

Sibilant Dissimilation in the History of Spanish: An Information-Theoretic Approach

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1. Introduction

The study of sound change has received a great deal of attention both in the past (e.g. Paul 1886) and in recent times (e.g. Lass 1980; Blevins 2004; Miller 2010; among many others). The importance of these studies lies in the fact that they point out the relevance of a given sound change to other linguistic domains, e.g. the change of a sound may incur modifications in segment inventories, syllable structure, stress patterns, etc. Researchers have viewed sound change within multiple perspectives, e.g. phonetic (Ohala 1981, 1993, 2003), phonological (Kiparsky 2003, 2008), sociolinguistic (e.g. Labov 2001) word-based (Bybee 2001, 2008), among others. In Spanish, such viewpoints have given rise to a rich amount of scholarly research (e.g. Alonso 1967, 1969; Ariza, 1994; Lapesa 1980; Lloyd 1987; Menéndez Pidal 1956, 1977; Penny 2000, 2002; etc). However, the scope of these approaches reveals itself narrow and detail-oriented, as they propose models which overlook a fundamental premise of spoken communication, i.e. the information conveyed by the sounds of a given message. Recently, a growing body of research has been focusing on the role that information plays in the shaping of sound patterns, as proposed by the principles of Information Theory (Shannon 1948; Cover & Thomas 2006; Goldsmith 1998; Hume et al. 2011; Hume & Mailhot, to appear). As the main tools of this approach, frequency, probability, and the concepts of entropy and surprisal shed light upon the mechanisms of sound change, because they manifest “the nature of the change affecting unstable language patterns” (Hume & Mailhot, to appear).

In this paper, I apply the notion of probability and the concepts of entropy and surprisal, as defined in information-theoretic terms, to the well-known case of sibilant dissimilation in medieval Spanish. As the current analysis will show, probability, entropy and surprisal reveal themselves as crucial in order to understand the dissimilatory changes in question, by explaining them as a resolution of the phonetic uncertainty and ambiguity that characterized the sibilant consonants prior to dissimilation. I argue, then, that the contrast enhancement resulting from this change not only contributes to the effectiveness in conveying information, but also results from the instability of low-frequency sounds.

This paper is organized as follows. In section 2, I provide the historical background of medieval Spanish sibilants. Section 3 discusses the basic tenets of Information Theory, while section 4 summarizes the phonetics of the consonants involved. Section 5 presents the application of information-theoretic tools to the sound changes in question, and Section 6 provides concluding remarks.

2. Historical Background

The devoicing and dissimilation of medieval Spanish voiced sibilants represents one of the most well documented cases of sound change in the evolution of this language, mainly because of the

* For discussion on many of the ideas presented in this paper and for insightful comments, I would like to thank Elizabeth Hume, the members of the 2011 Advanced Phonology Seminar at The Ohio State University, the audience of the 2011 Hispanic Linguistics Symposium (HLS) at the University of Georgia, and two anonymous reviewers. I alone am responsible for any and all errors.

emergence of two non-sibilant segments in its consonant inventory, i.e. the interdental fricative /θ/ and the velar fricative /x/ (e.g. Joos 1952; Alonso 1967; Kiddle 1977; Navarro Tomás 1977; Lloyd 1987 among many others).

Besides pre-palatal /tʃ/, which did not undergo any substantial changes, Old Spanish presented six other sibilant consonants, which contrasted in voicing in intervocalic position, as shown in (a) (Penny 2002:98).

(a) Old Spanish sibilants in intervocalic position, before the 16th century

Dento-alveolar sibilants		Alveolar sibilants	Palatal sibilants
/t ^s /	decir/deçir ‘to descend’	/s/ espeso ‘thick’	/ʃ/ fixo ‘fixed’
/d ^z /	dezir ‘to say’	/z/ espeso ‘spent’	/ʒ/ fijo ‘son’

In the early 16th century, the affricates /t^s/ and /d^z/ were weakened to fricatives /ʃ/ and /ʒ/, while the alveolar and palatal sibilants remained unchanged. By the mid 16th century, however, all voiced sibilants devoiced and merged with their voiceless counterparts, reducing the sibilant set to three consonants, as illustrated in (b) (Penny 2002:100).

(b) Spanish sibilants by the mid 16th century

Dento-alveolar sibilants	Alveolar sibilants	Palatal sibilants
/ʃ/	/s/	/ʃ/
caça (< [kát ^s ã]) ‘hunt’	passo (no change) ‘step’	caxa (no change) ‘box’
dezir (< [ded ^z ir]) ‘to say’	casa (< [káza]) ‘house’	mejor (< [mezór]) ‘better’

By the mid 17th century, the dental and palatal phonemes changed their place of articulation, distancing themselves from the alveolar consonant /s/ and becoming interdental /θ/ and velar /x/, respectively, in Castilian Spanish. The evolution of Spanish sibilants is summarized in (c) (Penny 2002:101).¹

(c) Sibilants’ evolution from Old to Modern Castilian Spanish

	Interdental	Dento-alveolar	Alveolar	Palatal	Velar
pre-sixteenth century		/t ^s / /d ^z /	/s/ /z/	/ʃ/ /ʒ/	
sixteenth century		/ʃ/	/s/	/ʃ/	
from 1650	/θ/		/s/		/x/

Most of the philological literature devoted to these changes focuses on the phonetics of the relevant sounds and attributes the dissimilation of the sibilant set /ʃ, s, ʒ/ to the relatively small articulatory window of its segments, which gave rise to potential acoustic confusion. Lloyd (1987:342, 334), for example, argues that the acoustic similarity between the alveolar and the palatal sibilants was “sufficient stimulus to induce speakers to retract the articulation” of the latter, motivating its velar realization; the interdental fricative, on the other hand, originated from “the exaggeration of the purely non-sibilant element and the elimination of all sibilant qualities.” Therefore, the subsequent set /θ, s, x/ would have resulted from an attempt to enhance the contrast—and thus create a greater distinctiveness—among said consonants, as stated in Penny (2002:101): “The potential confusion could *only* be avoided by making more perceptible the acoustic difference between the phonemes and this was achieved (...) by exaggerating the contrasts of locus” (emphasis added).

¹ The different paths of sibilant evolution in Andalusian Spanish are beyond the scope of this paper. In this variety, the dento-alveolar /ʃ/ evolved to dental /s/ (*seseo*) in some parts of Andalusia, while in other areas a more fronted variant resulted, displaying a similar acoustic effect of interdental /θ/ (*ceceo*). Instead of velar /x/, medieval Andalusian Spanish /ʃ/ evolved into glottal /h/ (Lapesa 1980; Penny 2002).

Such “exaggeration” has been the object of a handful of theoretical accounts (e.g. Harris 1969; Baker 2003; Bradley & Delforge 2006). While classical generative approaches typically rely on the mechanism of *ad hoc* phonological rules to account for these changes (e.g. Harris 1969), constrained-based approaches assume different rankings of universal constraints to explain the aforementioned sound patterns (e.g. Baker 2003). While descriptively adequate, these accounts ignore a fundamental premise of the result of a given sound change, which is to maintain the informative level of spoken communication between a speaker and a listener. Additionally, the highly abstract nature of such approaches poses a problem for their explanation, as they rely on different mechanisms to justify the path of sibilant evolution in Castilian Spanish and, thus, fail to provide a cohesive analysis of the observed sound changes and answer the question of why only the dento-alveolar and palatal sibilants changed, while the alveolar sibilant /s/ did not.

The current analysis attempts to fill this gap by providing a unified explanation for the dissimilatory changes of sibilants through a quantifiable method consistent with a theory of communication. As will be seen, the probability of occurrence of each sibilant from the set /ɣ, s, ʃ/ is crucial to understand its change, in addition to the phonetics and the amount of uncertainty (i.e. entropy) and surprisal associated with each consonant in the acoustically ambiguous system of which they formed part. Thus, the frequency of the sounds involved plays a decisive role in the changes in question, as the dento-alveolar and palatal sibilants display a much lower occurrence than the alveolar /s/, whose higher probability suggests a stronger perceptual bias towards this sound, hence making it more identifiable than the other two sibilants.

3. Information Theory

Initially put forth by Shannon (1948), and later developed by Cover & Thomas (2006), Information Theory has the central goal of determining the most efficient way of conveying a piece of information from one place to another, considering the various restrictions of a communication system (e.g. noise). One of the mechanisms to calculate this efficiency is entropy (H), which is “a probabilistic measure of the amount of uncertainty associated with selecting among outcomes, each occurring with a particular probability” (Hume & Mailhot, to appear). The higher the probability of a sound’s occurrence in a given phonological context, the more crucial it is for effective communication. Therefore, entropy reveals itself as crucial for understanding the dissimilation of sibilants in medieval Spanish, since it offers a mathematical tool to measure each sibilant’s contribution to the effectiveness of Spanish as a system of communication. If it is right to assume that sibilant dissimilation took place in an intervocalic environment (Lloyd 1987, Penny 2002), then it is possible to calculate and examine the entropic contribution of each sibilant in this phonological environment.

In addition to entropy, another mechanism of Information Theory is represented by the continuous measure of surprisal (S) (or information content) of each element, which takes values from 0 to ∞ and correlates inversely with the probability of this element. In mathematical terms, it represents the negative logarithm of its probability, as illustrated by the formula in (d):

$$(d) \quad S(x_i) = -\log_2 P(X = x_i)$$

where X may be a set of possible outcomes $\{x_1, x_2, \dots, x_i\}$, having each a probability value, $P(X = x_i)$.

As argued in Hume & Mailhot (to appear), the entropic contribution of a given element is its probability multiplied by its surprisal, which is represented by the formula in (e):

$$(e) \quad H_c(x_i) = -P(X = x_i) * \log_2 P(X = x_i)$$

The entropy of an entire system, then, will be the sum of each element’s entropic contribution, as stated in (f):

$$(f) \quad H(X) = -\sum P(X = x_i) * \log_2 P(X = x_i)$$

Thus, if we are able to calculate the frequency and probability of each sibilant in the intervocalic environment where their dissimilation occurred, it is also possible to determine their entropic contribution and examine how efficient the system is. As will be shown in section 5, the dento-alveolar and palatal sibilants occurred with a much lower probability than alveolar /s/, thus contributing less to the entropy of the system of which they formed part and, as less frequent sounds, they were also prone to be the target of diachronic change.

In addition to frequency and probability, the phonetics of the sibilants in question also play a role in the dissimilatory changes and thus must be addressed. In the following section, I summarize the acoustic features of such sibilants, which suggest an unstable system, the perceptual ambiguity of which contributed to the contrast enhancement observed after the dissimilation.

4. The phonetics of fricatives

As pointed out by Ladefoged & Maddieson (1996), fricative sounds result from a precise constriction between articulators, which generates a turbulent airstream in the vocal tract. Sibilant fricatives, in particular, tend to have high frequencies in the spectrum and, during their articulation, “an exactly defined shape of the vocal tract has to be held for a noticeable period of time” (*Ibid.*: 137). The frequency of their frication changes according to the point of constriction: fricatives that are realized further back from this point present, in general, lower frequencies. Additionally, Ali et al. (2001) show that the place of articulation of fricatives can be discriminated by their frication noise properties, such as frequency locus, spectral shape, and intensity. (For a full review of the articulatory patterns of sibilants, see Ladefoged & Maddieson 1996:145-164.)

In terms of noise frequency of Spanish fricatives, /s/ presents the highest noise frequency, while /x/ has the lowest, as indicated by the spectral peaks in Table 1 (Borzone de Manrique & Massone 1981; Quilis 1999):

Table 1. Spectral peak location of Spanish fricatives

<i>Spanish fricative</i>	<i>Spectral peak (Hz)</i>
/s/	5000
/ʝ/	3500
/ʃ/	2500
/x/	1000

Regarding Spanish interdental fricative /θ/, Quilis (1999) suggests a spectral peak value of around 1000Hz, although little agreement exists in this respect as compared to other languages (cf. Ladefoged 2001:182; Ladefoged & Maddieson 1996:143).

A comparison between the acoustic data of the former sibilant set and the acoustics of the resulting fricatives indicates that the acoustic distance in the former is considerably shorter than in the latter. This fact suggests that a perceptual confusability in the set /ʝ, s, ʃ/ may have been very likely in 16th century Spanish, which could have resulted in an unstable system whose fate was to dissimilate and disperse in order to enhance the contrast among these consonants, an issue correctly addressed in Baker (2003). However, phonetic facts alone do not suffice to explain the changes in question, as they ignore the unequal probability of occurrence for each sibilant consonant. Moreover, they overlook the fact that other languages also present a similar sibilant and/or fricative configuration that Spanish does, but which has not undergone the same process of dissimilation, as in the case of Modern Portuguese for example, which still has both /s/ and /ʃ/, in addition to /x/.

Therefore, in addition to their phonetic features, the probability of sibilants to occur in an intervocalic environment and their contribution to the entropy of the system also plays a crucial role in the changes in question. As argued in Hume & Mailhot (to appear), low-frequency sounds contribute less to a system’s entropic value and reveal themselves as more unstable than high-frequency sounds, hence their high probability of becoming the target of diachronic change. In the next section, I provide an account of how Information-theoretic tools, such as probability and entropy, help to understand the motivations behind the dissimilatory changes in the 16th century Spanish sibilants.

5. An Information-theoretic account of sibilant dissimilation

Let us assume, for our purposes, that the consonant system of 16th century Spanish consisted of the following three sibilants: $C = \{\text{ʃ}, \text{s}, \text{ɰ}\}$, which contrasted in intervocalic position, V_V . If we find the frequency with which each of these consonants occur in this phonological environment, then it is also possible to calculate their probability and their entropic contribution.

The frequency of each sibilant in intervocalic position was retrieved from 323 literary and non-literary texts written in the 16th century and provided by the online *Corpus del Español* (Davies 2002-), which was accessed on September 24 and 25, 2011. In order to compensate for the lack of oral corpora from said century, orthography plays a key role in the identification of the target sounds. According to descriptions of the orthographic system of medieval Spanish, the letters <ç> and <z> (and <c> before <e> and <i>) were considered to represent the dento-alveolar consonant /ʃ/, while <x> and <j> (and <g> before <e> and <i>) represent the palatal /j/, and <s> and <ss> represent alveolar /s/.

As each vowel of the five-vowel system /i, e, a, o, u/ could potentially occur either before or after a sibilant consonant, a total of twenty-five possible VCV combinations for each sibilant was extracted from the corpus search, which included all lexical categories. Table 2 summarizes the results obtained:

Table 2. Frequency and probability values of sibilants /ʃ, s, j/ in the context V_V in the 16th century

Sibilant	Occurrences	Probability
[ʃ]	117,403	.291
[s]	195,180	.484
[j]	90,244	.224

Total occurrences of [ʃ, s, j] in V_V context: 402,827.

As Table 2 indicates, both the dento-alveolar and the palatal sibilants presented a much lower probability of occurrence than the alveolar sibilant did in an intervocalic context. Using the formula in (e), we are now able to calculate each sibilant's entropic contribution to the system, as illustrated by Table 3.

Table 3. Entropic contribution of each sibilant [$H_c(x_i) = -P(X = x_i) * \log_2 P(X = x_i)$]

Sibilant consonant	Calculation	Entropic value
/ʃ/	$H_{\text{ʃ}} = -0.291 * \log_2 0.291 =$	0.518244
/s/	$H_{\text{s}} = -0.484 * \log_2 0.484 =$	0.506709
/j/	$H_{\text{j}} = -0.224 * \log_2 0.224 =$	0.483488

As seen in table 3, the entropic value of alveolar /s/ suggests a more stable sound than the other two sibilants, which is in agreement with a prediction of the Information-theoretic machinery, i.e. high and low values of entropic contribution make sounds contribute less to predicting the outcome from a pool of possibilities (in this case, the probability of which sibilant occurring in a V_V context) and are thus less crucial for effective communication. As a result, they reveal themselves unstable, and therefore, are prone to undergo diachronic change (Hume and Mailhot, to appear).

The question of why only the dento-alveolar and palatal sibilants changed in Castilian Spanish, as opposed to alveolar /s/, may now be addressed under more scientific terms. By considering the phonetics of 16th century Spanish sibilants, we are able to argue that they are acoustically—and also articulatorily—unstable, hence their possibility of being misinterpreted by speakers. However, what constitutes this likely “confusability” is not only the inherent quality of the sibilants in question, but also how often they occurred in the system to which they belonged and in the phonological context where their dissimilation took place.

The data provided in Tables 1 and 2 indicate the probability of expecting each sibilant in the context V_V . The higher probability of the alveolar sibilant suggests that there is a stronger bias towards [s], both perceptually and articulatorily, making this sound more identifiable, and as a result, contributing more to conveying the information within a given message and ensuring success in the spoken communication between speaker and listener. Meanwhile, the dento-alveolar and palatal

sibilants reveal themselves as unstable and confusable not only due to their articulatory and acoustic proximity to [s], but also because of their lower frequency in the context V__V, hence contributing less to conveying the information of a given a message and thus representing the target of diachronic change.

6. Conclusion

Utilizing the notions of frequency, probability and phonetic features, this paper provides an integrated and quantifiable communication-based account of sibilant dissimilation in the history of Spanish. While the acoustic and articulatory features of the 16th century sibilant set suggest a perceptually confusable and unstable system, it is shown that the frequency of each consonant plays a decisive role in predicting their occurrence in the context where the changes occurred, with the higher probability of alveolar /s/ suggesting a higher perceptual bias towards it. On the other hand, the lower probability of the dento-alveolar and palatal sibilants in an intervocalic environment amounts to their phonetic instability in relation to alveolar /s/ and provides an insight to their evolutionary pathways, with the resulting fricatives /θ/ and /x/ being more perceptually distinct, and therefore, less confusable. However, the results of this preliminary investigation are by no means definitive. The analysis presented here, based on data gathered from the online *Corpus del Español* (Davies 2002-), represents only a first step toward a thorough understanding of sibilant dissimilation in the history of Spanish viewed through the lens of Information-theoretic premises. In order to further the investigation on this sound change, research is already underway with the collection of data from other corpora, such as the *Corpus diacrónico del español* (CORDE). A comparison of the results provided by the data from different corpora may not only support the current analysis, but also reveal the substantial contribution that the Information-theoretic machinery provides for a scientific examination of phonological issues and for the study of sound change.

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Selected Proceedings of the 15th Hispanic Linguistics Symposium

edited by Chad Howe, Sarah E. Blackwell,
and Margaret Lubbers Quesada

Cascadilla Proceedings Project Somerville, MA 2013

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This paper can be cited as:

Zampaulo, André. 2013. Sibilant Dissimilation in the History of Spanish: An Information-Theoretic Approach. In *Selected Proceedings of the 15th Hispanic Linguistics Symposium*, ed. Chad Howe et al., 172-178. Somerville, MA: Cascadilla Proceedings Project. www.lingref.com, document #2883.