INTERSPEECH 2021
30 August – 3 September, 2021, Brno, Czechia

Synchronic Fortition in Five Romance Languages? A Large Corpus-Based Study of Word-Initial Devoicing

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Abstract

Devoicing is a process whereby a voiced consonant such as /bdg/ is realized as voiceless [ptk]. Some theorists [1,2] propose that this phenomenon is an instance of fortition, or consonant strengthening, especially when it occurs word-initially. This study proposes an in-depth exploration of voicing alternations in word-initial position in five Romance languages (Portuguese, Spanish, French, Italian, Romanian) using large corpora (ca. 1000h of speech) and automatic alignment. Our results show that (i) there is initial devoicing in all languages, and (ii) this devoicing is conditioned by the preceding context. This allows the languages to be divided into those displaying (a) only phrase-initial fortition (Spanish), (b) phrase-initial and post-obstruent fortition (French, Romanian and possibly Italian) and (c) generalized word-initial fortition (Portuguese).

Index Terms: phonology, voicing alternations, fortition, Romance languages, large corpora, automatic alignment.

1. Introduction

Devoicing is a process whereby a voiced consonant such as /bdg/ is realized as partially or totally voiceless [ptk]. Some historical theorists propose that this phenomenon is an instance of fortition, or consonant strengthening, especially when it occurs word-initially [1, 2]. However, its synchronic basis has been rarely investigated, although such studies are crucial to deepen our understanding of fortition in diachronic evolution as well as synchronic variation and, subsequently, to complete the current state of knowledge on linguistic change in general.

The present study aims to answer the following questions: (i) Is there synchronic initial devoicing in Romance languages? (ii) If so, is initial devoicing conditioned by its position in connected speech, i.e. can it be considered as fortition?

To answer these questions, we present an in-depth exploration of voicing alternations in word-initial position in five contemporary Romance languages (Portuguese, Spanish, French, Italian and Romanian) using automatic alignments to facilitate the study of large corpora (ca. 1000 hours of speech).

In the remainder of this paper, we first present a clearer picture of devoicing (2.1) and fortition (2.2). In Section 3, we show how our method, relying on large corpora and automatic speech recognition (ASR) tools, can contribute to these theoretical questions by describing the corpora (3.1) and methodology (3.2). In Section 4, we present and discuss our results followed by the conclusion in Section 5.

2. Devoicing and fortition

2.1. What is devoicing?

Voice is a commonly used feature, called *laryngeal feature*, referring to the vibration of the vocal folds – or absence thereof – during the production of a consonant. In the Romance languages under survey here, the laryngeal feature is distinctive in that the opposition between voiceless and voiced obstruents allows minimal pairs to be distinguished as in (1).

(1)	Por	***t**odo*, 'all'	***d**odo*, 'dodo'
	Spa	***t**odo*, 'all'	***d**odo*, 'dodo'
	Fre	***t**out*, 'all'	***d**oux*, 'sweet'
	Ita	***t**olce*, 'take away'	***d**olce*, 'sweet'
	Rom	***t**op*, 'top'	***d**op*, 'cork'

Devoicing is thus the process whereby a voiced consonant such as /bdg/ is realized with partial or total loss of the vibrations of the vocal folds and is realized as voiceless [ptk].

According to [3], word-initial consonants in particular are prone to devoicing, and that for two reasons: (i) utterance-initial as well as post-obstruent onsets lack all voicing cues normally residing in the preceding vowel or sonorant (the vowel's duration, F0, F1 values at the onset of closure) and may lack the closure duration cue: all things being equal, the word-initial context is less likely to maintain voicing contrasts than the intervocalic context; and (ii) the vibration of the vocal folds during the obstruent's closure will be more difficult to insure in utterance-initial (and, by paradigmatic extension, word-initial) position, because of insufficient subglottal pressure [4, 5]. Note that, according to [3], in the historical acquisition of systematic initial devoicing, utterance-initial positions are affected first, and then the pattern spreads to all word-initial positions.

Word-initial devoicing in synchrony has been the subject of some recent phonetic studies. It has been shown that Tokyo Japanese voiced stops are pre-voiced in word-internal position but show a high devoicing rate in word-initial position, in particular before pause [6]. The exploration of well-known word-initial devoicing of /b/ and /v/ in Dutch showed that the fricative clearly devoices more than the stop but did not delve into the phonetic causes of these realizations [7]. A recent study on devoicing in Romance languages can be found in a paper dealing more broadly with voicing alternations in all word positions [8]. However, devoicing has been massively less studied than its counterpart-phenomenon, voicing.

http://dx.doi.org/10.21437/Interspeech.2021-939

2.2. Fortition as a positionally conditioned strengthening

Fortition usually refers to a process whereby a segment is "strengthened" and originally stems from the observation of language evolution. It can be naively defined as the 'opposite' of lenition, a well-known process whereby a consonant is "weakened": "a segment X is said to be weaker than a segment Y if Y goes through an X stage on its way to zero" (Venneman in [9, p. 165]). Since voicing is a common lenition process (ex. Lat. pa**t**rem → pa**d**rem → pe**ð**re → Fr. *père*) [1, 10], we assume that devoicing is its counterpart, a fortition process (on whether final devoicing is fortition, see [11] *vs* [12]; on the definition of fortition and its relationship to lenition, see [1, 13, 14, 15]).

From the observation of the evolution of Romance languages, Ségéral and Scheer [1] propose that strong positions are so-called "onset" positions, i.e. word-initial (#_) or after a heterosyllabic consonant (C._), while weak positions are intervocalic (V_V) or so-called "coda" positions, i.e. word-final (_#) or before a heterosyllabic consonant (_.C). If we extend these results to the word-initial position in connected speech, this suggests that word-initial devoicing could be considered as fortition if it happens in the fortifying contexts: (i) at the beginning of the utterance, and (ii) when the preceding word ends in a consonant (ex. Fr. *ba/g/ **v**erte,* 'green ring'). To this effect, we examine the rate of word-initial fortition as a function of the preceding context: after a pause (strongest context), a consonant (strong context), and a vowel (weak context). Note that after a voiceless obstruent (ex. Fr. *ba/k/ vert*, 'green tray'), word-initial devoicing may be due to progressive voicelessness assimilation. The determining context here is then after voiced consonants, where devoicing could only be due to fortition.

Finally, we wish to find out how sonorants behave in this regard. As specified above, a segment is in strong position if it appears after a heterosyllabic consonant. Yet, whether sonorants belong to this fortifying group is language-specific. For instance, in the evolution of Latin into French or Romanian, the post-sonorant context was a fortifying context, in the sense that lenition did not occur in this position: Lat. tal**p**a → Fr. tau**p**e and not *tau**b**e or Lat. can**t**are → Ro. cân**t**a and not *cân**d**a. However, in other languages, post-coda consonants are strong only after obstruents (voiced and voiceless alike) and line up with weak intervocalic consonants if the preceding coda is a sonorant. For example, in American English, the flapping of /t/ does not occur after obstruents (*doc**t**or*) but does both intervocalically (*ci**t**y*) and after sonorants (*par**t**y*). A subsidiary question this study addresses is whether sonorants constitute a fortifying context or not: in languages where word-initial consonants tend to devoice after an obstruent, do they also devoice after a sonorant?

3. Data and methodology

Voicing alternation in word-initial position is a very precise issue. Examining this question in large corpora allows the quantification of such a variable tendency under less supervised settings than laboratory recordings, and the larger the corpora, the more precisely the phenomenon can be described [16]. The question of fortition is an old one, and most studies focus on comparative linguistics and reconstruction to assess its existence and functioning. Our approach is innovative in that it proposes an investigation of a typically theoretical question using methods generally not accessible to phonologists.

To that extent, we build on a study that compares alternation patterns in five Romance languages and shows that the stops' realizations are influenced by both the stops' position in the word and its adjacent (left and right) segments [8]. Our goal is to push this preliminary study towards more detailed results to answer more theoretical questions in both phonology and historical linguistics.

3.1. Corpora

A corpus containing almost 1000 hours of spoken data from five Romance languages, Portuguese, Spanish, French, Italian, and Romanian, is used in this study. Since these languages are widely spoken, both data and speech recognition technology are available for each of them. The languages are comparable in that they share some features due to their common Latin origin but also diverge because of their individual evolution over time.

All corpora are comprised of broadcast news (prepared speech) and conversations (semi-prepared speech) usually addressing a large audience of the general population and thus generally representing the standard varieties of the languages, although multiple dialects are covered for European and Latin American Spanish (and possibly Portuguese).

There are associated manual reference transcriptions for all of the audio data, with the exception of Romanian for which only 7 hours are manually transcribed, and the remainder automatically transcribed with a Romanian speech-to-text transcription system [17]. Baseline pronunciation dictionaries with canonical forms are also available for all languages. Table 1 specifies, for each language, the quantity in hours, the number of word tokens and word types, and average number of pronunciations per word in the variant lexicons.

Table 1: *Data characteristics: language, duration of the corpus (in hours), number of word tokens (in millions, M) and word types (in thousands, k), mean number of variants/word when allowing voicing alternation for each stop occurrence.*

Language	nb of hours	word token (M)	word types (k)	nb of variants
Portuguese	114	1.0	40.0	3.7
Spanish	223	2.6	61.9	4.4
French	176	2.4	55.7	6.8
Italian	168	1.8	57.0	5.3
Romanian	300	3.6	48.0	3.7

These corpora were acquired from the Linguistic Data Consortium (LDC) or from the European Language Resources Association (ELRA) or developed in the framework of international research projects [8].

3.2. Methodology

This study adopts the method proposed by Adda-Decker and Hallé [18] to study voicing alternations of the stops /ptkbdg/ by introducing specific variants in the pronunciation dictionaries used to produce forced alignments. The augmented lexicons contain both each word's so-called canonical pronunciation and potentially altered, non-canonical variants [19]. The (language-specific) speech recognition system is then used to carry out a forced alignment of the speech with the reference transcription, using the original (canonical) or augmented (canonical + variants) pronunciation dictionary, allowing the system to select the best matching pronunciation during the process. In-house speech recognition systems for each language, all comparable in terms of architecture, were previously trained on the same type of data as selected for the study (cf. [8]).

Therefore, voicing and devoicing are decided based on whether the best matching phone model corresponds to the original canonical phone or to the voiced or devoiced variant respectively. Hence, if the acoustic realization of the consonant best matches the corresponding model, the system can select:

- for any occurrence of a voiced stop /bdg/, its voiceless counterpart [ptk] (fortition)
- for any occurrence of a voiceless stop /ptk/, its voiced counterpart [bdg] (lenition).

For instance, the Romanian word *dop*, /dop/ could be transcribed either as [**d**op] or [**t**op].

This method, using large corpora and automatic alignment with pronunciation variants, has proven reliable and useful to the investigation of fine-grained phonetic variation and in particular of voicing alternations in several recent works on Spanish [20, 21], French [22, 23, 24] and Romanian [24, 25].

3.3. Data

Since there is no evidence that branching onsets behave differently than simplex ones [1], we did not proceed to any selection and took all initial stops into consideration. In total, ca. 3.4 million initial stops were analyzed, as shown in Table 2.

Table 2: *Count (in thousands, k) for each word-initial stop in each language*

	Nb of voiceless stops			**Nb of voiced stops**			**Total nb of stops**
	p	t	k	b	d	g	
Por	74	34	88	9	98	7	310
Spa	273	123	364	107	358	35	1,260
Fre	190	80	166	44	269	17	766
Ita	46	23	61	7	68	5	210
Rom	231	81	224	41	301	23	901
Total	814	341	903	208	1,094	87	3,447

4. Results

In this section, we answer our questions regarding the existence of initial devoicing in Romance languages (4.1), whether it is conditioned by positional factors (4.2) and, if so, how sonorants behave (4.3).

4.1. Is there initial devoicing in Romance languages?

In our data, non-canonical voicing of voiceless stops occurs in only 5 to 7% of the instances, while non-canonical devoicing of voiced stops occurs at rates varying from 5 to 20%, as shown in Table 3.

Table 3: *Rates of non-canonical realizations for each canonical stop in each language.*

	p	**t**	**k**	**ptk**	**b**	**d**	**g**	**bdg**
Por	6.6	7.4	7.5	**7.1**	11.9	21.8	12.8	**20.4**
Spa	5.5	7.6	9.5	**7.8**	13.0	11.0	12.9	**11.6**
Fre	8.1	6.0	8.1	**7.7**	11.0	9.7	11.2	**9.9**
Ita	6.7	4.2	9.2	**7.4**	7.1	4.8	8.3	**5.2**
Rom	5.7	4.5	5.5	**5.4**	4.7	6.3	8.4	**6.3**

Notably, voiced stops have a much higher tendency to be devoiced in Portuguese than in any other language, which is in line with [26]. All languages except Italian show more devoicing than voicing for word-initial consonants, which is consistent with the definition of the word-initial position as a "strong" one. The Italian exception might be due to the fact that a phonological standard in Italian does not exist *de facto*, and that our results may be biased by the geographical background of the speakers. Refined investigations will be the topic of future research.

4.2. Is devoicing conditioned by positional factors in Romance languages?

To establish whether Romance languages display word-initial fortition, i.e. devoicing after pause and possibly obstruents and not after voiceless obstruents only, we split the data into 5 categories depending on whether the onset was preceded by a pause (hesitation, breath or silence) or by another word beginning with a voiceless obstruent, a voiced obstruent, a sonorant, or a vowel. The results are shown in Figure 1.

Figure 1 shows that Portuguese stands out with the highest rates of word-initial devoicing. This result is in line with [26] who show that the voicing contrast in Portuguese is acoustically closer to German than to Italian, in that phonologically voiced stops show little voicing. Moreover, in the same data analyzed in [8], the devoicing effect is stronger in word-initial position, with an overall 22.6% devoicing rate, than in word-internal position, for which the authors report an 11.4% devoicing rate. Thus, Portuguese does show a special devoicing effect in word-initial position. However, while the high rate of devoicing after a voiceless obstruent (30.25%) suggests a progressive assimilatory effect, the difference between the devoicing rates after pause (the strongest position) and vowel (the weakest one) is only 2.03% (χ^2=25.301, df=1, p<0.0001), suggesting that the observed word-initial devoicing is indeed generalized.

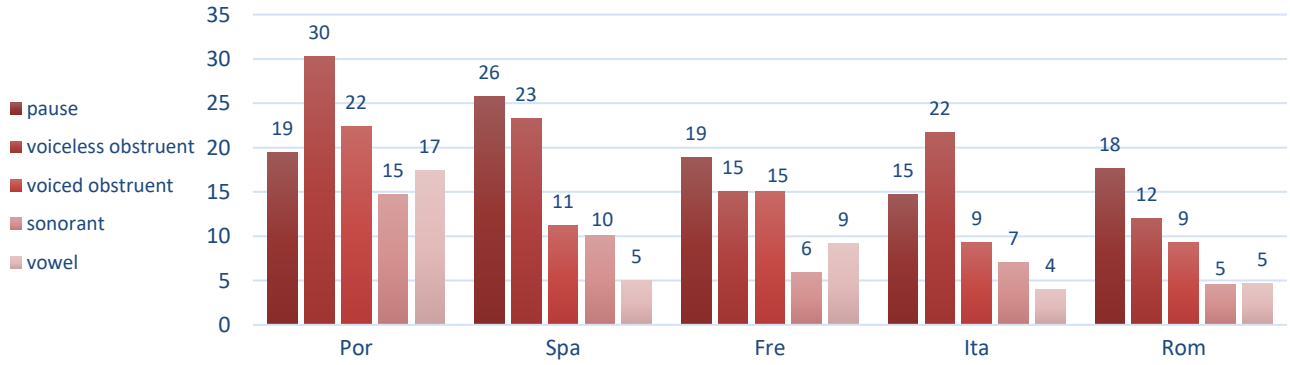

Figure 1: *Rates of word-initial devoicing as a function of the preceding context by language.*

In Spanish, word-initial devoicing is clearly stronger in two positions: utterance-initially (25.80%) and after a voiceless obstruent (23.30%). The second case could be analyzed as the result of progressive voicelessness assimilation. Since we find only 11.21% after a voiced obstruent (δ=14.59%, χ^2=913.43, df=1, p<0.0001), we conclude that word-initial devoicing in Spanish is limited to the utterance-initial position. Note that Spanish voiced stops /b, d, g/ are spirantized [β, ð, ɣ] in intervocalic position, including across a word boundary (V#CV) [21, 27]. We could therefore hypothesize that the phone models of /bdg/ correspond to a somewhat spirantized consonant, and that what is captured here as "devoicing" is the fact that the consonant is realized as occlusive in utterance-initial position. However, this realization is also expected after an obstruent (ex. Sp. *pared [**b**]erde*, 'green wall'), yet this parallelism between post-vocalic and post-obstruent context is not reflected by our results. Our results thus suggest a true tendency towards devoicing in utterance-initial position.

French behaves differently since the devoicing rates are similar after voiceless (15.00%) and voiced (15.03%) obstruents (δ=0.03%, χ^2=0.0050063, df=1, p=0.9), suggesting that devoicing is not due to progressive assimilation (in which case we would expect a difference between *ba[k] vert* and *ba[g] verte*) but is rather linked to the phonologically strong post-obstruent position. This is also supported by the fact that the utterance-initial position shows little difference from the post-obstruent context (δ=3.88%, χ^2=154, df=1, p<0.0001). Word-initial devoicing, however, is significantly weaker in the post-vocalic context (9.19%, δ=9.70%, χ^2=2071.1, df=1, p<0.0001).

Italian can be compared to Spanish and Portuguese in that we also find a high degree of devoicing after voiceless obstruents (21.74%). In the other contexts, we find that devoicing is barely stronger in utterance-initial position (14.68%) than after voiced obstruent (9.29%, δ=5.40%, χ^2=2.791, df=1, p=0.09). Although these results rely on a small number of occurrences (n=140), this suggests that, like French, there might be some post-obstruent devoicing in the language. The post-voiced obstruent context, finally, triggers significantly more devoicing than the post-vocalic one (3.96% after vowel, δ=10.72%, χ^2=1486.9, df=1, p<0.0001).

Finally, like French, Romanian initial devoicing happens at similar rates after voiceless (11.98%) and voiced (9.26%) obstruents (δ=-2.72%, χ^2=28.653, df=1, p<0.0001), suggesting that, in this language too, devoicing is not due to progressive assimilation but rather to the phonologically strong post-obstruent position. Moreover, this post-obstruent devoicing is similar to the post-pausal one (17.61%, δ=5.94, χ^2=450.4, df=1, p<0.0001) but not to the post-vocalic one (4.69%, δ=12.92%, χ^2=6265.7, df=1, p<0.0001).

In these last three languages, we thus find two degrees of fortition: in utterance-initial position, and to a lesser degree after an obstruent.

In conclusion, the devoicing rates are high after pause, suggesting at least utterance-initial fortition, in all five languages. In Portuguese, Spanish and Italian, there is also progressive voicelessness assimilation. In French, Romanian, and possibly Italian, there is also post-obstruent devoicing. In Portuguese, devoicing seems to be generalized to all word-initial positions. Inspired by [1] and [3], we conclude that the languages can be divided into three phases as to the extent of fortition:

- Phase I: phrase-initial fortition only, as in Spanish,
- Phase II: phrase-initial and word-initial fortition after a heterosyllabic consonant, as in French, Romanian, and possibly Italian,
- Phase III: word-initial fortition in any context, as in Portuguese.

4.3. Are sonorants a fortifying context?

To establish whether sonorants are a fortifying context, we should show that sonorants favor devoicing in languages where all preceding obstruents, voiceless and voiced, favor it as well, i.e. in the languages in Phase II.

The results thus concern exclusively French, Italian and Romanian., The post-sonorant context triggers a lower rate of devoicing than the post-voiced obstruent context in both French (5.87% *vs* 15.03%, δ=9.16%, χ^2=1200.9, df=1, p<0.0001) and Romanian (4.58% *vs* 9.26%, δ=4.68%, χ^2=1200.9, df=1, p<0.0001), thus regrouping with vowels. In French, vowels surprisingly trigger a stronger rate of devoicing than sonorants (9.19% *vs* 5.87% respectively, δ=3.32%, χ^2=556.24, df=1, p<0.0001). In Romanian, sonorants behave like vowels (4.58% *vs* 4.69% devoicing respectively, δ=-0.04%, χ^2=1.3493, df=1, p=0.2). As exemplified in 2.2, sonorants have been a fortifying context in the evolution of these two languages from Latin. Our results suggest that in contemporary French and Romanian, sonorants seem to have lost their status as fortifying consonants.

In Italian, however, devoicing after sonorants (7.05%) is closer to that after voiced obstruents (9.29%, δ=2.23%, χ^2=0.72175, df=1, p=0.4) than that after vowels (3.96%, δ=-3.09%, χ^2=130.91, df=1, p<0.0001), suggesting that in this language, sonorants align with the fortifying context. Italian seems to show an intermediate stage where word-initial voiced stops may be devoiced in utterance-initial position (14.68%), less so, but without statistical significance, after a voiced obstruent (9.29%) and a sonorant (7.05%) and very little after vowels (3.96%).

5. Discussion and conclusion

In this paper, we investigate word-initial voicing alternations in five Romance languages with the goal of extending our understanding of fortition, lenition's lesser-known counterpart.

We take advantage of recent approaches in linguistic investigation by making use of methods allowing to confront hypotheses with large corpora to fuel phonological debates with new information. We establish that all languages seem to display phrase-initial fortition, but only French, Romanian and possibly Italian seem to display word-initial fortition after heterosyllabic consonants (Phase II) and Portuguese word-initial fortition in any context (Phase III). Our results also show that in Romanian and French, sonorants have lost their historic status as fortifying contexts, now aligning with vowels.

This preliminary study of word-initial voicing alternation would benefit from investigating more finely several factors such as speaker gender or regional varieties or from adding more parameters such as various speech styles. Nevertheless, it helps better understand fortition in major Romance languages, and can be the starting point of many new studies on the subject.

6. Acknowledgements

This research was partially supported by DigiCosme (project ANR-11-LABEX-0045-DIGICOSME) and DATAIA / MSH Paris-Saclay "Excellence" grant, as well as the Labex EFL.

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