# Lenition of word-final plosives in Basque

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## ABSTRACT

Basque has a phonological contrast between voiceless /ptk/ and voiced /bdg/ in onset position. Word-finally there is only /t/ and /k/. These word-final consonants, although rare stem-finally, have great textual frequency, since they are found in several frequent inflectional suffixes. We examine the realization of final /t k/ before a vowel across word boundaries, comparing them with word-medial and word-initial intervocalic consonants. Based on a corpus of natural speech, we test the hypothesis that prevocalic word-final plosives are weaker than other intervocalic plosives, since they do not contrast with voiced phonemes in this position. We test two methodologies for quantifying plosive lenition based on differences in intensity that have been proposed in prior work. Both methodologies returned very similar, but not identical, results. Intensity results are consistent with the hypothesis, especially for velars. /t k/ are also more voiced word-finally than elsewhere.

**Keywords**: Basque, lenition, contextual neutralization, plosives

## 1. INTRODUCTION

We test the effects of phonological contrast on lenition by comparing the realization of intervocalic voiceless stops in Basque across morphological contexts.

Basque has a phonological contrast between voiceless and voiced plosive phonemes in onset position, both word-initially and word-medially (e.g. word-initial: *puru* 'pure', *buru* 'head'; post-consonantal: *arto* 'corn', *ardo* 'wine'; word-medial intervocalic: *ekin* 'undertake', *egin* 'do'). Word-finally, however, only /k/ and /t/ are allowed. These two word-final consonants have very low lexical incidence, but high textual frequency. There are no major-category words that end with a plosive, but several inflectional suffixes end in /t/ or /k/, including, for /t/, the benefactive suffix (e.g. *Peru-rentzat* 'for Peru') and the first person singular transitive subject agreement marker (*daki-t* 'I know'). Suffixes ending in /k/ include the ergative, which marks the subject of a transitive verb (*Peru-k* 'Peru, erg.'), the absolutive and ergative plural (*mendi-ak* 'the mountains'), the partitive (*mendi-rik* 'mountain, part.'), the ablative (*mendi-tik* 'from the mountain') and the second person singular masculine familiar transitive subject agreement marker (*daki-k* 'thou, male, knowest'). In addition, there are several function words ending in /t/, including the numeral/indefinite article *bat* 'one, a'.

Voiceless intervocalic stops have been reported to voice and weaken to approximants, in at least some Basque varieties [10, 11, 23].

In this paper, we examine the realization of word-final plosives before a vowel in a corpus of natural speech, comparing them with intervocalic plosives in other positions. Since only /t/ and /k/ are possible plosives word-finally, we limit our comparison to these two consonants.

Our hypothesis is that word final plosives before a vowel (VC#V) will show greater voicing lenition than plosives in either word-internal intervocalic position (VCV) or word-initially after a vowel (V#CV), given the fact that, word-finally, /t k/ do not contrast with /b g/. We also predict velar /k/ to undergo greater lenition than dental /t/, based on the fact that word-internal intervocalic velar /g/ tends be deleted in many Basque varieties [9, 10]. Intervocalic voiceless velars have also been found to show more lenition than other consonants in Iberian Spanish [13].

Besides examining the effects of morphological context and phonological contrast on intervocalic lenition in Basque, we also have methodological goals in this paper. We compare two methods that have been used in recent work to quantify lenition based on the intensity curve. We would like to determine whether both methodologies produce similar results when applied to the same data.

## 2. METHODS

Our data come from recorded interviews on everyday topics with 6 native Basque speakers from Azpeitia, Gipuzkoa (4 female, 2 male). Among all towns in the Basque Country with over 5000 people, Azpeitia has the highest proportion of Basque speakers (82%). Basque is by far the most commonly used language within the town. The interviewer was also a native speaker of Azpeitia Basque. All participants signed a consent form before being recorded. The conversations took place in Azpeitia, in a quiet place familiar to the participants, and were recorded with a MicroTrack 24/96 digital recorder using a SONY F-720 external microphone.

The recordings were analyzed in Praat [2]. From these recordings we extracted 2482 tokens of /t/ and /k/ in the following contexts: (a) word-final before a vowel (VC#V), (b) word-medial intervocalic (VCV), (c) word-initial following a vowel (V#CV) and (d) word-final before another consonant (VC#C). For this study, however, we are excluding the word-final preconsonantal tokens, as we are focusing on the realization of intervocalic consonants. Only tokens produced without a pause between words have been included.

After removing pre-consonantal tokens and some other tokens for the additional reasons explained below, a resulting total of 2252 intervocalic tokens were analyzed for this paper, with the distribution of contexts shown in Table 1.

**Table 1**. Number of analyzed tokens by context

| | Final | Initial | Medial |
|---|---|---|---|
| k | 180 | 75 | 821 |
| t | 83 | 126 | 967 |

To quantify lenition, we took measurements of intensity between the consonant and the following vowel, as a correlate of the degree of constriction. The less constricted the consonant, the smaller the difference in intensity is expected to be.

Intensity was measured in two different ways. First, we calculated the difference between the intensity maximum and minimum in the CV sequence (*IntDiff*), using a similar methodology as in other work on intervocalic lenition [3, 4, 5, 6, 13, 15, 17, 18,19, 22]. To take this measurement, an interval tier was created in Praat, manually placing boundaries around the target consonant, taking care that the selected intervals contained the minimum intensity in the consonant and the maximum in the following vowel. While delineating the boundaries of lenited consonant can be difficult, exact segmentation is not required for this measurement. The only requirement is for the interval to include the intensity minimum within the consonant and the intensity maximum during the following vowel. Some, but not all, of the studies mentioned above have used high and/or low-pass filters in order to remove energy from voicing at low frequencies and possibly from background noise at high frequencies. For instance, in [22] energy was measured applying a Hann band-pass filter between 250 Hz and 10 kHz. Here, we do not apply a filter and compare the results with the those obtained by applying the methodology described in [7], where changes in energy are taken from a band between 400 Hz and 1200 Hz.

Thus, we used the R script by [7], which focuses on changes in intensity from the beginning of the consonant. To run this script, we created a separate point tier, placing a single boundary near the beginning of each target consonant. Edges of closing and opening gestures are automatically determined from changes in intensity velocity, and segment boundaries are placed in relation to these points. The script returns *Delta-i* (Δi) values, which reflect the magnitude of change in intensity within the defined segment. Tokens where there was no visible dip in intensity or other evidence for a consonantal gesture in the spectrogram were discarded. We take these as instances of consonant deletion. To make the two analyses fully compatible, we removed those tokens from the computation of *IntDiff* as well.

We consider to what extent both methodologies produce similar results. As noted, neither method requires accurate manual placement of segment boundaries. We will use the term *Delta-i* to refer to the results obtained with the script by [7] and *IntDiff* to refer to the measurement that calculates the difference between intensity maximum and minimum within the CV sequence, without applying a filter.

A second potential dimension in the lenition of voiceless stops, besides a decrease in the degree of constriction, is voicing. To analyze voicing separately, we used the intervals created for the *IntDiff* measurement, classifying each token as either fully voiced or not. The voice report in Praat returns the percentage of frames in an interval that are produced as voiced, but since our intervals include not only the target consonant but also part of the following vowel, we are treating voicing as a binary feature. We consider a consonant to be voiced only if there is voicing throughout the entire interval (unvoiced frames in the selected interval = 0 in Praat's voice report). This avoids the need to place exact boundaries at the beginning and end of the consonant. A justification for our binary analysis is that only fully voiced tokens can be said to show potential neutralization between underlyingly voiced and voiceless phonemes [13].

For the statistical analysis of the intensity results, we ran linear mixed effects regressions on *IntDiff* and *Delta-i* in R [20] and RStudio [21] with the function *lmer* in the package *lme4* [1]. P-values were obtained with the Satterthwaite approximation in *lmerTest* [14]. Voicing was analyzed with the function *glmer* (family= binomial) in *lme4*.

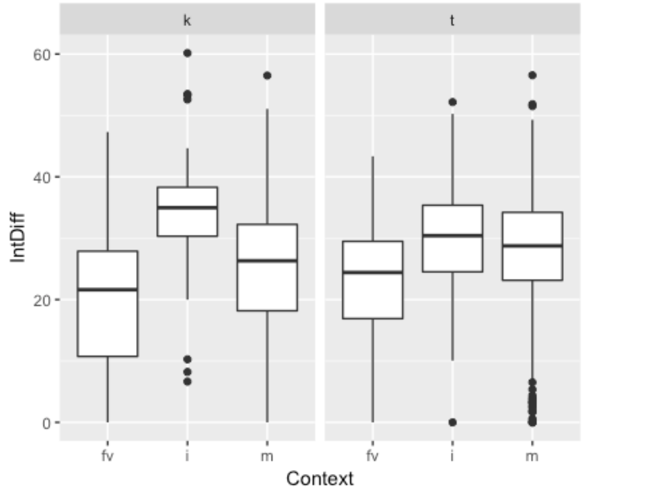
Details regarding the structure of the regressions are given in the results section.

## 3. RESULTS

### 3.1. IntDiff

The boxplots in Figure 1 show the results of our *IntDiff* measurement by context (made with the package *ggplot2* [25]). From visual inspection of the plots, word-final tokens are generally more lenited (smaller *IntDiff*) than other tokens. For /k/, word-initial tokens appear to be strongest.

**Figure 1**: *IntDiff* for /t/ and /k/ by context: fv = word-final prevocalic, i =word initial after a vowel, m = word-medial intervocalic




We ran a linear mixed effects regression on *IntDiff* with Context (three levels: i= V#CV, m=VCV and fv =VC#V), Consonant (two levels: /t/, /k/) and their interaction as fixed factors, and Speaker and Word as random factors.

The output of the regression shows a significant difference between word-final prevocalic and both word-initial postvocalic ($\beta = 13.7$, $t= 10.4$, $p < 0.001$) and word-medial intervocalic tokens ($\beta = 5$, $t= 6.1$, $p < 0.001$), as well between /t/ and /k/, with the velar being more lenited ($\beta = 3.6$, $t= 2.3$, $p = 0.02$).

Post-hoc comparisons (with the package *emmeans* [16]) return significant differences among all three contexts for both consonants, with the initial position being strongest (largest *IntDiff*) and the final position being weakest, see Table 2.

**Table 2**: Post-hoc comparisons, *IntDiff*

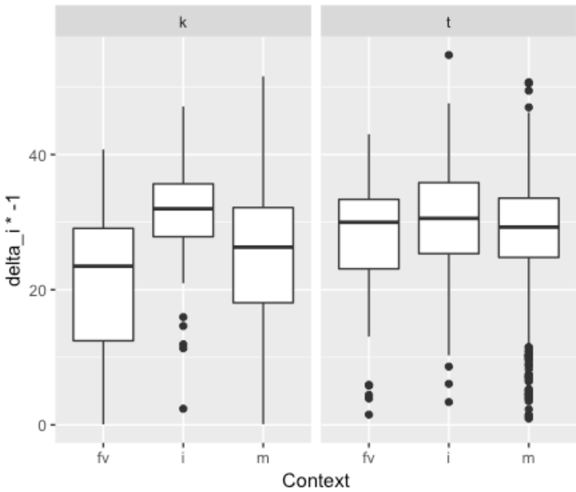
| /k/ | Estimate | t.ratio | p.value |
|---|---|---|---|
| fv-i | -13.7 | -10.4 | <0.0001 |
| fv-m | -5 | -6.1 | <0.0001 |
| i-m | 8.7 | 7.7 | <0.0001 |
| /t/ | | | |
| fv-i | -10 | -4.9 | <0.0001 |
| fv-m | -4.1 | -3 | =0.0076 |
| i-m | 5.9 | 3.7 | =0.0007 |

Regarding our research question, we find that the target intervocalic consonants are more lenited when they are word-final than when they are word-initial or word-medial. The differences between contexts are greater for /k/ and there is a clear hierarchy of strength for this consonant among the three positions examined.

### 3.2. Delta-i

The boxplots in Figure 2 show differences in intensity calculated with the methodology of [7]. The results for /k/ are very similar to those in Figure 1, with a clear effect of position on degree of constriction: initial > medial > final. For /t/, on the other hand, the differences between contexts are less clear in Figure 2 (for ease of comparison, the *Delta*-i output has been multiplied by -1).

**Figure 2**: *Delta*-i for /t/ and /k/ by context: fv = word-final prevocalic, i = word initial after a vowel, m = word-medial intervocalic




*Delta-i* values were modeled as the dependent value in an *lmer* with the same structure as the one for the *IntDiff* results. Significant effects were found for both fixed factors. Regarding context, word-final is significantly weaker than word-initial ($\beta = 10$, $t= -8.3$, $p < 0.001$) and word-medial ($\beta = 3.8$, $t= 4.9$, $p < 0.001$). There is also a significant difference between /t/ and /k/, with the velar being weaker ($\beta = 7$, $t= 4.9$, $p =0.001$). An interaction was also found between Consonant and the comparison between the final and initial positions ($\beta = -4.8$, $t= -2.1$, $p =0.032$).

In post-hoc comparisons with *emmeans*, all three place comparisons are significant for /k/ ($p < 0.0001$), but for /t/, only final vs initial and initial vs medial contexts approach significance at the $p <0.01$ level (see Table 3).

**Table 3**: Posthoc comparisons, *Delta-i*

| /k/ | Estimate | t.ratio | p.value |
|---|---|---|---|
| fc-i | -10 | 8.3 | <0.0001 |
| fv-m | -3.8 | -4.9 | <0.0001 |
| i-m | 6.3 | 6.1 | <0.0001 |
| /t/ | Estimate | t.ratio | p.value |
| fv-i | -5.2 | -2.2 | =0.016 |
| fv-m | -0.9 | -0.7 | =0.8 n.s. |
| i-m | 4.3 | 2.9 | =0.0103 |

### 3.3. Voicing

Regarding voicing, word-final prevocalic consonants also show a greater propensity to be realized as fully voiced than other tokens in intervocalic position. On the other hand, word-initial postvocalic consonants are almost never fully voiced (see Table 4). Both medially and finally, /k/ voices more often than /t/.

**Table 4**: Percent of fully voiced tokens of intervocalic /t/ and /k/ by morphological context

| Context | /t/ | /k/ |
|---|---|---|
| Final VC#V | 13/83 (15.7%) | 58/180 (32.2%) |
| Initial V#CV | 7/127 (5.5%) | 3/75 (4%) |
| Medial VCV | 85/976 (8.7%) | 146/821(17.8%) |

A binomial mixed-effects logistic regression was fit to the voicing data with the same fixed effects structure as for the intensity data and with Speaker as a random factor. (A model including Word as an additional random factor failed to converge). Our statistical model returned a significant effect of consonant, where /k/ is significantly more likely to be realized as fully voiced than /t/ ($\beta$ = -1.0279, z= -2.588, $p < 0.01$). Intervocalic /t/ and /k/ are voiced with significantly higher frequency when word-final than when word-initial ($\beta$ = -2.6626, z= -4.161, $p < 0.001$) and word-medial ($\beta$ = -1.0594, z= -4.665, $p < 0.001$). No significant interaction between consonant and context was found.

Although we chose to focus on numbers of fully voiced tokens in each context for the reasons mentioned above, an analysis based on 'fractions of locally unvoiced frames' in each token returns fully comparable results, with more voicing for /k/ than for /t/ and the same hierarchy among contexts.

### 3.4. Comparison of the results of methods of quantifying lenition

The two intensity measures that we have employed show a relatively strong correlation, r = 0.7087. Our *IntDiff* and our *Delta-i* measurements produced more similar results for /k/, as is clear from comparing the left-hand panels of Figures 1 and 2 (for /k/ only, r = -0.7454). Regressions using these two measurements as the dependent variable returned a significant effect of context, with the initial context being the strongest and the final context being the most lenited. We thus conclude that there is a strong effect of word position on the lenition of /k/ that is captured by both measurements.

For /t/, on the other hand, the measurement that is used matters. Whereas the regression on *IntDiff* returned a significant difference between final tokens of /t/ and tokens in other positions (as well as initial vs final), the regression on *Delta-i* found much smaller differences.

The explanation for the difference in the results of applying the two methodologies may be that *Delta-i* excludes energy at low frequency ranges, where the voice bar is found, and *IntDiff* does not (since intervocalic /t/ is most often realized as fully voiced when word-finally and least frequently when word-initial). To answer this question more directly, a voice report could be obtained for the intervals created to calculate *Delta-i* by adding this functionality to the script.

As mentioned for /k/, on the other hand, the correlation between *IntDiff* and *Delta-i* is somewhat higher and the statistical results are very similar. We may suspect that for /k/, voicing and the reduction of the oral gesture tend to go hand in hand more frequently than for /t/. This difference between the lenition of /k/ and /t/ is consistent with what we know about the allophony of their voiced counterparts in Basque. Whereas intervocalic /g/ tends to delete in Basque dialects, /d/ is very frequently realized as a flap, neutralizing with phonemic /ɾ/ (e.g. *bide ~ bire* 'path') [9], including in the variety of Azpeitia [8]. Dentals and velars thus show somewhat different paths of reduction.

The voicing of a phonological stop is obviously independent from the magnitude of the oral articulatory gesture. From a phonological point of view, on the other hand, it may make sense to consider these two articulatory dimensions together as part of a single process of lenition, with differences among places of articulation perhaps to be explained by articulatory factors.

## 4. CONCLUSIONS AND DISCUSSION

All consonant tokens that we have analysed are found in the same phonetic context: between two vowels. There are, however, morphological differences among them related to word boundaries, which have an effect on the realization of these consonants. The VC#V context conditions more lenited consonants than other contexts. In this context, consonants are less constricted (especially for /k/) and are more frequently fully voiced. Since there is no phonological contrast between voiced and voiceless consonants word-finally in Basque, these results can be interpreted as showing an effect of phonological contrast on phonetic realization. On the other hand, this hypothesis does not explain the finding that word-medial tokens are also more lenited than word-initial intervocalic ones. The explanation may be found in differences in the pattern of gestural coordination of intervocalic consonants depending on position in the word (see [12, 24]). The fact that final stops are usually in suffixes may also be relevant.

## 7. REFERENCES


[1] Bates, D., Maechler, M., Bolker, B., Walker, S. 2015. Fitting linear mixed-effects models using lme4. *Journal of Statistical Software* 67(1), 1-48.

[2] Boersma, P., Weenink, D. 2018. Praat: doing phonetics by computer, version 6.035, www.praat.org [computer program].

[3] Carrasco, P., Hualde, J. I., Simonet, M. 2012. Dialectal differences in Spanish voiced obstruent allophony: Costa Rican vs. Iberian Spanish. *Phonetica*, 69, 149–179.

[4] Colantoni, L., Marinescu, I. 2010. In: Ortega-Llebaria, M. (ed.), The scope of stop weakening in Argentine Spanish. *Selected Proceedings of the 4th Conference on Laboratory Approaches to Spanish Phonology*. Somerville:MACascadilla Proceedings Project, 100–114.

[5] Cole, J., Hualde, J. I., Iskarous, K. 1999. In: Fujimura, O., Joseph, B. D. and Palek, B. (eds.), Effects of prosodic and segmental context on/g/-lenition in Spanish. *Proceedings of the 4th international linguistics and phonetics conference*. Prague: The Karolinium Press 2: 575–589.

[6] Eager, C. 2017. *Contrast preservation and constraints on individual phonetic variation*. Doctoral dissertation. Urbana-Champaign, IL: University of Illinois at Urbana-Champaign

[7] Ennever, T., Meakins, F., Round, E. 2017. A replicable acoustic measure of lenition and the nature of variability in Gurindji stops. *Laboratory Phonology: Journal of the Association for Laboratory Phonology,* 8(1), 20. DOI: http://doi.org/10.5334/labphon.18

[8] Hualde, J. I., Beristain, A. 2019. "Bi alofonia gertakari Azpeitiko euskaran". In: Festchrift [to appear].

[9] Hualde, J.I., Elordieta, G., Elordieta, A. 1994. *The Basque dialect of Lekeitio* (Supplements of *ASJU*). Bilbao/Donostia: Univ.del País Vasco – Euskal Herriko Unib./ Diputación de Gipuzkoa – Gipuzkoako Foru Aldundia.

[10] Hualde, J.I., Lujanbio, O., Zubiri, J.J. 2010. Goizueta Basque. *Journal of the International Phonetic Association*, 40, 113–127.

[11] Hualde, J. I., Nadeu, M. 2011. Lenition and phonemic overlap in Rome Italian. *Phonetica* 68(4), 215–242, DOI: https://doi.org/10.1159/000334303

[12] Hualde, J. I., Prieto, P. (2014). "Lenition of sibilants in Catalan and Spanish". *Phonetica* 71, 109–127, DOI: https://doi.org/10.1159/00036819

[13] Hualde, J. I., Simonet, M., Nadeu, M. 2011. Consonant lenition and phonological recategorisation. *Laboratory phonology* 2(2): 301–329, DOI: https://doi.org/10.1515/labphon.2011.011

[14] Kuznetsova A., Brockhoff, P.B., Christensen R.H.B. 2017. lmerTest Package: Tests in Linear Mixed Effects Models. *Journal of Statistical Software*, 82(13): 1-26. doi: 10.18637/jss.v082.i13

[15] Lavoie, L. M. 2001. Consonant strength: Phonological patterns and phonetic manifestations. New York: Routledge.

[16] Lenth, R. 2018. emmeans: Estimated Marginal Means, aka Least-Squares Means. R package version 1.2.3. https://CRAN.R-project.org/package=emmeans

[17] Nadeu, M., Hualde, J.I. 2015. Biomechanically conditioned variation at the origin of diachronic intervocalic voicing. *Language and Speech* 58(3): 351–370

[18] Lewis, A. 2001. Weakening of Intervocalic /p, t, k/ in Two Spanish Dialects: Towards the Quantification of Lenition Processes. Doctoral dissertation. Urbana-Champaign, IL: University of Illinois at Urbana-Champaign

[19] Ortega-Llebaria, M. 2004. Interplay between phonetic and inventory constraints in the degree of spirantization of voiced stops: Comparing intervocalic /b/ and intervocalic /g/ in Spanish and English. In: Face, T. L. (ed.), *Laboratory approaches to Spanish phonology*. Berlin: Mouton de Gruyter, 237–253.

[20] R Core Team. 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.

[21] RStudio Team. 2016. RStudio: Integrated Development for R. RStudio, Inc., Boston, MA URL http://www.rstudio.com/.

[22] Recasens, D. 2017. The effect of contextual consonants on voiced stop lenition: Evidence from Catalan. *Language and Speech* 59(1): 139-161.

[23] Salaburu, P. 1984. *Hizkuntzaren soinu-egitura. Hizkuntz teoria eta Baztango euskalkia*. Leioa, Bizkaia, Spain: Univ.del País Vasco-Euskal Herriko Unib.

[24] Strycharczuk, P., Kohlberger, M. (2016). "Resyllabification Reconsidered: On the Durational Properties of Word-Final /s/ in Spanish". *Laboratory Phonology: Journal of the Association for Laboratory Phonology*, 7(1), 3. DOI: http://doi.org/10.5334/labphon.5

[25] Wickham, H. 2016. *ggplot2: Elegant Graphics for Data Analysis*. Springer-Verlag New York.