The choice of the variables PLACE_ETYM and MANNER also requires some comments. An alternative approach would be to have a variable representing the etymological sound with four levels (/s̪/, /s̻/, /ts̪/, /ts̻/). However, this approach is not feasible as the low number of affricate sibilants (and especially of apico-alveolar affricates) in our dataset would cause some interactions to have very few tokens. Having two separate variables, PLACE_ETYM and MANNER, is a compromise which enables us to model both features whenever possible and relevant.

Taking these considerations into account, the interactions specified in the model are the following:

- PLACE_ETYM – MANNER: to find out whether there is a difference between the four sounds of interest, or rather the processes are better described in terms of place or manner only.
- FREQUENCY_CLASS – PLACE_ETYM, FREQUENCY_CLASS – MANNER: frequency might interact differently with different sounds.
- FREQUENCY_CLASS – CATEGORY: frequency might interact differently with different categories.
- CONTEXT – PLACE_ETYM: the phonetic environment might interact differently with different sounds.
- LOAN – PLACE_ETYM: words of different origin might show different behaviour.
- CATEGORY – PLACE_ETYM, CATEGORY – MANNER: the lexeme's category might interact differently with different sounds.

Furthermore, the model includes the following random effects:

[8] We decided not to use a numeric variable because the frequency values come from modern data, and thus they are only an approximation, which is better reflected in broader frequency classes. Furthermore, as we will show, the relation between frequency and other variables does not appear to be linear. Adding frequency as a factor is the simplest way to reflect this in the model.

[9] For English, the frequency of 35 per million words is sometimes used as the cut-off point between the high-frequency words and the rest, and this is motivated by psycholinguistic studies as explained by Bybee (2007: 203). An alternative approach would be to use, for example, k-means to cluster values, as done in Kang, Yoon and Han (2015). However, this would not solve the problem of different top frequency values for laminal and apical sibilants (apical sibilants would not have lexemes in the highest frequency class).

https://doi.org/10.3765/pda.v4art5.67 Published online by Cambridge University Press

- PAGE: page on which the example is found. Lubieta's text is a manuscript, and the effect of PAGE is treated as a proxy of (writing) session (or trial in experimental studies), under the assumption that the different parts/pages of the text were written in different moments/days.
- LEXEME: different lexemes might show different tendencies.

3.3 Predictions

3.3.1 General predictions

Taking into account what we know about the chronology and geographic extension of the sibilant merger in Basque, both patterns of merger are expected to be quite advanced in Lubieta's variety but not necessarily completed. Less variability is expected in affricate consonants than in fricatives because for the affricates, the direction of change is apical to laminal in both the Western and the Central merger.

3.3.2 Phonetic environment

As explained in Section 2.2, in the Western merger, sibilants are more likely to neutralise before a consonant and in word-final position than before a vowel, where the contrast is preserved until later (Zuloaga 2020). Thus, if the merger was complete in Lubieta's variety, the phonetic environment would not determine the choice of spelling. However, if there was a conditional merger (with neutralisation of the alveolar sibilants restricted to a particular phonological context), innovative spelling would be more common in some environments than others. Furthermore, if hypercorrection was responsible for the change from apical to laminal in the Central pattern, we hypothesise that the change would start from the contexts where the Western merger was not systematic yet: speakers are unlikely to start to hypercorrect in contexts where the opposition between the two fricatives was already completely lost, but would rather do so in contexts where the contrast is partially maintained.

3.3.3 Lexical effects and frequency

The relation between lexical frequency and the generalisation of the sibilant neutralisation or the potential role of word class have not been discussed in the literature on Basque yet (among other reasons, because of the usually small number of examples and the limited range of vocabulary found in texts). Therefore, we cannot formulate precise predictions regarding these factors. Our results might be important to determine the nature of the change that resulted in the loss of contrast in sibilants. In particular, they can shed light on the role of hypercorrection: following Bybee (2001, 2007, 2012), we hypothesise that a change initiated as hypercorrective would start from low-frequency lexemes and affect most frequent words last (Bybee 2001: 81).

However, if the change from laminal to apical was initiated due to articulatory reasons (e.g. if it followed from contextual coarticulatory patterns), the data might show the opposite: frequent words showing innovative behaviour contrary to infrequent words (cf. Bybee 2001: sec. 4.4; Bybee 2007: 201; Bybee 2012).

Because of the sociolinguistic situation of Basque, another potentially relevant lexical factor is the distinction between native vocabulary, adapted loanwords and unadapted (recent) loanwords. The lexeme's origin might influence spelling: writers are likely to borrow a given word alongside its spelling. It is important to note that spelling was much more normalised for Spanish than it was for Basque at the time the text was written and that writers were more proficient in writing Spanish than they were in writing Basque. Therefore, we expect a low occurrence of innovative spelling in recent loanwords.

https://doi.org/10.3765/pda.v4art5.67 Published online by Cambridge University Press

4 Data exploration

4.1 Overview

6316 tokens of alveolar sibilants, spelled with <z>, <c> or <s>, were gathered from the text.[10] Taking into account their etymological value, /s̻/ is the most frequent (64% of examples), followed by /s̺/ (20%) and /ʦ̻/ (9%). /ʦ̺/ appears only in 2% of the examples. Thus, laminal sibilants have much higher token frequency than apical sibilants. However, the type frequency (the number of distinct lexemes in which the sound appears) is only slightly higher for laminals (Table 1). The lexemes' mean frequency (based on an external corpus, as discussed earlier) is also higher for laminal consonants, as is the maximum frequency value. This means that, generally speaking, laminal sibilants occur in high-frequency lexemes, while apical sibilants occur in many infrequent ones.

Table 1: Number of examples, distinct lexemes and lexemes' frequency (per 10 000 words) for apical and laminal consonants

PLACE_ETYM	Tokens	Distinct lexemes	Mean frequency	SD	Max frequency
Laminal	4907	521	13.8	81.9	805
Apical	1409	426	1.6	9.2	164

4.2 Manner and place of articulation

We observe innovative spelling in 29% of the tokens. InnSpell is found for all sounds under study, but with varying proportions (Figure 5). Fricative sibilants are represented with InnSpell in around 30% of the cases, and the difference in place of articulation is small (34% laminal vs 28% apical). In affricates, InnSpell is more common in apical sibilants than in laminal sibilants (39% vs 7%).

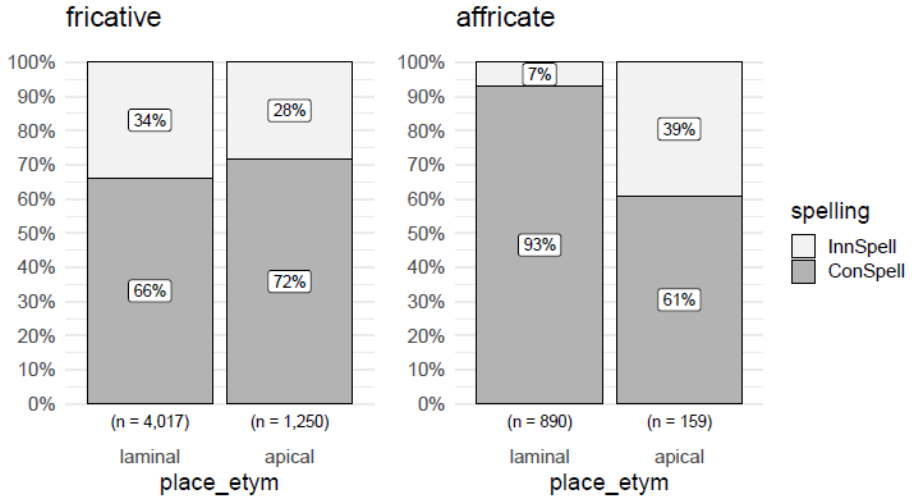


Figure 5: Proportions of InnSpell and ConSpell for fricative and affricate sibilants

4.3 Context

For laminal sibilants, InnSpell appears most often in preconsonantal position (73%). It is also frequent in word-initial and word-final position (53% and 41%, respectively; Figure 6). The results for word-initial position are somewhat skewed because of two frequent lexemes, *zu* 'you (sg.)' and *zuek* 'you (pl.)', which

[10] More details on spelling can be found in the supplementary materials.

https://doi.org/10.3765/pda.v4art5.67 Published online by Cambridge University Press

are consistently spelled in an innovative manner. The proportion of word-initial InnSpell drops to 26% when these two lexemes are not taken into account (see Figure S8 in the supplementary materials). Prevocalic laminal sibilants are represented with InnSpell only in 6% of the cases.

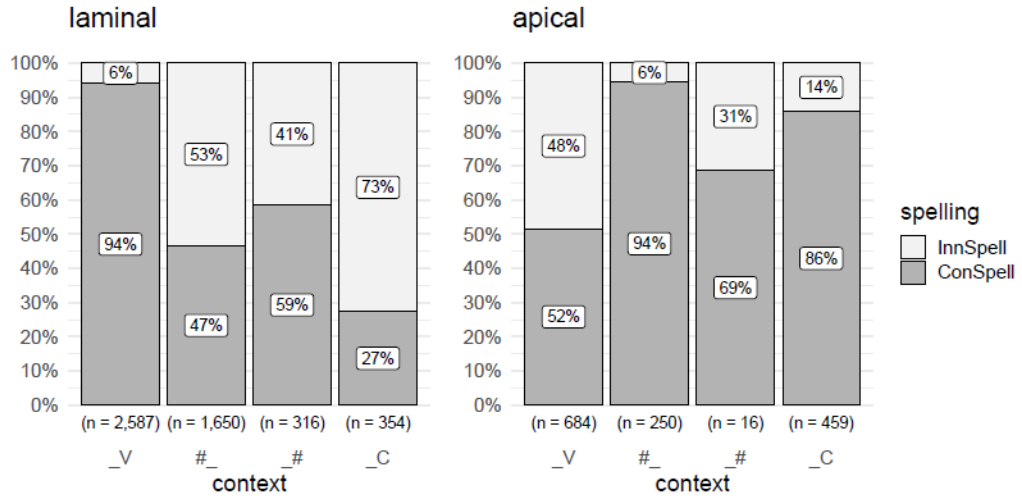


Figure 6: Proportions of InnSpell and ConSpell in the different contexts for laminal and apical sibilants

The situation is different for apical sibilants, where the prevocalic context favours the appearance of InnSpell most (48%) followed by the word-final context (31%). Apical sibilants which appear at the beginning of a word or before a consonant are spelled conservatively most of the time (94% and 86% respectively).

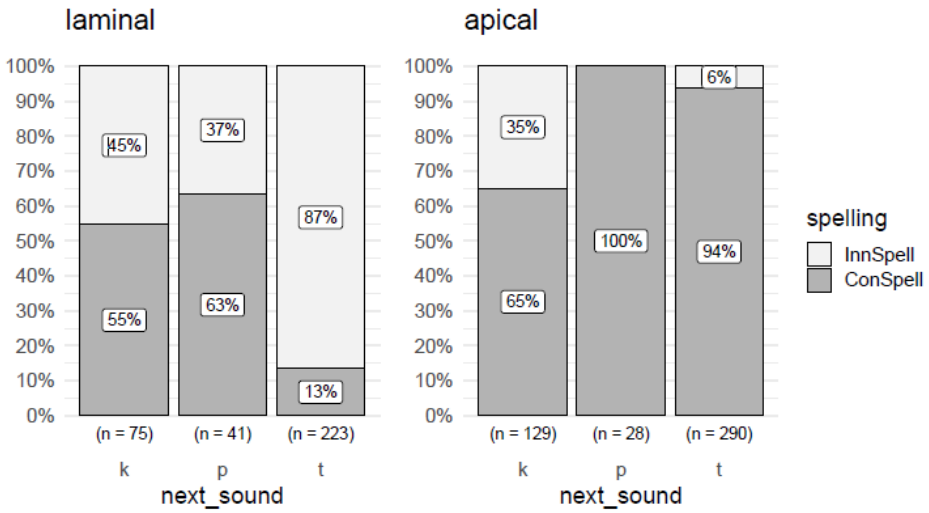


Figure 7: Proportions of InnSpell and ConSpell in preconsonantal position

With regards to voiceless stops (the most common consonants after a sibilant in Basque, Figure 7), sibilants preceding /t/ and /p/ exhibit different patterns: InnSpell is found in etymologically laminal sibilants (37% for [p] and as much as 87% for /t/), but not in apical sibilants (0% for /p/ and 6% for /t/). The most common examples for laminals include verbal forms (e.g. the imperative *zaitezte*) and negated verbs (*ezta* 'it is not'). A following /k/ triggers InnSpell in both apical and laminal sibilants (35% and 45%, respectively). The most frequent examples include *asko* 'a lot', *esku* 'hand', *eskatu* 'ask' for apicals, and *ezkondu* 'marry', *bizkotxo* 'cake' and various verbal forms for laminals.

https://doi.org/10.3765/pda.v4art5.67 Published online by Cambridge University Press

4.4 Category

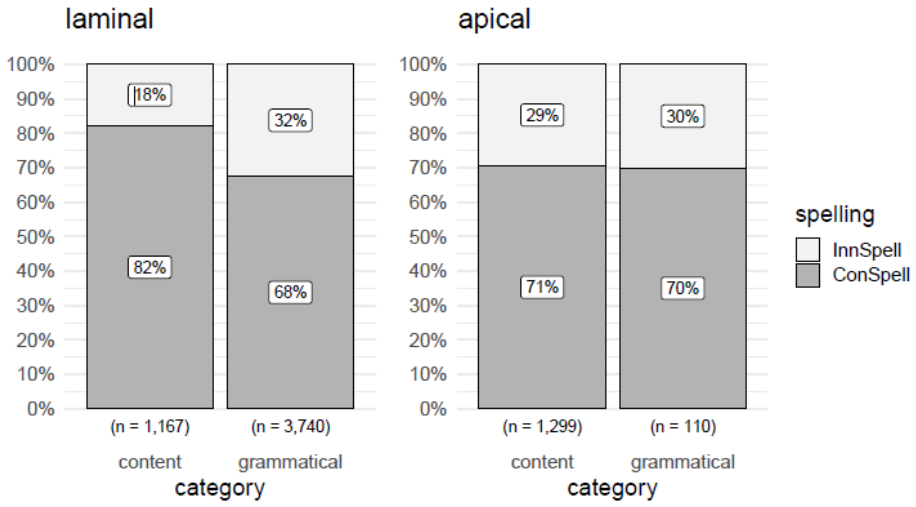


Figure 8: Proportions of InnSpell and ConSpell in content and grammatical items for laminal and apical sibilants

As regards laminal sibilants, InnSpell is more common in grammatical items (32%) than it is in content words (18%) (Figure 8). However, not all grammatical items behave in the same way. For example, forms of the verbs *izan* 'to be' or **edun* 'to have' are only rarely spelled innovatively, but the negative particle *ez* 'no', personal pronouns *zu* 'you (sg.)' and *zuek* 'you (pl.)', or the interrogatives *zer* 'what' and *zein* 'which', and the indefinite *ezer* 'something' often show InnSpell.

The proportion of InnSpell in apical sibilants is similar for content words and grammatical words and affixes. Nevertheless, it is important to mention that apical sibilants are very infrequent in grammatical words. Some examples from the text analysed here are *oso* 'very', *asko* 'a lot', *ainbeste* 'so much', *beste* 'other' and adjectives with the suffix *-so* (borrowed from Spanish) such as *odioso* 'hateful'. Among them, *asko* tends to be spelled with InnSpell. There are also a few examples of the suffix *-so* spelled with <z>.

4.5 Loanwords

There are many loanwords in our text: 522 lexemes out of 871 are recent (barely adapted) loanwords (60%), 6% are adapted loanwords and 34% are native words. This distribution is, to some extent, related to the nature of the text: it is partly a dictionary, which is likely to contain words for which the translator could not find Basque equivalents. Loanwords have low token frequency, though: taking into account word forms instead of lexemes, 76% of the examples (4802/6316) pertain to the native lexicon, while 20% involve recent loanwords and 3% older borrowings.

In general, as shown in Figure 9, InnSpell is more common in the native lexicon (32% for laminal sibilants and 50% for apical sibilants) than in recent or older loanwords (7-16%). The lowest proportion of InnSpell is for borrowings with an apical sibilant (7%). Generally speaking, older and more recent loanwords appear to behave in a similar way.

https://doi.org/10.3765/pda.v4art5.67 Published online by Cambridge University Press

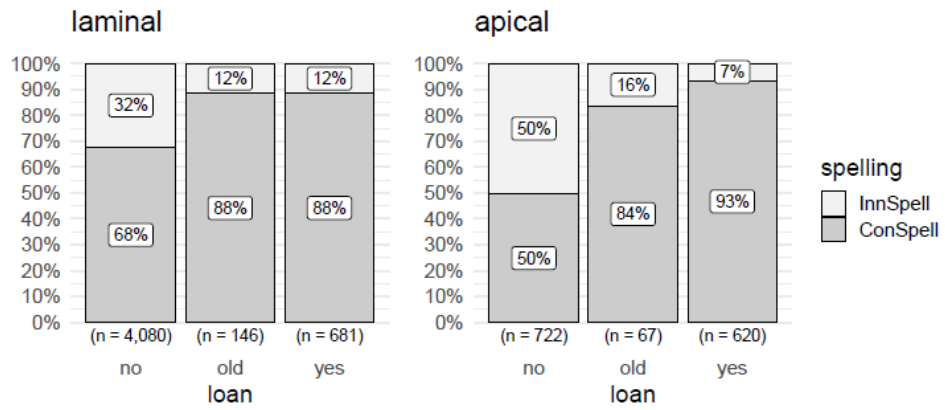


Figure 9: Proportions of InnSpell and ConSpell in lexemes of different origins for laminal and apical sibilants

4.6 Frequency

There are 871 lexemes in the corpus. Mean number of tokens is 7.25, but there are huge differences between lexemes: standard deviation is 42.9. 425 lexemes have only one occurrence, which is not surprising in a text which is, in part, a dictionary. Figure 10 plots log number of tokens found in the text and log frequency for lexemes which have more than 10 occurrences. For lexemes with a lower number of occurrences, the frequency values assigned from the external corpus vary greatly, as expected considering the type of text. Most recurrent lexemes in the text tend to have high frequency values, but there are exceptions: for example, the word *aborrezitu* 'abhor' appears so many times because it is used in a verbal paradigm, but it is an infrequent word.

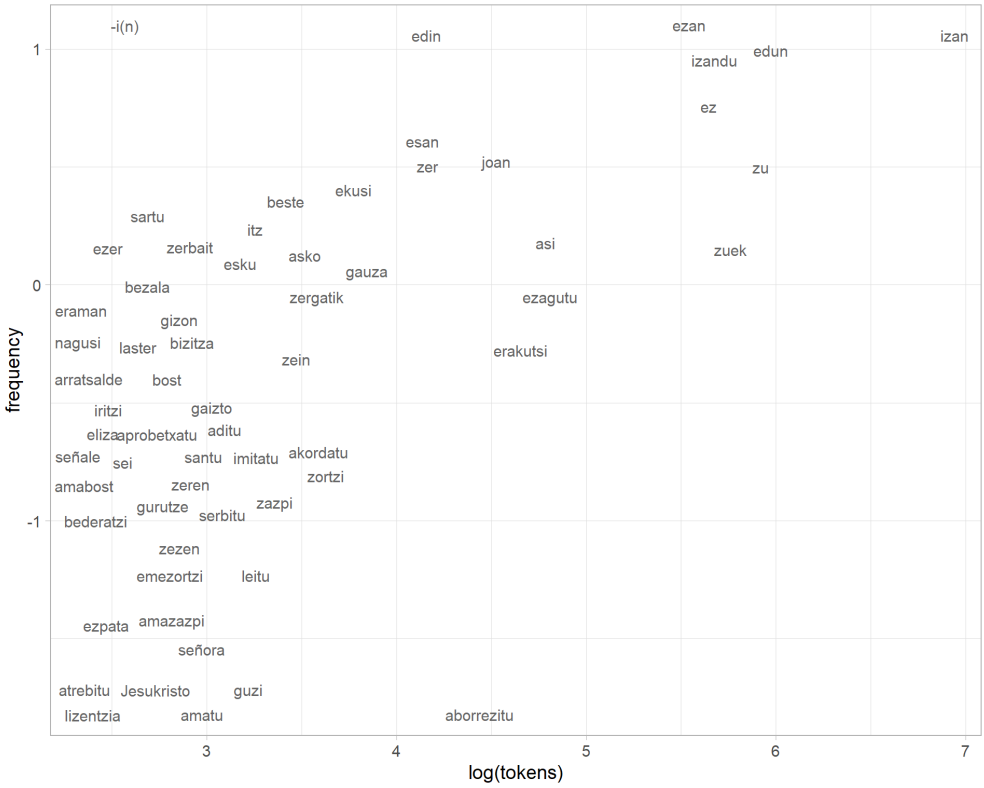


Figure 10: Log number of tokens and log frequency for lexemes with more than 10 examples in the text

https://doi.org/10.3765/pda.v4art5.67 Published online by Cambridge University Press

As explained in 3.2, we grouped frequency values into three classes for statistical modelling. It is nevertheless important to explore the data using numeric values as well. As shown in Figure 11, forms of highest-frequency lexemes tend not to show InnSpell, but for those of slightly lower values InnSpell predominates. For mid- and low-frequency lexemes, the conservative spelling is more common.

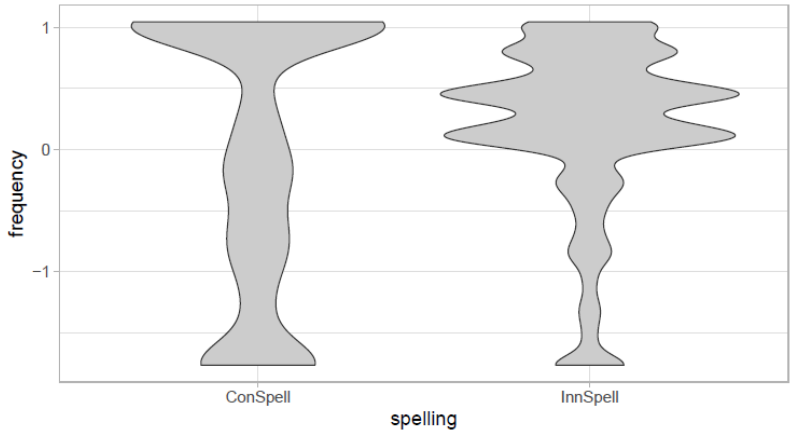


Figure 11: Violin plots for frequency and the variable SPELLING

Figure 12 shows how frequency interacts with other variables. The pattern just described (highest, mid and low values tend to show conservative spelling, and high-mid values show InnSpell) applies to laminal fricative sibilants appearing in native grammatical words. Items with the highest frequency values are auxiliary verbs (*izan* 'to be', **edin* 'to be (irrealis)', **edun* 'to have'...), which only show a significant proportion of InnSpell in forms where the sibilant appears before a consonant. In turn, lexemes in the lower part of the high-frequency class that are often spelled innovatively include forms of the content verb *joan* 'to go', and the grammatical items *zer* 'what' and *zu* 'you (sg.)'.

For apical sibilants, low-frequency lexemes (which tend to be borrowings) show InnSpell less frequently than mid- and high-frequency items. High-frequency lexemes with a high proportion of InnSpell are the following: *esan* 'say', *hasi* 'start', *ekusi* 'see', *oso* 'very' (all intervocalic). Examples of mid-frequency words with a high proportion of InnSpell include *nagusi* 'major', *arratsalde* 'afternoon', *eseri* 'sit', *asko* 'much', *osasun* 'health'.

For content words, InnSpell is slightly more common in the highest-frequency lexemes, but less common in the lowest-frequency ones. As regards manner of articulation, for affricate sounds InnSpell appears equally common for mid- and low-frequency lexemes, but less common for the high-frequency ones. Finally, loans have lower frequencies than inherited words, and their distribution has similar shapes for InnSpell and ConSpell.

Finally, Figure 13 plots the proportion of InnSpell for the three frequency classes in apical and laminal sibilants (see supplementary materials for plots showing interactions of the variable FREQUENCY_CLASS with other variables). It shows that the way in which we binned the data respects the original distribution fairly well: for laminal sibilants mid- and high-frequency items show high proportion of InnSpell, and for apical sibilants the proportion is highest in the high-frequency class, which, as discussed earlier, is rather small (few frequent lexemes have apical sibilants).

https://doi.org/10.3765/pda.v4art5.67 Published online by Cambridge University Press

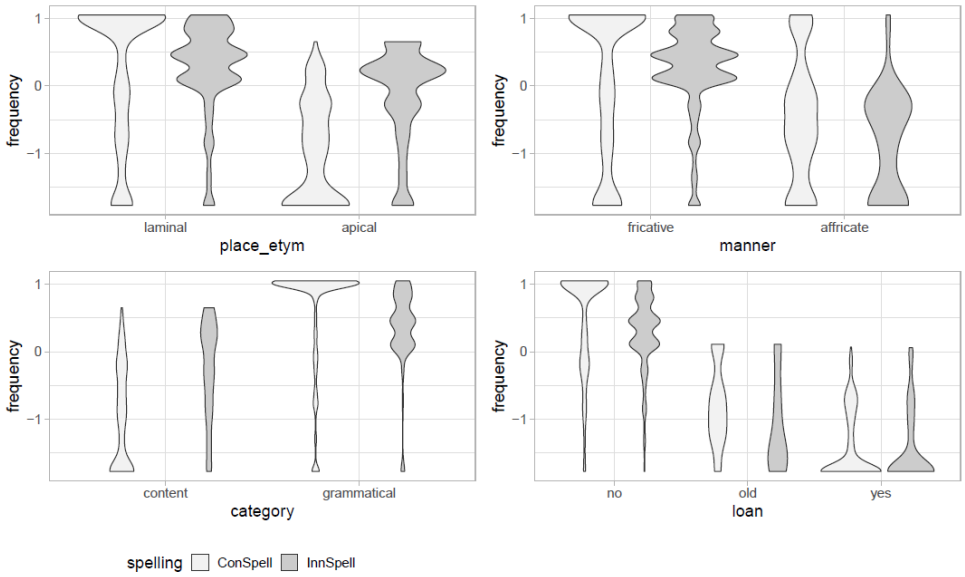


Figure 12: Violin plots for frequency and SPELLING for the variables PLACE_ETYM, MANNER, CATEGORY and LOAN

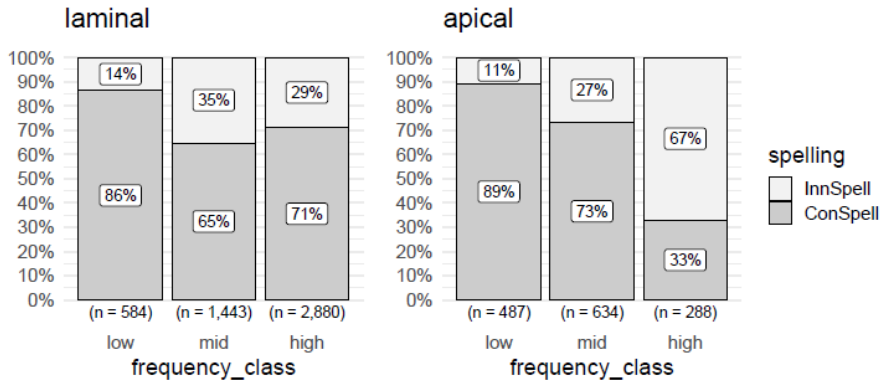


Figure 13: Proportions of InnSpell and lexeme's frequency class

4.7 Lexeme (random effect)

Figure 14 plots the lexeme frequency and the proportion of InnSpell for laminal and apical sibilants. The plot includes lexemes with 8 or more occurrences (not all labels are displayed to avoid overlap). Figure 15 shows histograms for the same data, i.e. the number of lexemes which have the given proportion of InnSpell.

Some differences in the distribution of InnSpell in laminal vs. apical sibilants seem to coincide with differences in lexical frequency between the two groups, as already discussed. Lower-frequency lexemes show ConSpell in apicals and a high proportion of InnSpell only occurs with higher-frequency items. Moreover, highest frequency lexemes with laminals (all grammatical) usually appear with ConSpell.

Generally speaking, for both laminal and apical sibilants, there are many lexemes which are spelled consistently in the conservative manner, but few lexemes show consistent InnSpell. Inconsistently spelled lexemes are more common for laminal sibilants. If we define consistent spelling as having 90% or more of examples spelled in the same manner, then for lexemes with 6 or more occurrences, for laminal sibilants 51% are spelled inconsistently compared to 36% for apical sibilants. Among the consistently written items (49% for laminals and 64% for apicals), ConSpell predominates: only a few lexemes are consistently spelled in the innovative way in each series of sibilants. They are *arrats* 'afternoon' (10/11 have InnSpell),

https://doi.org/10.3765/pda.v4art5.67 Published online by Cambridge University Press

nagusi 'major, senior' (11/11), *ikasi* 'learn' (7/7), *zu* 'you (sg.)' (324/344) and *zuek* 'you (pl.)' (288/293). (More details on the most common lexemes in the corpus are given in the supplementary materials).

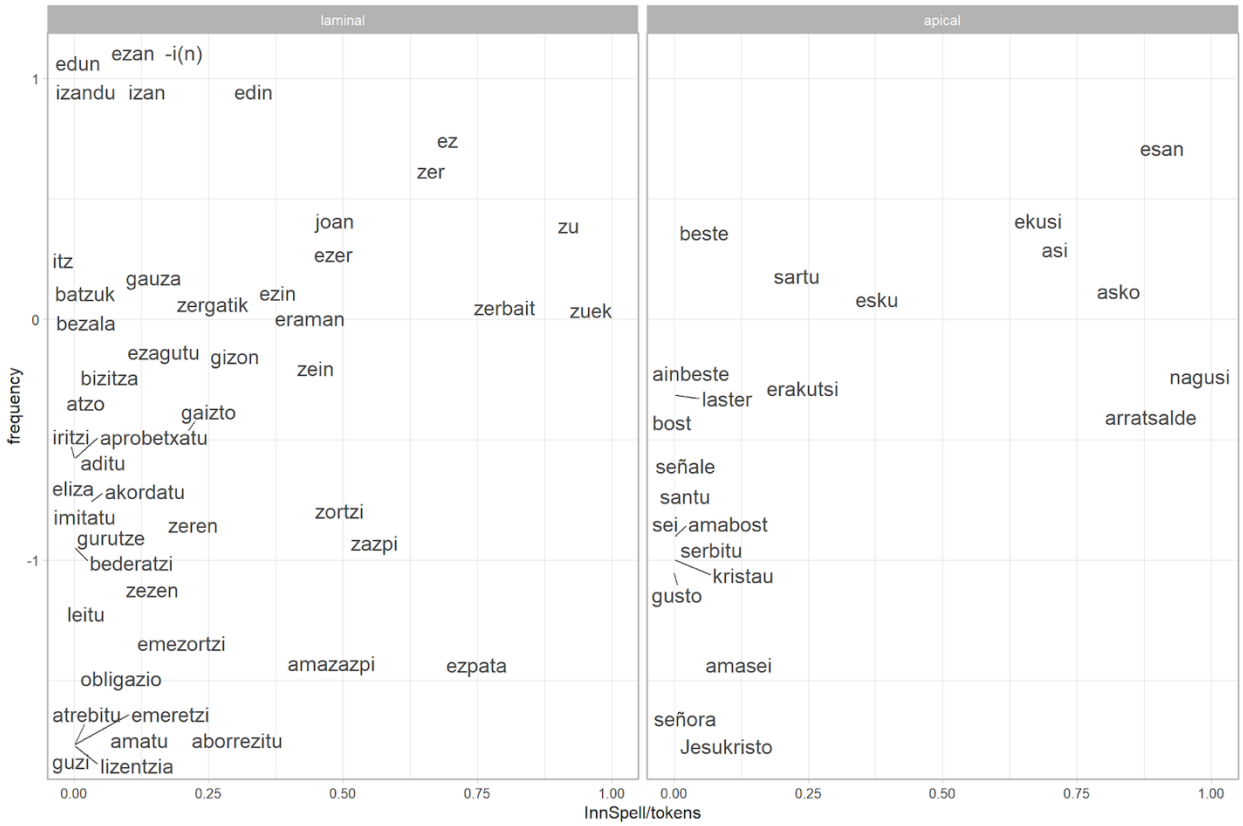


Figure 14: Lexemes' frequency and the proportion of InnSpell for laminal and apical sibilants (for lexemes with 8 or more tokens)

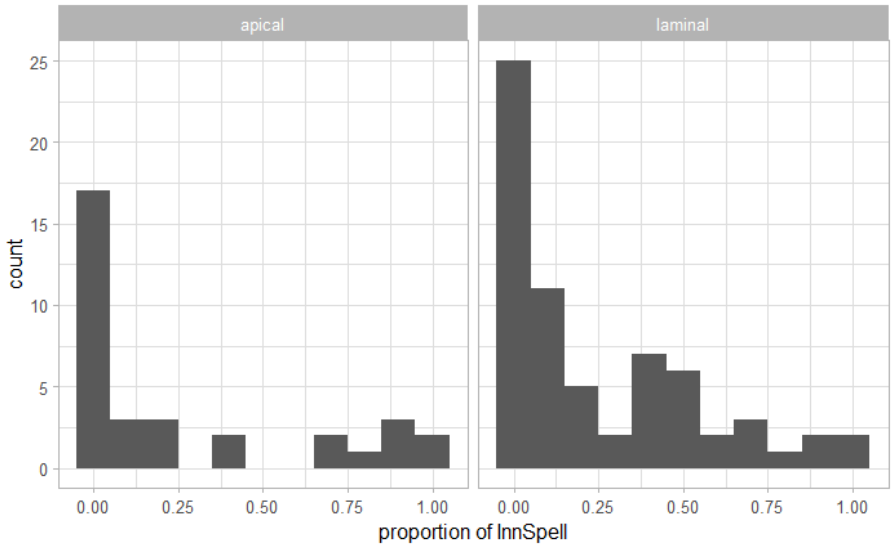


Figure 15: Histograms of the proportion of InnSpell for laminal and apical sibilants (for lexemes with 8 or more tokens)

https://doi.org/10.3765/pda.v4art5.67 Published online by Cambridge University Press

4.8 Page (random effect)

The number or sibilants varies from page to page, the mean being 14 (SD = 7.8, min = 1 and max = 39). The proportion of InnSpell in sibilants is also different on different pages of the text: mean = 0.29, SD = 0.195, min = 0 and max = 1. Figure 16 shows the proportion of InnSpell for pages with more than 20 examples. As can be seen, the proportion of InnSpell does not change significantly throughout the text, but there are a few places where high values cluster (e.g. pages 101-104 and 213-214, which happen to contain the verbal paradigms with the participle *hasi*, which is frequently spelled innovatively).

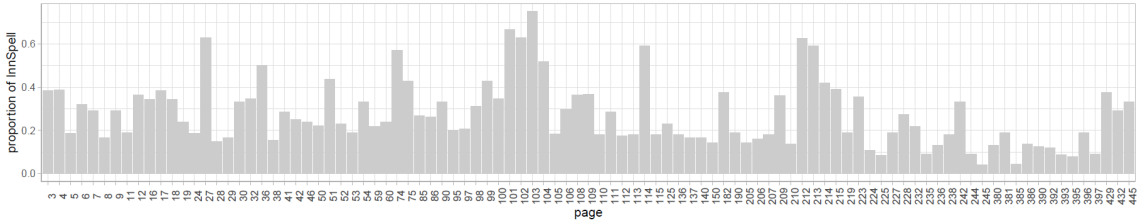


Figure 16: Proportions of InnSpell for pages in the text with more than 20 examples of sibilants

5 Modelling

5.1 Model building

The initial model consists of two random effects (LEXEME and PAGE), six independent variables (PLACE_ETYM, MANNER, CONTEXT, LOAN, CATEGORY, FREQUENCY_CLASS) and eight interactions (PLACE_ETYM – MANNER, FREQUENCY_CLASS – PLACE_ETYM, FREQUENCY_CLASS – MANNER, FREQUENCY_CLASS – CATEGORY, CONTEXT – PLACE_ETYM, LOAN – PLACE_ETYM, CATEGORY – PLACE_ETYM, CATEGORY – MANNER), as specified in Section 3.2. The model only includes random intercepts, as fitting random slopes proved unfeasible with our data.

As for the fixed effects, a likelihood ratio test indicates that excluding the MANNER – FREQUENCY_CLASS interaction results in a model which is not significantly worse ($\chi^2(2) = 4.68$, $p = 0.097$). Further deletions worsen the model's fit. Thus, the final model includes all the variables and interactions except for MANNER – FREQUENCY_CLASS.

Moving to the random effects, the inclusion of LEXEME improves the model. A likelihood ratio test shows that the model with the random effect is significantly better than the model without it ($\chi^2(1) = 1305.4$, $p < .0001$). The inclusion of the random effect PAGE similarly results in a better model ($\chi^2(1) = 133.3$, $p < .0001$).

The results of this model are given in Table 2 and Table 3 and will be discussed in the next section. Before that, we will comment on the model's goodness of fit.

We used the package DHARMa (Hartig 2022) to verify the model's assumptions. The checks of the model's residuals do not raise any concerns, with the exception of some issues caused by the random effect LEXEME, which shows strong intercept adjustments for some items and thus violates the assumption of uniformity for random effects. We decided to continue with this model despite this problem, because there are studies which suggest that this generalised linear mixed-effects models show robustness to misspecifications of random-effect distribution (Bell, Fairbrother & Jones 2019: 1051; Silk, Harrison & Hodgson 2020 and references therein). We include more details on the model's diagnostics in the supplementary materials (Section 5.3.1 in the document with the code used in the paper).

An assumption of regression models is the lack of collinearity. The model fitted here does not appear to have major collinearity issues: the condition number with the intercept included is 19.28, which is lower

https://doi.org/10.3765/pda.v4art5.67 Published online by Cambridge University Press

than the level of 30, which indicates collinearity.[11] Nevertheless, a few variables and interactions have Variance Inflation Factor values higher than 10, which is often considered a level suggesting problems with collinearity. Those are MANNER (12.0), FREQUENCY_CLASS (11.6), PLACE_ETYM – FREQUENCY_CLASS (12.8), CATEGORY – FREQUENCY_CLASS (11.8), MANNER – CATEGORY (11.6). Taking into account the value corrected for the degrees of freedom, the highest value is that of MANNER (3.5) and MANNER – CATEGORY (3.4).

Table 2: Fixed effects in the final mixed-effects logistic regression model. Predicted odds are for InnSpell. The variables' reference levels are the following: PLACE_ETYM – laminal, MANNER – fricative, CONTEXT – _V, LOAN – no, CATEGORY – content, FREQUENCY_CLASS – mid

Predictors	Log-Odds	SE	*z* value	*p*	
(Intercept)	-3.33	0.48	-6.96	< 0.001	***
PLACE_ETYM [apical]	3.65	0.71	5.11	< 0.001	***
MANNER [affricate]	-3.82	0.84	-4.55	< 0.001	***
CONTEXT [#_]	1.86	0.22	8.34	< 0.001	***
CONTEXT [_#]	2.17	0.28	7.86	< 0.001	***
CONTEXT [_C]	3.82	0.30	12.92	< 0.001	***
LOAN [old]	-0.92	1.07	-0.87	0.387	
LOAN [yes]	0.40	0.58	0.68	0.494	
CATEGORY [grammatical]	-0.22	0.53	-0.41	0.678	
FREQUENCY_CLASS [high]	-3.51	0.72	-4.86	< 0.001	***
FREQUENCY_CLASS [low]	-0.55	1.31	-0.42	0.673	
PLACE_ETYM [apical] * MANNER [affricate]	6.07	1.19	5.09	< 0.001	***
PLACE_ETYM [apical] * FREQUENCY_CLASS [high]	4.13	0.89	4.65	< 0.001	***
PLACE_ETYM [apical] * FREQUENCY_CLASS [low]	3.29	1.50	2.19	0.028	
CATEGORY [grammatical] * FREQUENCY_CLASS [high]	5.57	0.76	7.31	< 0.001	***
CATEGORY [grammatical] * FREQUENCY_CLASS [low]	0.87	1.28	0.68	0.494	
PLACE_ETYM [apical] * CONTEXT [#_]	-4.90	0.88	-5.56	< 0.001	***
PLACE_ETYM [apical] * CONTEXT [_#]	-0.78	1.46	-0.54	0.593	
PLACE_ETYM [apical] * CONTEXT [_C]	-6.22	0.58	-10.70	< 0.001	***
PLACE_ETYM [apical] * LOAN [old]	-2.38	1.48	-1.61	0.108	
PLACE_ETYM [apical] * LOAN [yes]	-5.88	0.84	-6.99	<0.001	***
PLACE_ETYM [apical] * CATEGORY [grammatical]	-4.06	1.08	-3.75	<0.001	***
MANNER [affricate] * CATEGORY [grammatical]	2.38	0.90	2.65	0.008	**

Table 3: Random effects in the final mixed-effects logistic regression model

Random effect	*N* of groups	SD
LEXEME	871	3.43
PAGE	450	0.99

As for the model's goodness of fit, the model's index of concordance *C*, which measures how well the model predicts the data, is 0.97 (0.5 denotes random predictions and 1 a perfect correlation between data and model predictions). Another measure of goodness of fit we can use is pseudo-R^2 (Nakagawa &

[11] For the diagnostics we used the following tools: the index of concordance C and the condition number for collinearity were calculated with *JGmermod* library (Grafmiller 2019) and VIF values with *car* (Fox & Weisberg 2019). R^2 was obtained with the library MuMIn (Bartoń 2020).

https://doi.org/10.3765/pda.v4art5.67 Published online by Cambridge University Press

Schielzeth 2013; Nakagawa, Johnson & Schielzeth 2017). The marginal R^2 measures the variance explained by the fixed effects, and the conditional R^2 expresses the variance explained by the entire model, i.e. including random effects. For the model fitted here, the marginal R^2 is 0.31 and the conditional R^2 is 0.86. The intra-class correlation coefficient (ICC) is 0.795, which means that as much as 80% of variance can be explained with the random effects and especially with the variable lexeme, which has the ICC of 0.733.

5.2 Effects of the predictors

The model's coefficients are listed in Table 3 and also represented visually in Figure 17, which orders the predictors by the value of the coefficients predicted by the model. Items to the right of the line at 0 show an increased probability of InnSpell, and those to the left show a decreased probability of InnSpell. Those with the confidence interval crossing the line at 0 have no significant effect. We can easily see, for example, that the strongest effects favouring InnSpell are related to the apical affricates and low-frequency grammatical lexemes. Another strong effect is CONTEXT: preconsonantal position is the context most strongly linked to InnSpell. At the other extreme, with the lowest coefficients (and thus the lowest probability for InnSpell) we find, for instance, preconsonantal apical sibilants and loanwords with an apical sibilant. The interpretation of coefficients is nevertheless not straightforward in a rather complex model as the one discussed here, and because of that we will use the plots in Figure 18. For each level of the predictors, they plot probabilities of InnSpell (expressed in percentages) computed while keeping all other factors in the model constant.[12] The lines represent 95% confidence intervals.

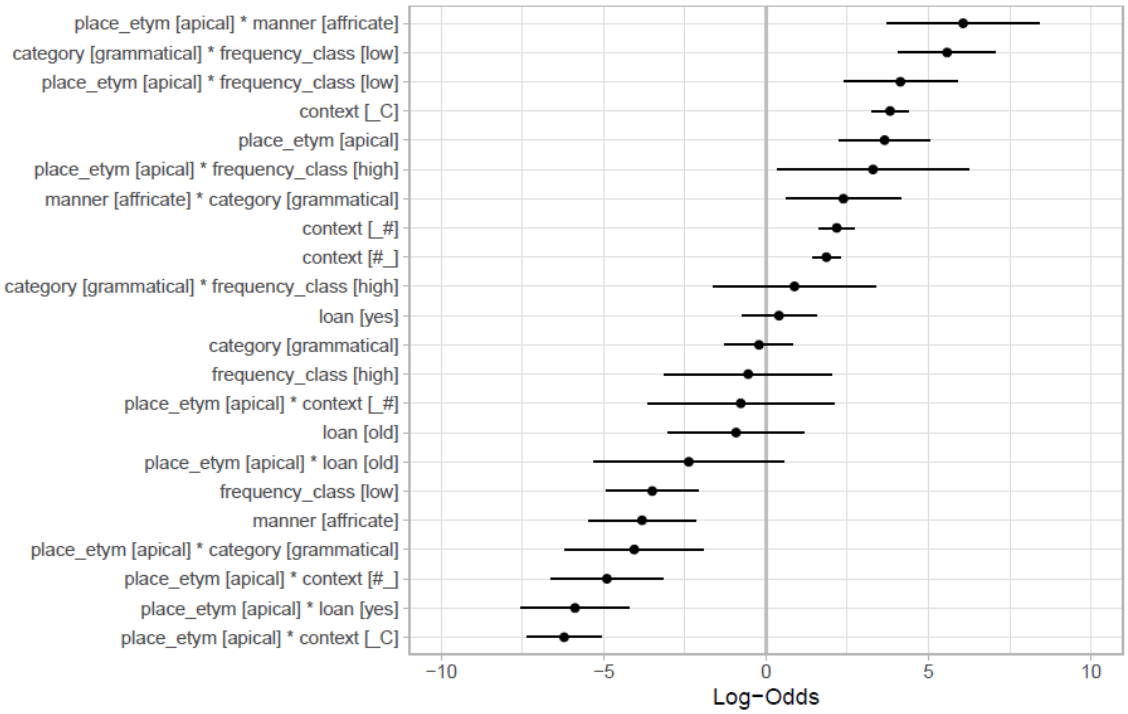


Figure 17: Log-odds predicted for InnSpell. Dots indicate the value predicted for each predictor, with horizontal lines showing 95% confidence intervals

[12] Calculated with the *ggeffects()* function in the *ggeffects* library (Lüdecke 2018).

https://doi.org/10.3765/pda.v4art5.67 Published online by Cambridge University Press

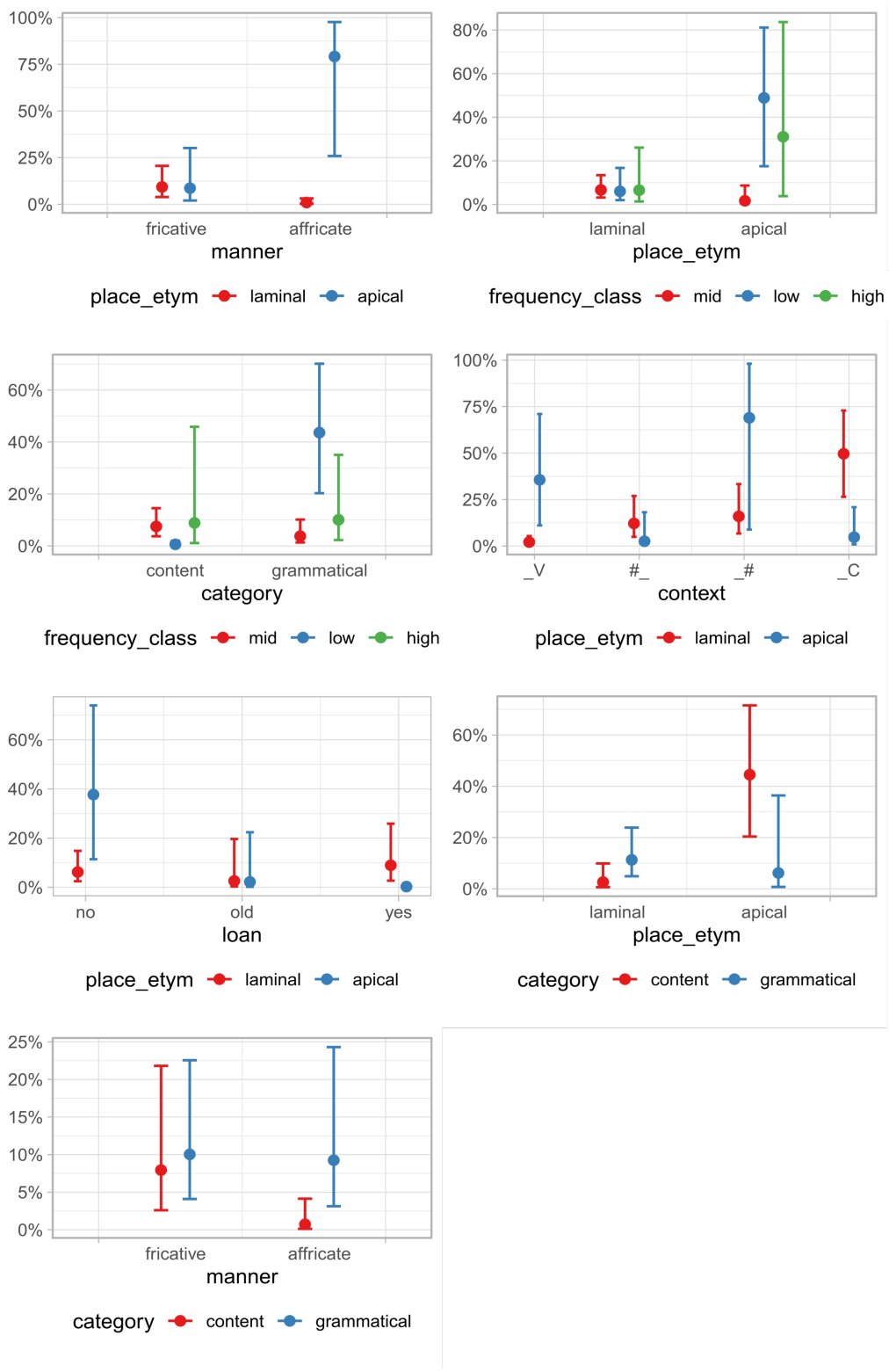


Figure 18: Interactions between predictors in the model (the *y* axis shows probabilities of InnSpell expressed in percentages)

Etymologically laminal and apical sibilants differ in various respects. Apical affricates show a very high probability of InnSpell (0.79) compared to their fricative counterpart (0.09). Among laminal

https://doi.org/10.3765/pda.v4art5.67 Published online by Cambridge University Press

consonants, fricatives are slightly more likely to be written with InnSpell than affricates (0.09 vs 0.01). The variable CONTEXT shows clearly different patterns for apical and laminal sibilants. As regards laminal sibilants, the context where InnSpell is most likely to occur is the preconsonantal position (0.5), followed by word-final and word-initial contexts (0.16 and 0.12, respectively). The environment showing the least probability of InnSpell is the prevocalic position (0.02). For apical sibilants, word-final position shows the greatest probability of InnSpell (0.69), but the confidence interval is quite big (most probably due to the small number of examples). The prevocalic context comes next with 0.36. Word-initial and preconsonantal environments are much less likely to show InnSpell with apical consonants (0.03 and 0.05, respectively).

There are only non-significant differences between native words and loanwords for laminal sibilants (0.09 for recent loanwords, 0.06 for native words and 0.03 for older borrowings). Native words with an apical sibilant, however, show a high probability of InnSpell (0.38) as compared to older loanwords (0.02) and recent loanwords (0).

In the variable CATEGORY, grammatical words or affixes with a laminal sibilant show a slightly higher probability of InnSpell than content words (0.11 vs 0.03). For apical sibilants, there is a clearer contrast between categories, with content words showing a higher occurrence of InnSpell (0.45) than other items (0.06) (but it must be taken into account that the confidence intervals overlap). Category also interacts with manner, where content words with an affricate consonant show the lowest probability of InnSpell (0.01 as compared to around 0.1 for fricatives and grammatical items).

Finally, we observe a number of frequency-related effects. For laminal sibilants, the probability of InnSpell is low for words from all frequency levels (around 0.07). However, for apical sibilants, mid-frequency words have the lowest probability of InnSpell (0.02), as compared to high-frequency (0.31) and low-frequency words (0.49). Nevertheless, for both high- and low-frequency words confidence intervals are quite big and they have to be interpreted with caution. As regards the interaction between frequency and category, differences are small for content words: 0.09 for high, 0.07 for mid and 0.01 for low-frequency words. In grammatical items, the highest probability of InnSpell is associated with the low-frequency class (0.44) and the lowest with the high and mid-frequency groups (0.1 and 0.04, respectively).

In sum, the highest probability of InnSpell (>0.3) is predicted for: affricate apicals, apicals in high and low-frequency items, prevocalic apicals, word-final apicals, apicals in native words, apicals in content words, low frequency grammatical words and preconsonantal laminals. The lowest (<0.05) is predicted for: older loanwords, loanwords with an apical, word-initial apicals, prevocalic laminals, low-frequency content words, apicals in mid-frequency words and laminal affricates.

5.3 Random effects

Finally, let us have a look at the two random effects in the model, PAGE and LEXEME. As indicated earlier, the random effects' contributions to the final model are highly significant. Table 3 above shows that the standard deviation is 3.4 for LEXEME and 1 for PAGE, which means that there is much greater variability between different lexemes than there is between pages.

The lexemes with the highest and lowest intercept adjustments (among lexemes with more than 20 tokens in the text) are listed in Table 4.

As regards the effect for PAGE, it appears that negative adjustments are more common towards the end (Figure 19).

https://doi.org/10.3765/pda.v4art5.67 Published online by Cambridge University Press

Table 4: Lexemes with highest and lowest intercept adjustments (for lexemes with more than 20 tokens)

Lexeme	Intercept adj.	Lexeme	Intercept adj.
asko 'much'	7.6	*hitz* 'word'	0
zuek 'you (pl.)'	5.8	*edun* 'have'	-1
zu 'you (sg.)'	4.3	*imitatu* 'imitate'	-1.4
zortzi 'eight'	4.2	*ekusi* 'see'	-1.5
aborrezitu 'abhor'	2.8	*asi* 'start'	-2
joan 'go'	2.3	*guzi* 'all'	-3.1
ez 'no'	0	*erakutsi* ' show'	-3.5
zer 'what'	1.9	*izandu* 'be'	-3.7



Figure 19: Intercept adjustments for the effect PAGE (for pages with more than 15 tokens)

6 Discussion

The statistical model explains only a part of the variation present in the data, but, at the same time, it shows that all the variables included in the model influence spelling. Of the variation explained by the model, the greatest part is explained by the random effect LEXEME. This is hardly surprising, given that we analyse spelling, which tends to be associated with lexemes. Nevertheless, other variables have also proven significant, which makes it possible to make inferences about the phonology of the language.[13] In this section, we thus propose answers to the questions posed in Section 2.4.

6.1 Neutralisation tendencies and the role of context and lexical effects

As regards the first question (Q1), our analysis suggests that the neutralising change that would result in a merger of alveolar sibilants was still in progress in the early 18th century Basque of San Sebastián, with the merger more advanced in the affricate than in the fricative class.

The neutralisation tendency of affricate sibilants is quite straightforward. Apical affricates are the most likely segments to show innovative spelling among the sibilants –most cases in our dataset being prevocalic (see Figure S11 in the supplementary materials), while laminal affricates remain largely unchanged with very few examples of innovative spelling. This is likely the consequence of no conflicting neutralisation patterns being found in the affricate class: the apical affricate becomes a laminal in both the Western and the Central pattern, and this is the only merger affecting affricates found in the area during the 19th and 20th centuries.

The case of the fricative sibilants, on the other hand, is more complex. Both patterns of neutralisation, the Western and the Central, show similar incidence in Lubieta's text, with roughly 1/3 of the sibilants

[13] It should be noted that the basis for our inferences, i.e. spelling, is not necessarily directly related to the pronunciation (cf. Section 2.1), but regularities and patterns found in spelling such as those we study in this paper are helpful to understand the sound system of earlier stages of a language.

https://doi.org/10.3765/pda.v4art5.67 Published online by Cambridge University Press

showing innovative spelling: <z>/<c> are used instead of <s> in 34% of the cases, while <s> appears instead of <z>/<c> in 28% of the cases.

A closer look at the distribution of innovative spelling is necessary to understand the nature of each pattern. Generally speaking, our results show that the phonetic context is more relevant for explaining the changes in Basque sibilants than lexical or frequency effects. We will discuss both kinds of effects in turn.

Segmental context (Q2) has resulted highly significant in our model, thus suggesting that contextual neutralisation was a factor at this point in the evolution of the two mergers. Starting with the most pronounced trend, innovative spelling of laminal fricatives is most frequent in preconsonantal position, especially before /t/. In phonological terms, /s̻/ > /s̺/ /_t is almost systematic in our corpus (87%, n = 223). This is especially illustrative in combination with the extremely low rate of innovative spelling in etymologically apical sibilants (6%, n = 290) in this position. This is the only environment where we can observe a virtually complete neutralisation of the alveolar sibilants: with very few exceptions, all alveolar sibilants are produced as apicals before /t/ and, more generally, before voiceless stops. It is worth noting that this is one of the most common contexts for a sibilant to appear in Basque, and even more in running speech, where word-initial voiced stops show devoicing when preceded by a word-final sibilant in the previous word.

As for the word-final position, on the basis of previous descriptions of the Western merger, we could expect it to pattern with the preconsonantal context. Indeed, laminal sibilants are frequently spelled innovatively. However, unlike in preconsonantal position, apicals also frequently show innovative spelling word-finally. The word-final context should be interpreted cautiously, however, because of the low number of examples in the text.

Turning to word-initial and prevocalic contexts, these are usually considered the last stages in the spread of the Western neutralisation. The data presented here are in line with this. Innovative spelling appears quite frequently word-initially for laminals. Nevertheless, only a few lexemes with an etymological laminal fricative in this position show consistent innovative spelling (the personal pronouns *zu* 'you (sg.)' and *zuek* 'you (pl.)'). If we leave out these lexemes, the proportion of innovative spelling drops considerably in the word-initial position. Thus, the data suggest that in this context the change from laminal to apical was underway, but not very advanced. Apicals are mostly written conservatively in this position.

Finally, laminals are usually spelled conservatively before a vowel (as predicted from what we know about the evolution of the Western merger). Conversely, this is the context most linked to innovative spelling in apical sibilants.

These tendencies can be summarised as follows:

- _# – both (with a high proportion of innovative spelling in both series)
- _V – laminals maintained (half of the apicals show innovative spelling)
- _C – apicals only (most laminals show innovative spelling)
- #_ – both maintained (with exceptions with consistent innovative spelling)

Turning to lexical and frequency effects, as we have already said, the way in which a word is written is highly related to the word itself and less so to other factors (which is reflected in the importance of the random effect of lexeme). This is not surprising due to the indirect nature of the data we are dealing with, namely spelling. Nevertheless, differences between the two mergers may help us understand the processes behind each.

For etymologically laminal sibilants, grammatical words and affixes are slightly more likely to show innovative spelling than content words, even though in the statistical analysis the differences between frequency classes have not proven significant. However, as shown in 4.6, it appears that there are two classes among grammatical words: the most frequent ones are written conservatively, but those slightly less frequent (e.g. *zer* 'what', *zu* 'you (sg.)') are more innovative. Since the most frequent lexemes tend to be verbs (especially auxiliary and copular verbs), we might have an effect of word class too (cf. Phillips 2015: 366). Low-frequency words, in turn, tend to show conservative spelling. As noted by Phillips (2015: 367), the effects of word class and frequency might be independent. We observe that in our data: for content

https://doi.org/10.3765/pda.v4art5.67 Published online by Cambridge University Press

words the proportion of innovative spelling decreases with frequency, but for grammatical words the most common items maintain conservative spelling.

The picture is even more complex in the apical series. Our prediction was that the apical to laminal neutralisation would start in lower frequency words. Generally speaking, the frequency values are lower for apicals (i.e. they do not appear in extremely frequent lexemes and appear in many very infrequent words). The most frequent words show innovative spelling often (contrary to what we predicted), and there are a few lexemes showing consistent innovative spelling. These words usually have an intervocalic sibilant, which makes it difficult to distinguish between contextual and lexical effects. On the other hand, in the low-frequency class, where we could expect high incidence of the innovation, most words are loans, and they are expected to follow the Spanish orthography. Native low-frequency lexemes show higher proportions of innovative spelling, but the results are hard to interpret because they usually only occur once in the text.

6.2 Accounting for the observed distributions of innovative spellings

In this section we focus on Q3: how to explain the emergence and spread of the two neutralisation patterns on the basis of the data from Lubieta's text.

We will start from the change from the lamino-alveolar /s̪/ to the apico-alveolar sibilant fricative /s̺/. We have shown that in Lubieta's variety the Western neutralisation had started but it was far from completed, and that we can order the contexts according to the strength of innovative spelling in the following way: preconsonantal > word-final > word-initial > prevocalic. Scholars agree that the order of extension of the Western neutralisation was from preconsonantal and word-final position to word-initial and prevocalic position. Data from our study allows us to better understand mechanisms behind this change.

Our account of the extension of the neutralising contexts in the Western merger can be summarised as follows (each Roman number represents a step in the extension process):

(1) Phases of the Western Basque merger
/s̪/ > /s̺/
i / _t
ii / _C
iii / _(C)$
iv / _(C)$ | #_
v / _(C)$ | $_V [general]

We propose that the process started as a phonetically conditioned sound change in preconsonantal position, and, more specifically, before /t/. In modern Basque, the canonical articulation of /t/ is usually described as apico-dental and transcribed as [t̪] (cf. Hualde 2003: 18).14 Although we cannot be certain about the articulation of any of these sounds in Lubieta's time, a classic description of Astarloa (1883: 179–180) states that in the pronunciation of [s̺] the tongue tip approximates the higher teeth while in that of [s̪] the tongue tip touches the lower incisors while folding towards the higher teeth (Michelena 1990: 279–280). Thus, unlike in the production of apico-dental [t̪], where the tongue tip goes upwards and touches the

[14] More research on the articulation of Basque dental stops is needed to determine to exact shape of the tongue. Due to the scarcity of accurate articulatory descriptions of Basque stops, they are often assumed to be similar to those of (Northern) Peninsular Spanish. In Peninsular Spanish, generally, the passive articulator is the back of the higher incisors, and the active articulator is the apex, with the lamina also contacting with the alveolar ridge (Martínez-Celdrán, Fernández-Planas & Carrera-Sabaté 2003). If /t/ was more laminal than apical at the time the Western merger was initiated, our explanation loses a bit of strength: as noted by one of the reviewers, a change from laminal to apical sibilant before a laminal stop is not so likely. Note, however, that the tongue tip would still point upwards (as in /s̺/) rather than downwards (as in /s̪/). In addition, a more general explanation would be still possible: the place retraction could have started more generally in preconsonantal position (fricatives are weakened in coda position, cf. e.g. Solé (2010)), though this would not directly account for the direction of the change.

https://doi.org/10.3765/pda.v4art5.67 Published online by Cambridge University Press

higher incisors (and the alveolar ridge), in the lamino-(denti-)alveolar [s̪], the apex goes downwards and contacts with the lower incisors. Apico-alveolar [s̻] is like [t̻] in that the tongue tip stays upwards and approximates the base of the higher incisors and the alveolar ridge. A canonical modern Basque [t̻] would not have the exact same place of articulation of [s̻], but it would be close to it (much closer than it is to [s̪]), and the tongue shape would be way more similar.[15] Thus, coarticulation of a coda laminal sibilant to a following dental-alveolar stop may have resulted in the retraction of the place of articulation of this sibilant alongside the apicalisation of its lingual gesture. The change then extended first to all preconsonantal contexts and the perceptually ambiguous word-final position. In the next step the change reached word-initial position and, finally, any prevocalic position. Prevocalic positions were the last contexts of this change because, in word-initial position, coarticulation to a following vowel can enhance the apical/laminal distinction, and, in intervocalic position, both surrounding vowels likely helped the perception of various perceptually relevant phonetic cues.

Although occurring in a slightly different region of the mouth, this change observed in Basque would not be very different from sibilant retractions observed in many languages, which are especially common in preconsonantal position and syllable coda (cf. Kümmel 2007). For example, in English, /s/ (which is more posterior than Basque /s̪/) is retracted to /ʃ/ in /stɹ/ clusters (Shapiro 1995). Acoustically, the sibilant in /str/ clusters of Australian English has been shown to have a lower average M1 (first spectral moment) than these in /spr/ and /skr/, and these, in turn, lower than these in /sp, st, sk/; all clusters (also those without the rhotic) having lower average M1s than that in /sV/ (Stevens & Harrington 2016: 125–126, 133). In a subsequent perceptual experiment also involving speakers of Australian English, it was shown that sibilants in /str/ and /st/ clusters can be perceived as /ʃ/ by native speakers when extrapolated to prevocalic /_V contexts (Stevens & Harrington 2016: 133). In German, /s/-retraction occurs before any consonant in word-initial position, but it is extended to all coda clusters in some varieties (see, e.g., Alber, Kokkelmans & Rabanus 2021). Another example is Portuguese, where /s/ > /ʃ/ has extended to all codas (Zampaulo 2016). In all these cases, the sound change has been argued to begin in coarticulatory contexts where synchronic variation shows a bias in a given direction (Stevens, Bukmaier & Harrington 2015). In this situation, an extreme coarticulatory bias can be reinterpreted by a listener as an intended articulatory target (Baker, Archangeli & Mielke 2011). Once a conditioned merger is completed after the phonologisation of the variants in a coarticulatory context, a perceptual realignment favouring the innovative variants can extend to the rest of the instances of the affected phoneme (Harrington 2012).

Our proposal finds support within Basque, in both phonetic and historical data. The seed for this particular sound change can be observed in the modern varieties which did not develop the Western or the Central merger. One such case is that of Mixean Basque, in which a recent acoustical study has found evidence in line with the described preconsonantal sibilant retraction (Egurtzegi et al. 2022).[16] The second step, a conditional merger after the phonologisation of the neutralising change in a coarticulatory context, is found in historical records. In Kapanaga's text from 1656, written in the Western dialect, for instance, most cases of innovative spelling of <z, c> as <s> occur before a voiceless stop, with only a few examples elsewhere (Zuloaga 2020).

As regards the Central Basque merger, our study suggests that the order of extension of this neutralisation pattern was different:

[15] Nonetheless, note that a recent articulatory description (based on static MRI data) of the alveolar fricative sibilants of Basque highlights their high degree of variability in the modern language (Iribar Ibabe, Pagola Petrirena & Túrrez Aguirrezábal 2020).

[16] This variety has been proposed to show a third kind of merger that collapses the apico-alveolar and postalveolar sibilant categories for both fricatives and affricates (Egurtzegi & Carignan 2020).

https://doi.org/10.3765/pda.v4art5.67 Published online by Cambridge University Press

(2) Phases of the Central Basque merger
/s̻/ > /s̺/
i / V_V
ii / $_V
iii / $_V | _#
iv / $_V | _(C)$ [general]

Innovative spelling appears mostly in prevocalic position, i.e. the context with the least incidence of innovative spelling in the Western pattern, and is uncommon in the preconsonantal position, the earliest and most prominent context of influence in the Western pattern. The Central neutralisation shows its biggest incidence in the intervocalic context, a position where we would expect a phonetically based neutralisation of place to have the least strength given that place-related acoustic cues are likely best perceived intervocalically.

The most straightforward way to account for an intervocalic apical to laminal change early in the merger process is through non-phonetic means, such as hypercorrection. Following Zuloaga (2020), we propose that the Central neutralisation resulted from hypercorrection, and we add that it started due to the ambiguous situation that was caused by the third step of the Western merger: after /s̺/ > /s̻/ was already a conditioned merger (as in Lubieta's Basque, where virtually only /s̻/ occurs before /t/), a perceptual realignment that slowly brought the alveolar exemplars towards the apical prototype gave rise to the first ambiguous realisations in non-coarticulatory contexts and speakers resolved this ambiguity by reverting the ongoing rule.

Thus, we propose that both mergers started due to the same coarticulatory bias, and we predict that the varieties that show the Central merger today initially developed the first stages of the Western merger, with /s̺/ > /s̻/ /_t, but then a hyper-corrective process due to the ambiguity resulting from a then non-robust opposition pushed the merger in the opposite direction. If this seemingly back-formed rule were the consequence of a certain degree of sociolinguistic awareness by the urban speakers of San Sebastián, then what we observe in the Central merger could be a case of what DeCamp (1972) called *rule symmetry* or the development of *mirror-image rules*:

> Whenever the application of a rule carries strong negative prestige, I suggest that the rule is not (within the same generation of adult speakers) dropped from the grammar or even skipped over in the derivation. Rather, a new rule may be added to the grammar, immediately following the offensive rule and symmetrical to it in form. If this new rule remains perfectly symmetrical, its effect is only to undo the effects of the offensive rule. It seldom remains perfectly symmetrical, however. Specifically, it is especially susceptible to rule generalization (Decamp 1972: 88)

We believe that Lubieta, who was familiar with other varieties of Basque, aimed to reflect the apical/laminal distinction that was gradually disappearing from his variety. The distinction was still preserved in those contexts to which the Western merger spread later. It was also present in many varieties spoken around San Sebastián and also reflected in most works printed in Basque. Thus, maintaining the distinction might be seen as more prestigious pronunciation. However, Lubieta lacked a standard variety or a reference grammar that would serve him as a guideline (the first Basque grammar was published just one year after his dictionary in 1729). This could have resulted in an over-representation of the presence of the laminal fricative sibilant in both Lubieta's written and spoken language. In the light of other sources of the period and current speech data, the application of rule-symmetry is not limited to Lubieta's manuscript: it was a more or less generalised phenomenon in the middle of the 18th century and, subsequently, it has been reinforced and extended in wide areas of the central dialect.

Thus, our account of changes in the sibilant system in the fricative class is summarised in Figure 20.

https://doi.org/10.3765/pda.v4art5.67 Published online by Cambridge University Press

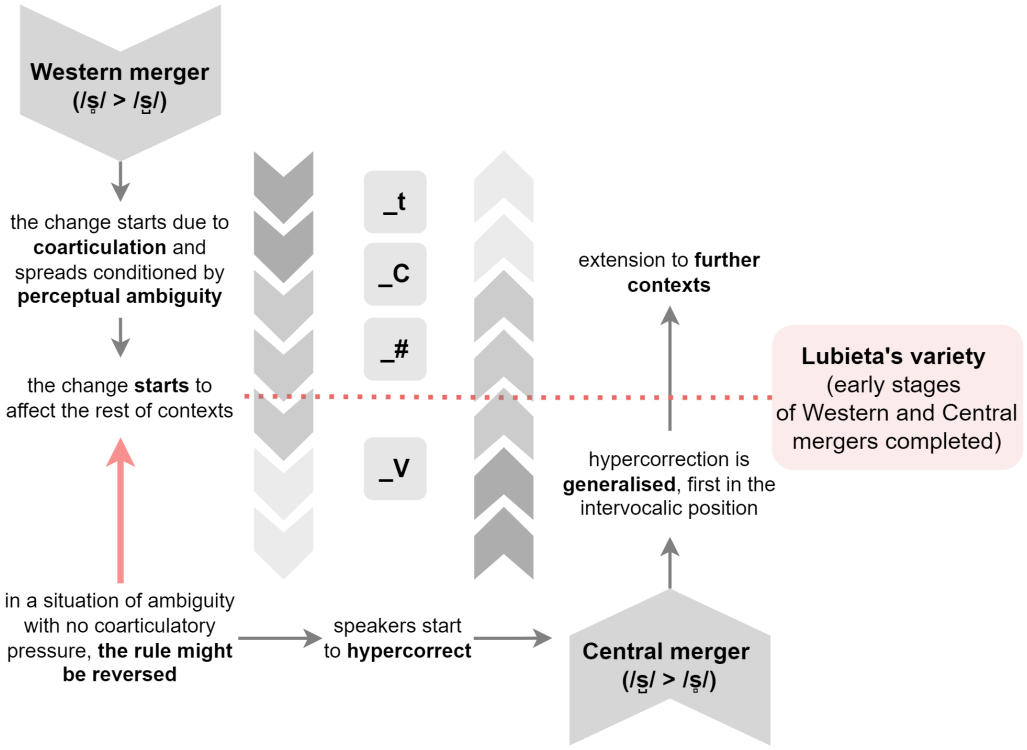


Figure 20: Changes in the sibilant system in Basque

As regards the nature of each merger, we can probably consider the Western pattern a merger by approximation, in which the phonetic targets of /s̪/ and /s̻/ gradually converge into /s̻/, while the Central pattern could be a merger by transfer, a unidirectional process in which one phoneme is replaced with another in a word-by-word manner (Labov 1994: 321). Under this account, we would expect the Western merger to be a sound change from below (cf. Labov 1994) that would gradually extend following a hierarchical model structure, but the hypercorrections that gave rise to the Central merger would be a case of a change from above, and thus its isogloss could show an uneven geographic spread, potentially with greater presence in urban areas than in rural areas (Zuloaga 2020).

As a final note, we want to emphasise that we were only able to understand our graphematic data by interpreting our results on the grounds of current theories of phonetically based sound change. Quantitative approaches to historical phonological datasets offer an attractive (although narrow) window into the intermediate steps of attested historical sound change. Nevertheless, we can only be able to understand what we observe by benefiting from an articulated theory of sound change, rooted in typological observations as well as in tested phonetic biases.

References

Alber, Birgit, Joachim Kokkelmans & Stefan Rabanus. 2021. Preconsonantal s-retraction in the Alps: Germanic, Romance, Slavic. *STUF - Language Typology and Universals* 74(1). 17–38. https://doi.org/10.1515/stuf-2021-1022.

Astarloa, Pablo Pedro. 1883. *Discursos filosóficos sobre la lengua primitiva o Gramática y análisis razonada del euskera o bascuence*. Bilbao: Pedro Velasco.

Baayen, Harald R. 2001. *Word frequency distributions*. Dordrecht: Kluwer.

Baker, Adam, Diana Archangeli & Jeff Mielke. 2011. Variability in American English s-retraction suggests a solution to the actuation problem. *Language Variation and Change* 23(3). 347–374. https://doi.org/10.1017/S0954394511000135.

https://doi.org/10.3765/pda.v4art5.67 Published online by Cambridge University Press

Barteld, Fabian, Stefan Hartmann & Renata Szczepaniak. 2016. The usage and spread of sentence-internal capitalization in Early New High German: A multifactorial approach. *Folia Linguistica* 50(2). 385–412. https://doi.org/10.1515/flin-2016-0015.

Bartoń, Kamil. 2020. MuMIn: Multi-model inference. Software package. https://CRAN.R-project.org/package=MuMIn.

Bates, Douglas, Martin Mächler, Ben Bolker & Steve Walker. 2015. Fitting linear mixed-effects models using lme4. Journal of Statistical Software 67(1). 1–48. https://doi.org/10.18637/jss.v067.i01.

Bell, Andrew, Malcolm Fairbrother & Kelvyn Jones. 2019. Fixed and random effects models: Making an informed choice. *Quality & Quantity* 53(2). 1051–1074. https://doi.org/10.1007/s11135-018-0802-x.

Beristain, Ander. 2018. Azpeitiko euskararen hiztegi dialektal bat – I. *Fontes Linguae Vasconum* 125. 7–54. https://doi.org/10.35462/FLV125.1.

Beristain, Ander. 2019. Azpeitiko euskararen hiztegi dialektal bat – II. *Fontes Linguae Vasconum* 127. 7–58. https://doi.org/10.35462/FLV127.1.

Beristain, Ander. 2021. Spectral properties of anterior sibilant fricatives in Northern Peninsular Spanish and sibilant-merging and non-merging varieties of Basque. *Journal of the International Phonetic Association* 1–32. https://doi.org/10.1017/S0025100320000274.

Bilbao, Gidor. 2012. Lubieta, izen berri bat euskal testuen historian. In Joseba A. Lakarra, Joaquín Gorrochategui & Blanca Urgell (eds.), *2nd Conference of the Luis Michelena Chair - Koldo Mitxelena Katedraren II. Biltzarra - II. Congreso de la Cátedra Luis Michelena*, 621–649. Vitoria-Gasteiz: UPV/EHU.

Brown, Keith & Jim Miller. 2013. *The Cambridge dictionary of linguistics*. Cambridge: Cambridge University Press.

Bussmann, Hadumod, Kerstin Kazzazi & Gregory Trauth. 1998. *Routledge dictionary of language and linguistics*. London: Routledge.

Bybee, Joan. 2001. *Phonology and language use*. Cambridge: Cambridge University Press.

Bybee, Joan. 2007. The phonology of the lexicon: evidence from lexical diffusion. In Joan Bybee (ed.), *Frequency of use and the organization of language*, 199–215. Oxford: Oxford University Press.

Bybee, Joan L. 2012. Patterns of lexical diffusion and articulatory motivation for sound change. In Maria-Josep Solé & Daniel Recasens (eds.), *The initiation of sound change: Perception, production, and social factors*, 211–234. Amsterdam / Philadelphia: John Benjamins.

Camino, Iñaki. 2000. Abiaburu bat Donostiako euskera aztertzeko. In Koldo Zuazo (ed.), *Dialektologia gaiak*, 53–84. Vitoria-Gasteiz: Arabako Foru Aldundia.

Coupé, Christophe. 2018. Modeling linguistic variables with regression models: Addressing non-Gaussian distributions, non-independent observations, and non-linear predictors with random effects and generalized additive models for location, scale, and shape. *Frontiers in Psychology* 9(513). https://doi.org/10.3389/fpsyg.2018.00513.

De Smet, Isabeau & Freek Van de Velde. 2020. A corpus-based quantitative analysis of twelve centuries of preterite and past participle morphology in Dutch. *Language Variation and Change* 32(2). 1–25. https://doi.org/10.1017/S0954394520000101.

Decamp, David. 1972. Hypercorrection and rule generalization. *Language in Society* 1(1). 87–90.

Dücker, Lisa, Stefan Hartmann & Renata Szczepaniak. 2020. The emergence of sentence-internal capitalisation in Early New High German: Towards a multifactorial quantitative account. In Marco Condorelli (ed.), *Advances in historical orthography*, c. 1500–1800, 67–92. Cambridge: Cambridge University Press. https://doi.org/10.1017/9781108674171.004.

Echenique, Maria Teresa. 2013. La lengua vasca en la historia lingüística hispánica. In Rafael Cano (ed.), *Historia de la lengua española*, 59–82. Madrid: Ariel.

https://doi.org/10.3765/pda.v4art5.67 Published online by Cambridge University Press

Egurtzegi, Ander. 2013. Phonetics and phonology. In Mikel Martínez-Areta (ed.), *Basque and proto-Basque. Language-internal and typological approaches to linguistic reconstruction*, 119–173. Frankfurt am Main: Peter Lang.

Egurtzegi, Ander & Christopher Carignan. 2020. An acoustic description of Mixean Basque. *The Journal of the Acoustical Society of America* 147(4). 2791–2802. https://doi.org/10.1121/10.0000996.

Egurtzegi, Ander, Dorota Krajewska, Iñigo Urrestarazu & Christopher Carignan. 2022. An acoustic description of sibilants in Mixean Basque. Manuscript.

Euskara Institutua. 2011. Goenkale Corpusa. Bilbao: UPV/EHU. https://www.ehu.eus/ehg/goenkale/.

Fox, John & Sanford Weisberg. 2019. *An R companion to applied regression*, 3rd edn. Thousand Oaks: Sage. https://socialsciences.mcmaster.ca/jfox/Books/Companion/index.html.

Gordon, Matthew J. 2015. Exploring chain shifts, mergers, and near-mergers as changes in progress. In Patrick Honeybone & Joseph Salmons (eds.), *The Oxford handbook of historical phonology*, 173–190. Oxford: Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199232819.013.009.

Grafmiller, Jason. 2019. JGmermod: custom functions for mixed-effects regression models. https://rdrr.io/github/jasongraf1/JGmermod/.

Gries, Stefan Th. 2010. Useful statistics for corpus linguistics. In Aquilinio Sánchez Pérez & Moisés Almela Sánchez (eds.), *A mosaic of corpus linguistics: Selected approaches*, 269–291. Frankfurt am Main: Peter Lang.

Gries, Stefan Th. 2013. *Statistics for linguistics with R: A practical introduction*. Berlin: Mouton de Gruyter.

Gries, Stefan Th. 2015a. Some current quantitative problems in corpus linguistics and a sketch of some solutions. *Language and Linguistics* 16(1). 93–117. https://doi.org/10.1177/1606822X14556606.

Gries, Stefan Th. 2015b. The most under-used statistical method in corpus linguistics: Multi-level (and mixed-effects) models. *Corpora* 10(1). 95–125. https://doi.org/10.3366/cor.2015.0068.

Gries, Stefan Th. & Martin Hilpert. 2010. Modeling diachronic change in the third person singular: a multifactorial, verb- and author-specific exploratory approach. *English Language and Linguistics* 14(3). 293–320. https://doi.org/10.1017/S1360674310000092.

Harrington, Jonathan. 2012. The coarticulatory basis of diachronic high back vowel fronting. In Maria-Josep Solé & Daniel Recasens (eds.), *The initiation of sound change: Perception, production and social factors*, 103–122. Amsterdam / Philadelphia: John Benjamins.

Hartig, Florian. 2022. DHARMa: Residual diagnostics for HierARchical regression models. Software package. http://florianhartig.github.io/DHARMa/.

Herold, Ruth. 1990. *Mechanisms of merger: The implementation and distribution of the low back merger in eastern Pennsylvania*. Philadelphia: University of Pennsylvania dissertation. https://repository.upenn.edu/dissertations/AAI9026574.

Hualde, José Ignacio. 2003. Segmental phonology. In José Ignacio Hualde & Jon Ortiz de Urbina (eds.), *A grammar of Basque*, 15–64. Berlin: De Gruyter Mouton.

Hualde, José Ignacio. 2010. Neutralización de sibilantes vascas y seseo en castellano. *Oihenart: Cuadernos de Lengua y Literatura* 25. 89–116.

Igartua, Iván. & Xabier Zabaltza. 2012. *Euskararen historia laburra* [A brief history of the Basque language]. Donostia: Etxepare Euskal Institutua.

Iribar-Ibabe, Alexander, Rosa Miren Pagola Petrirena & Itziar Túrrez Aguirrezábal. 2020. Caracterización articulatoria de las fricativas sibilantes alveolares del euskera: Primera parte. *Loquens* 7(2). e073. https://doi.org/10.3989/loquens.2020.073.

Kang, Yoonjung, Tae-Jin Yoon & Sungwoo Han. 2015. Frequency effects on the vowel length contrast merger in Seoul Korean. *Laboratory Phonology* 6. 469–503. https://doi.org/10.1515/lp-2015-0014.

Kümmel, Martin. 2007. *Konsonantenwandel bausteine zu einer typologie des lautwandels und ihre konsequenzen für die vergleichende rekonstruktion*. Wiesbaden: Reichert Verlag.

Labov, William. 1972. *Sociolinguistic patterns*. Philadelphia: University of Pennsylvania Press.

https://doi.org/10.3765/pda.v4art5.67 Published online by Cambridge University Press

Labov, William. 1994. *Principles of linguistic change. Volume 1: Internal factors*. Oxford: Blackwell Scientific Publications.
Lakarra, Joseba A. 1995. Reconstructing the Pre-proto-Basque root. In José Ignacio Hualde, Joseba A. Lakarra & Robert L. Trask (eds.), *Towards a history of the Basque language*, 189–206. Amsterdam: John Benjamins.
Lakarra, Joseba A. 2013. Root structure and the reconstruction of Proto-Basque. In Mikel Martínez-Areta (ed.), *Basque and proto-Basque. Language-internal and typological approaches to linguistic reconstruction*, 173–221. Frankfurt am Main: Peter Lang.
Lakarra, Joseba A., Julen Manterola & Iñaki Segurola. 2019. *Euskal hiztegi historiko-etimologikoa* (EHHE-200). Bilbao: Euskaltzaindia.
Lüdecke, Daniel. 2018. ggeffects: Tidy data frames of marginal effects from regression models. *Journal of Open Source Software* 3(26). 772. https://doi.org/10.21105/joss.00772.
Lüdecke, Daniel. 2020. sjPlot: Data visualization for statistics in social science. Software package. https://CRAN.R-project.org/package=sjPlot.
Martínez Alcaide, María José. 2010. *La fijación ortográfica del español: Norma y argumento historiográfico*. Bern: Peter Lang.
Martínez-Celdrán, Eugenio, Ana María Fernández-Planas & Josefina Carrera-Sabaté. 2003. Castilian Spanish. *Journal of the International Phonetic Association* 33(2). 255–259. https://doi.org/10.1017/S0025100303001373.
Michelena, Luis. 1990. *Fonética histórica vasca*, 2nd edn. San Sebastián: Diputación Foral de Gipuzkoa.
Minkova, Donka. 2015. Establishing phonemic contrast in written sources. In Patrick Honeybone & Joseph Salmons (eds.), *The Oxford handbook of historical phonology*, 72–85. Oxford: Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199232819.013.024.
Mounole, Céline & Joseba A. Lakarra. 2018. Euskara Arkaikoa. In Joakin Gorrotxategi, Iván Igartua & Joseba A. Lakarra (eds.), *Euskararen historia*, 345–468. Vitoria-Gasteiz: Eusko Jaurlaritza.
Mujika, José Antonio. 2002. *Euskal ortografiaren hastapenak iparraldeko literaturan*. Bilbao: UPV/EHU.
Muxika-Loitzate, Oihane. 2017. Sibilant merger in the variety of Basque spoken in Amorebieta-Etxano. *Languages* 2(4). 25. https://doi.org/10.3390/languages2040025.
Nakagawa, Shinichi, Paul C. D. Johnson & Holger Schielzeth. 2017. The coefficient of determination R2 and intra-class correlation coefficient from generalized linear mixed-effects models revisited and expanded. *Journal of The Royal Society Interface* 14(134). https://doi.org/10.1098/rsif.2017.0213.
Nakagawa, Shinichi & Holger Schielzeth. 2013. A general and simple method for obtaining R2 from generalized linear mixed-effects models. *Methods in Ecology and Evolution* 4(2). 133–142. https://doi.org/10.1111/j.2041-210x.2012.00261.x.
Oyosa, Anabel Eugenia. 2015. Consideraciones sobre grafemática en el ámbito hispánico: en torno a los usos gráficos en la documentación medieval de las lenguas romances peninsulares. *Anuario de Letras. Lingüística y Filología* 1(1). 273–347.
Patil, Indrajeet. 2018. ggstatsplot: "ggplot2" based plots with statistical details. Software package. https://doi.org/10.5281/zenodo.2074621.
Phillips, Betty S. 2015. Lexical diffusion in historical phonology. In Patrick Honeybone & Joseph Salmons (eds.), *The Oxford handbook of historical phonology*, 359–373. Oxford: Oxford University Press.
R Core Team. 2021. R: A language and environment for statistical computing. Software package. Vienna: R Foundation for Statistical Computing. https://www.R-project.org/.
Rutkowska, Hanna & Paul Rössler. 2012. Orthographic variables. In Juan Manuel Hernández Campoy & Juan Camilo Conde Silvestre (eds.), *The handbook of historical sociolinguistics*, 213–236. Oxford: Blackwell.
Sagarzazu, Txomin. 2005. *Hondarribiko eta Irungo euskara*. Irun: Alberdania.
Shapiro, Michael. 1995. A case of distant assimilation: /str/ → /ʃtr/. *American Speech* 70(1). 101–107. https://doi.org/10.2307/455876.

https://doi.org/10.3765/pda.v4art5.67 Published online by Cambridge University Press

Silk, Matthew J., Xavier A. Harrison & David J. Hodgson. 2020. Perils and pitfalls of mixed-effects regression models in biology. *PeerJ* 8. e9522. https://doi.org/10.7717/peerj.9522.
Solé, Maria-Josep. 2010. Effects of syllable position on sound change: An aerodynamic study of final fricative weakening. *Journal of Phonetics* 38(2). 289–305. https://doi.org/10.1016/j.wocn.2010.02.001.
Stenroos, Merja. 2002. Free variation and other myths: Interpreting historical English spelling. *Studia Anglica Posnaniensia: International Review of English Studies* 38. 445–469.
Stevens, Mary, Véronique Bukmaier & Jonathan Harrington. 2015. Pre-consonantal /s/ retraction. Presented at the International Congress of Phonetic Sciences, Glasgow, University of Glasgow. https://www.phonetik.uni-muenchen.de/~jmh/papers/sretractionicphs15.pdf.
Stevens, Mary & Jonathan Harrington. 2016. The phonetic origins of /s/-retraction: Acoustic and perceptual evidence from Australian English. *Journal of Phonetics* 58. 118–134. https://doi.org/10.1016/j.wocn.2016.08.003.
Trask, Robert Lawrence. 1997. *The history of Basque*. London: Routledge.
Wickham, Hadley. 2016. *ggplot2: Elegant graphics for data analysis*. New York: Springer-Verlag New York. https://ggplot2.tidyverse.org.
Winter, Bodo. 2020. *Statistics for linguists: An introduction using R*. New York: Routledge.
Wolk, Christoph, Joan Bresnan, Anette Rosenbach & Benedikt Szmrecsanyi. 2013. Dative and genitive variability in Late Modern English: Exploring cross-constructional variation and change. *Diachronica* 30(3). 382–419. https://doi.org/10.1075/dia.30.3.04wol.
Zampaulo, Andre. 2016. Sibilant sound change in the history of Portuguese: An information-theoretic approach. *Diachronica* 33(4). 503–529. https://doi.org/10.1075/dia.33.4.03zam.
Zuloaga, Eneko. 2020. *Mendebaleko euskararen azterketa dialektologiko-diakronikorantz*. Bilbao: UPV/EHU dissertation. https://addi.ehu.es/handle/10810/49846.
Zuur, Alain F., Elena N. Ieno, Neil Walker, Anatoly A. Saveliev & Graham M. Smith. 2009. *Mixed effects models and extensions in ecology with R*. New York: Springer New York.

Dorota Krajewska
Department of Linguistics and Basque Studies
University of the Basque Country UPV/EHU
Unibertsitateko Ibilbidea, 5
01006 Vitoria-Gasteiz, Spain
dorota.krajewska@ehu.eus

Eneko Zuloaga
Department of Linguistics and Basque Studies
University of the Basque Country UPV/EHU
Unibertsitateko Ibilbidea, 5
01006 Vitoria-Gasteiz, Spain
eneko.zuloaga@ehu.eus

Ander Egurtzegi
CNRS IKER (UMR5478)
Campus de la Nive, Château-Neuf
15, Place Paul Bert
64100 Bayonne, France
ander.egurtzegi@iker.cnrs.fr

https://doi.org/10.3765/pda.v4art5.67 Published online by Cambridge University Press