Towards quantifying lenition in Ondarroan Basque

Eman Saadah
University of Illinois at Urbana-Champaign
esaadah2@illinois.edu

This study investigates lenition of intervocalic /b d g/ in Ondarroan Basque. Previous work has suggested that intervocalic voiced stops in Spanish and other languages are produced with varying degrees of voicing, fricativization, or approximation. Based on this, voiced stops in Ondarroan Basque will be realized [β ð ɣ] in a similar environment. Productions of intervocalic voiced stops are submitted to acoustic analysis considering three independent variables: speech tempo or articulation rate, place of articulation, and position in word, and three dependent variables: Voice Onset Time (VOT) or Consonant Duration, Root-Mean-Square (RMS), and conservation of release bursts.

The results show that speech tempo or articulation rate, place of articulation, and position in word are significant factors that place lenited phones in different positions along the lenition continuum. VOT measurements show that slow speech has higher mean VOT values than normal and fast speech, resulting in a longer temporal window in slower speech compared to faster one. Furthermore, RMS energy mean values decrease as the speech tempo or articulation rate becomes faster. Release bursts, however, were not present in the lenited allophonic variants due to the realization of voiced stops as fricatives intervocalically. In sum, lenition is a gradient process that is quantifiable through measuring certain acoustic correlates.

1. Introduction

This study investigates lenition or weakening of intervocalic /b d g/ in Ondarroan Basque. In line with previous research and based on traditional reports on voiced stops in Spanish and other languages, voiced stops in Ondarroan Basque are realized as [β, ð, ɣ] intervocalically. A number of recent studies report that voiced /b d g/ (Browman & Goldstein 1991; Watson 2006; Dalcher 2007) and voiceless /p t k/ (Lewis 2001; Mitterer & Ernestus 2006) stops are produced with varying degrees of voicing, fricativization, or approximation intervocalically. Productions of intervocalic voiced stops are submitted to acoustic analysis considering three independent variables: speech tempo or articulation rate, place of articulation, and position in word; and three dependent variables: Voice Onset Time (VOT) or Consonant Duration (CD), Root-Mean-Square

(RMS), and conservation of release bursts. Thus, the main focus of this study is to investigate how the aforementioned factors govern the degree of lenition in Ondarroan Basque.

Lenition is a phonological process that involves the change of manner of articulation of a certain class of sounds, i.e., stops (voicing: /k/ > /g/, fricativization: /g/ > /ɣ/), or degemination of consonants (/kk/ > /k/) intervocalically. Interestingly, this process is claimed to have affected west Romance languages, e.g. Spanish, in the Dark Ages as a result of the influence of Celtic languages in areas where the population of Romance and Celtic languages were in contact (Penny 1991). As reported, this phonological process is characterized by weakening or articulatory reduction (Browman & Goldstein 1991), showing that the presence or inhibition of lenition is mainly dependent on the segmental environment of the obstruent. As it will be shown, lenition in Ondarroan Basque is inhibited if word-medial stops are preceded by /n/, /l/, or /r/ (for example, as in *dendeleske* meaning 'something hanging' and *garbitshu* meaning 'clean').

Traditional accounts of lenition report that voiced stops /b d g/ are realized with a wide range of allophonic variation, manifested with varying degrees of fricativization along a lenition gradation continuum. This phonological process has been investigated in several of the world's languages: Spanish (Cole et al. 1998; Harris 1969), Basque (Hualde 1993); English (Kahn 1976; Watson 2006), and Gujurati (Cardona 1965), among others. Because of linguistic, historic, and geographical ties between Ondarroan Basque and Basque on one hand and Ondarroan Basque and Spanish on the other, lenition in Ondarroan Basque is expected to exhibit similar patterns as the ones in Basque and/or Spanish in similar contexts.

Lenition has been investigated as a phenomenon that falls under several approaches in the phonetic/phonological literature. A lot of debate has been generated on classifying the structural changes that affect sounds (i.e., stops) and which of those should be treated as lenition (Bauer 1988). Phonological theory proposes that lenition should be treated as a process that involves "element-based analysis" (Harris 1990). Lenition under this model involves segments that undergo reduction in complexity. Hence, stops are thought of as more complex than fricatives. However, dependency phonology (see, e.g. Ewen 1995) provide support that lenition, actually, involves increase in complexity because of increased sonority in intervocalic positions. Similarly, Articulatory Phonology claims that lenition can be accounted for through interpretations presented under this branch of phonetics. Furthermore, Hsu (1995) presents aerodynamic evidence in favor of intervocalic stop lenition in Taiwanese. The

researcher attributes this to gestural overlap in consonant clusters. Likewise, gestural overlap and/or speech economy is reported by Cole et al. (1998) as a major factor(s) that contribute to /g/ lenition in intervocalic positions in Spanish. Based on this, the degree of /g/ spirantization is measured in terms of relative acoustic energy. Cole et al. find that if the flanking vowels to /g/ are /u, o/, a greater degree of lenition is detected compared to /i e a/. This is explained by articulatory movements of /g/ where no articulatory change in tongue body occurs if flanked by /u o/ unlike when it is flanked by /i e o/.

Recently, quantification of lenition has caught the interest of many researchers who focus on investigating the acoustic correlates that describe this abstract construct. For example, Cole et al. (1998) uses energy measurement which is the ratio of time-averaged energy of the consonant to time-averaged energy of the whole word (RMS measure). Also, Lewis (2001) investigates intervocalic voiceless Spanish stops /p t k/ as produced in three different styles: conversational, reading of text, and from a list of words, through examining five acoustic parameters: closure duration, VOT duration, percentage of closure voicing, peak intensity, and conservation of release burst. Lewis reports that speech style and lexical accent provide a strong evidence of lenition, concluding that different dialects of Spanish mark its position differently along the stop lenition continuum ranging from fortis to lenis. Moreover, Dalcher (2007) introduces Principal Components Analysis (PCA) as a new method to quantify the best acoustic measurements that capture lenition in order to derive latent variable score. The lenited stops are classified into six allophone categories and vary between weak approximant, approximant, fricative, semi-fricative, fricated stop and finally stop. The higher the range the allophone has based on L scores, the more weakened or lenited it is. Based on visual and auditory evidence from spectrograms and speech files collected from Florentine Italian, the researcher reports that PCA is found a dependable means for measuring the degree of lenition in the investigated dataset. Dalcher concludes that intensity ratio, relative periodicity power, and burst release have high positive L scores and thus can be good measures of lenition.

Many studies investigate lenition; however, there is a lot of variation in the methods used to quantify it. Broadly speaking, speech tempo or articulation rate and burst release have been found reliable correlates of stop lenition, and these will be used in quantifying lenition in the current study.

2. Method

2.1. Research hypothesis

Ondarroan Basque voiced stops /b d g/ are expected to undergo lenition in intervocalic positions. A process of fricativization yields [β ð ɣ] for the voiced stops respectively. Evidence from spectrograms and wave files indicate that lenition is a gradient process affected by speech tempo or articulation rate; as speech rate moves from slow to fast, there is an increase in the degree of lenition.

2.2. Subjects

One female speaker of Ondarroan Basque was recorded in this study. Recordings were done within a soundproof booth in the Phonetics and Phonology lab at the University of Illinois at Urbana-Champaign using a Marantz recorder and professional headset-mounted microphone.

2.3. Stimuli

Since Ondarroan Basque has no native writing system, the speech stimuli are presented to the subject in Spanish orthography following the commonly used tradition. The subject was asked to utter target words as presented in carrier phrases which translated to "say *X* again" where *X* represents a target word. The set of voiced stops includes /b d g/, presented word-initially in target words and followed by a vowel. The stops were also presented in word-medial positions flanked by vowels. The subject was asked to utter each phrase three times, representing three degrees of effort: slow, normal, and fast speech. All tokens were collected in the same session to control amplitude and to make sure that the speech rate was consistent across different speaking articulating rates.

A total of 126 tokens were divided into six groups: 7 (words) x 6 (groups where stops occur word-initially and word-medially) x 3 (speech rates) = 126. The tokens were picked from a pool of various vocalic contexts and from several grammatical classes. Each group consisted of one stop (word-initially) or its allophone (intervocalically) spoken in one speech tempo or articulation rate. For example, one group consisted of all the tokens collected for /b/; 7 target tokens. Within this group, all tokens occurred intervocalically and were recorded in a slow speaking rate. In the

other group, /b/ had the same tokens but recorded in a normal speakeing rate and in another group with a fast speaking rate.

2.4. Data analysis

Recordings were analyzed at 48.0 kHz, and using PRAAT 4.5.16 software. Each token was measured for the following acoustic correlates:

1) Voice Onset Time (VOT) or Consonant Duration (CD);

2) Root-Mean-Square (RMS), which is the measurement of energy as a ratio of the time-averaged energy of the consonant to the time-averaged energy of the following vowel;

3) The presence and absence of stop release bursts at consonant release.

2.4.1. Acoustic analysis/Segmentation

The goal of the present study is to determine how VOT/CD and RMS values of voiced stops in Ondarroan Basque are affected when measured in intervocalic positions in different speech tempo or articulation rates, and also comparing word-initial positions where lenition is not expected to have occurred. VOT/CD and RMS are two important acoustic correlates that have been used extensively to measure the degree of lenition in stops in intervocalic contexts (Cole et al. 1999, Lewis 2001). Since lenition or spirantization is a process of articulatory reduction or overlap, we expect CD to be affected as speech rate changes from slow to normal to fast. More specifically, it is expected that as speech rate becomes faster the consonant undergoes more articulatory reduction because it is flanked by vowels from both sides. Also, the RMS measure is another acoustic measure of the amount of energy present within one segment. For example, stops have very small acoustic energy compared to their intervocalic fricative counterparts, as Figures 1 and 2 show. In analyses of Spanish as well as in other languages, spirantization is described as a process of assimilation, articulatory reduction, or weakening, depending on which phonological analyses are applied and within which tradition lenition is investigated.
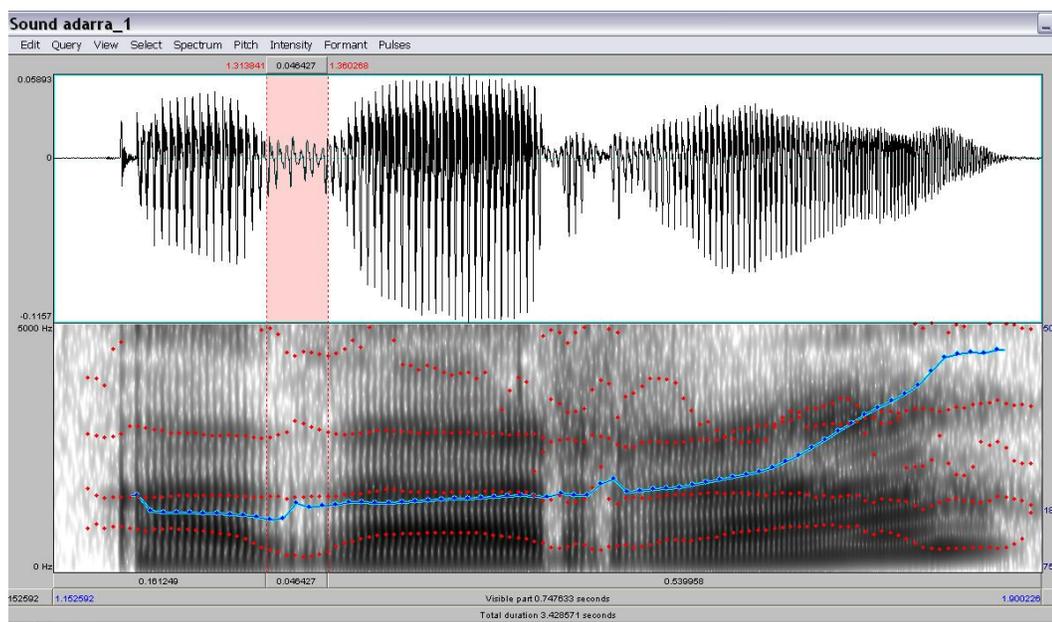
Figure 1. Intervocalic /d/ in the word 'adarra' (meaning "branch") produced in slow speech rate. There is low energy in this spirant but enough to rank it as semi-fricative.
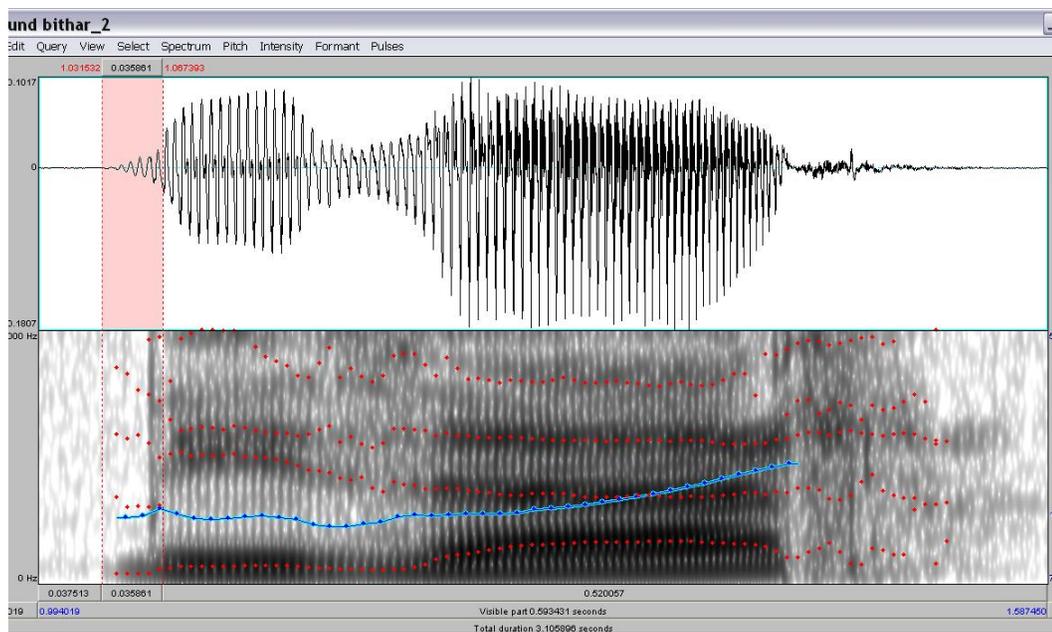

Figure 2. Word-initial /b/ in 'bithar' (meaning "times") produced in normal speech rate. The voiced stop has the expected lead voicing VOT value which indicates low energy for this particular stop in this context.

3. Independent variables

Three independent variables were taken into account in the process of quantifying lenition and these are: speech tempo or articulation rate, place of articulation, and position (initial or medial) in word.

3.1. Speech tempo or articulation rate

Three different speech tempo or articulation rates were considered in this experiment: slow, normal, and fast. The slow rate is considered equivalent to reading from a list of words, the normal rate resembles average speech spoken in normal conversation, and a fast rate of articulation is associated with fast speech. The goal of testing lenition through measuring acoustic correlates in different speech tempo or articulation rates is to see if speech rate affects the degree of lenition. Various studies have investigated the relation between speech rate and consonant weakening in several languages e.g. American English (Byrd 1994), Spanish (Romero 1996 and Harris 1969), and German (Kohler 1991). All these studies agree that a faster or more casual speech rate has a positive effect on consonant reduction and that if a consonant lenites at any given rate of articulation, it also lenites in a faster or more casual rate (Zwicky 1972).

3.2. Place of articulation

The voiced labial, dental, and velar stops /b d g/ were measured in this study to test for the correlation between place of articulation, acoustic measurements, and degree of lenition.

3.3. Position in word

The position of a stop in the word is important in influencing the strength of acoustic correlates: stops that occur word-initially or are accented are thought of or characterized as stronger segments than the ones which occur word-medially or are unaccented (Browman & Goldstein 1992 and Cole et al. 1998). For the purposes of this study, only position in word (initial and medial) is considered, while accent is overlooked because of the interplay between stress and tone in Ondarroan Basque and the difficulty in determining whether a certain token is accented or not.

4. Dependent variables: Acoustic correlates

In the present study, target stops are examined for: 1) Voice Onset Time (VOT) or Consonant Duration; 2) Root-Mean-Square (RMS); and 3) the presence and absence of stop release bursts at consonant release.

4.1. Voice Onset Time (VOT) or consonant duration (CD)

VOT is known as the time between the release of a stop consonant and the onset of vocal fold vibration. VOT is cited extensively in the field as an acoustic measure that plays an important role in the production and perception of stops (Lisker & Abramson 1964). Here, the term VOT refers to the duration of the formant-like structure that precedes burst release of the stop word-initially. Consonant duration (CD) refers to the duration of the lenited stop when it occurs intervocalically.

4.2. Root Mean Square (RMS)

RMS is another type of measurement that is used to quantify lenition by means of measuring acoustic intensity in the speech signal. Its purpose is to evaluate the amount of energy within the stop relative to the following vowel.

4.3. The presence/absence of stop release bursts at consonant release.

Production of stops is usually accompanied by a concentration of energy which is high in frequency; techniqually referred to as release burst, and this normally occurs when increased air pressure in the vocal tract is released as the air escapes from the mouth. I hypothesize that target voiced segments are lenited intervocalically. Therefore, the lenited stop will lack a stop release, especially since this variable is categorical. This happens because articulators will not achieve a stage of complete seal and therefore these segments are produced without release bursts.

5. Results

This section presents the results of the independent variables (speech tempo or articulation rate, place of articulation, and position in word) along with the dependent variables (the acoustic correlates: VOT/CD, RMS, and release burst).

5.1. Speech tempo or articulation rate

5.1.1. The effect of speech tempo or articulation rate on consonant duration

Acoustic Measures	Slow			Normal			Fast		
	Mean	Range	SD	Mean	Range	SD	Mean	Range	SD
Consonant Duration (CD) ms	58.10	115.58	29.97	45.99	91.43	26.32	30.90	73.79	21.88
RMS difference dB	10.78	17.14	4.56	9.03	18.06	4.38	5.39	15.61	3.62

Table 1. Means, ranges, and standard deviations of Voice Onset Time/Consonant Duration and RMS measures according to different speech tempo or articulation rates (slow, normal, and fast).

Table 1 illustrates means, ranges, and standard deviations for the dependent variables CD and RMS according to speech tempo or articulation rate. The mean value for CD indicates that faster speech is associated with lower closure durations followed by normal speech and finally longer durations are associated with slower speech tempo or articulation rate. CD mean values steadily decrease as speech tempo or articulation rate becomes faster as shown in Figure 3. The same is true for value ranges where fast speech is associated with lower ranges, followed by normal speaking rate and finally longer ranges for slow speech. Standard deviation values are smallest for slow speech, and increase for normal speech and finally fast speech rate has the largest values.
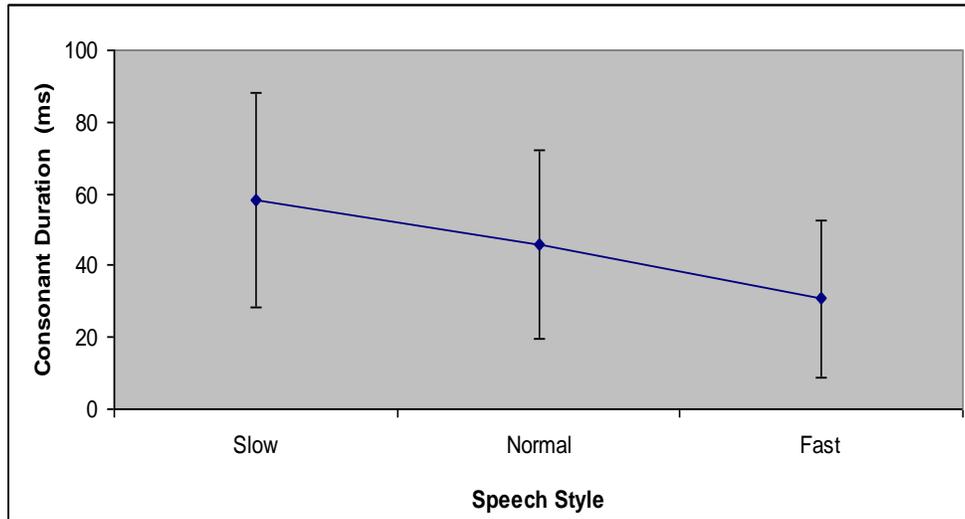
Figure 3. Mean value of consonant duration (in milliseconds) for all intervocalic voiced stops /b d g/ across different speech tempo or articulation rates: slow, normal, and fast. Error bars indicate the standard error of estimate.

The data were analyzed with Analysis of variance (ANOVA) for several cases. ANOVA analysis indicates a highly significant effect [$F(2) = 10.767$, $p < 0.001$] of speech tempo or articulation rate on CD.

5.1.2. The effect of speech tempo or articulation rate on RMS measure

The purpose of measuring RMS value in intervocalic position is to see how much energy is present in a consonant relative to flanking vowels. Following Soler and Romero (1999) and Lewis (2001), this was calculated by subtracting RMS energy in dB of the prevocalic consonant from the RMS energy in dB of the following vowel. Figure 4 illustrates mean RMS values for different speech tempo or articulation rates. There is a general tendency for RMS mean values to decrease as the speech tempo or articulation rate becomes faster. ANOVA results indicate a highly significant effect [$F(2) = 17.052$, $p < 0.001$] of speech tempo or articulation rate on RMS of the consonant.
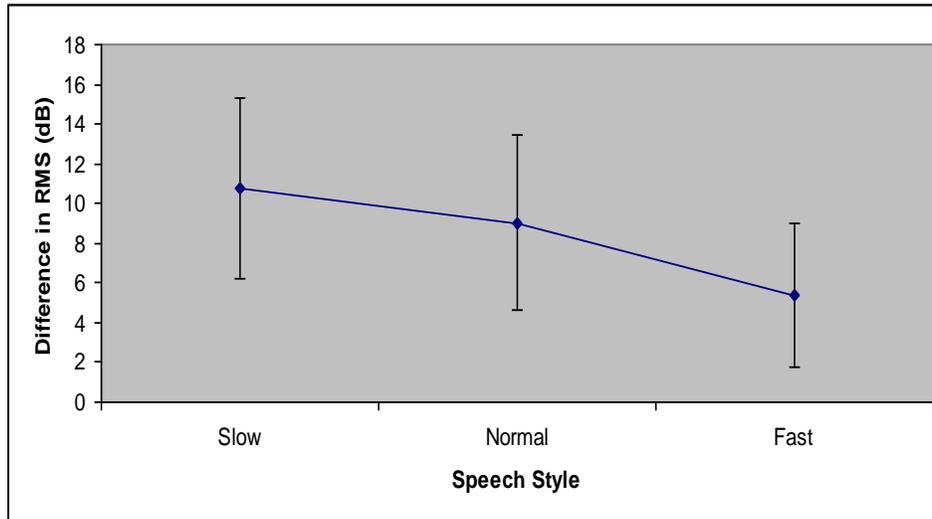
Figure 4. Mean value of Root-Mean-Square (RMS) difference (in dB) between the vowel and the consonant for slow, normal, and fast speech tempo or articulation rates. Error bars indicate the standard error of estimate.

5.1.3. Silent closure and release bursts

The presence of silent closure and release burst in the waveforms are indicative of stops. Silent closure refers to the complete closure of the vocal tract when articulators prepare for the stop gesture, and release refers to articulators' separation when they move away from each other. Absence of silent closure or burst release in the waveform means that the articulators did not achieve a complete seal and therefore the stops are in advanced stage of lenition. Closures and release bursts *were not* present in the target segments that occur intervocalically. For the purposes of the present study, both silent closure and release bursts were treated on a binary scale of 0 or 1 (where 0 refers to the absence of this parameter and 1 to its presence).

5.1. Place of articulation

Table 2 shows mean, range and standard deviations for the voiced stops based on place of articulation when they occur intervocalically. Mean CD values for /d/ and /g/ are almost identical while /b/ productions have lower mean values. Similarly, ranges of mean values for /d/ and /g/ are very close while /b/ ranges are lower. Table 2 illustrates that RMS values for /b/ is lower than /d/ and /g/, which have almost identical RMS energy values.

In general, alveolar and velar segments exhibit very similar values in terms of CD and RMS measure while the bilabial segment consistently has lower values.

Acoustic Measures	/b/			/d/			/g/		
	mean	range	SD	mean	range	SD	mean	range	SD
Consonant Duration (CD) ms	28.91	80.3	16.33	52.20	115.58	29.10	51.58	110.97	30.53
RMS difference dB	6.32	16.12	4.88	9.69	18.76	4.86	8.90	18.85	3.94

Table 2. Means, ranges, and standard deviations of Consonant Duration CD (in ms) and RMS measure (in dB) for the voiced stops /b d g/.

5.2.1. The effect of place of articulation on consonant duration

Figure 5 shows mean values for CD for target stops based on place of articulation: bilabial /b/, alveolar /d/, and velar /g/. The figure indicates that the mean values for alveolar and velar stops are comparable, whereas it is lower for the bilabial stop. The physiological motivations underlying this result will be discussed in the next section. The ANOVA indicates a highly significant statistical variation [$F(2) = 9.4621$, $p < 0.001$] for place of articulation on CD.
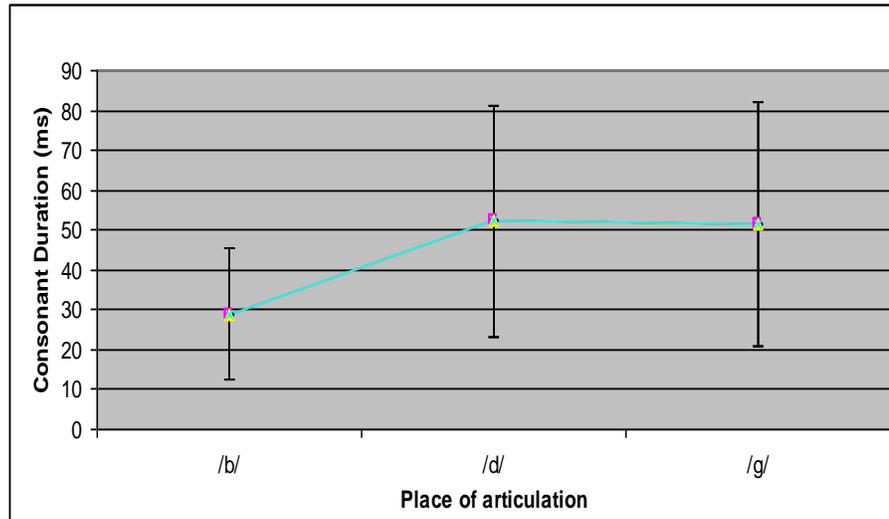
Figure 5. Mean value of Consonant Duration (CD) based on place of articulation: bilabial /b/, alveolar /d/, and velar /g/.

5.2.2. The effect of place of articulation on the RMS measure

Figure 6 illustrates that RMS mean value is low for bilabial /b/ but significantly increases for /d/ before it drops marginally for velar /g/. Error bars have comparable ranges for all three different places of articulation which indicates that all target voiced consonants were distributed with similar ranges around the mean. This suggests that our subject was consistent articulating various stops at different places of articulation. The ANOVA results indicate a significant effect of place of articulation [$F(2) = 5.6501$, $p < 0.01$] on RMS of the consonant. This suggests that place of articulation is in fact a major factor that contributes to the difference in RMS values for the lenited stops.
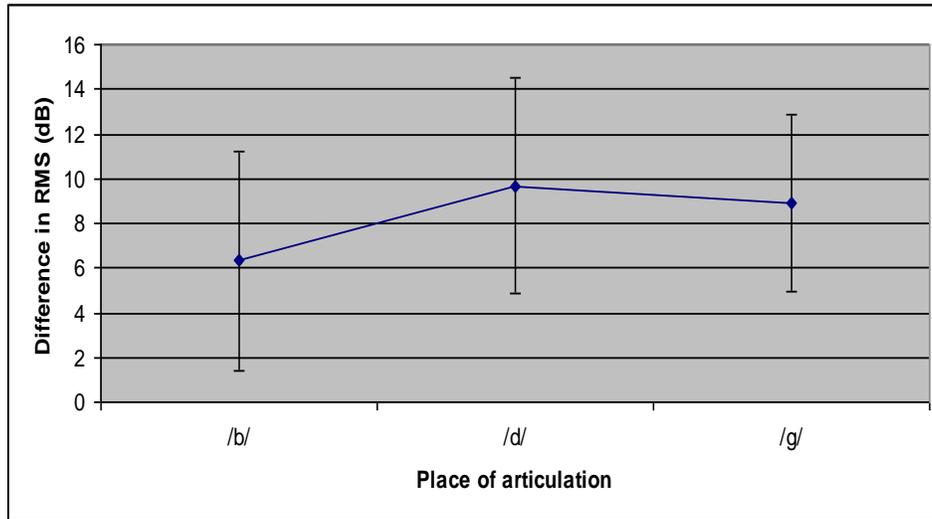
Figure 6. Mean value of difference in Root Mean Square (RMS) in (dB) on place of articulation: bilabial /b/, alveolar /d/, and velar /g/. Error bars indicate the standard error of estimate.

5.2.3. The effect of place of articulation on release bursts

As mentioned earlier, due to the realization of voiced stops as fricatives intervocalically, release bursts were not present in the lenited allophonic variants. Therefore, no results related to this acoustic correlate are reported here.

5.3. Position in word

In this section, results of the effect of the position of voiced stops /b d g/ on VOT or on CD and RMS values are investigated. The two positions are: word-initially and word-medially or intervocalically.

5.3.1. The effect of position in word on consonant duration (CD)

Table 3 presents mean, range and standard deviation of CD and RMS measure for the productions of word-initial and word-medial /b d g/.

Acoustic Measures	Word-initial			Word-medial		
	mean	range	SD	mean	range	SD
Consonant Duration (CD) ms	30.74	101.71	25.69	57.90	102.8	24.28
RMS difference dB	9.70	18.54	4.59	7.22	18.85	4.60

Table 3. Mean, range, and standard deviation values of consonant duration (CD) in (ms) and RMS difference in (dB) for word-initial and word-medial (intervocalic) voiced stops /b d g/.

The results suggest that there is a significant variation in CD between stops when they occur word-initially and medially (or intervocalically) as figure 7 indicates. However, ranges and standard deviations have comparable values for both positions in words. This indicates that our informant's production across different positions was consistent. Mean value of CD intervocalically is significantly higher than word-initially. This indicates that lenited segments intervocalically have longer duration than those in word-initial position. Interpretation of this result is presented in the discussion section. The ANOVA analysis was performed to see the effect of position of consonant in word on CD. The results show that the position of consonant in word has a highly significant effect on CD [$F(1)$ = 35.438, $p < 0.001$].
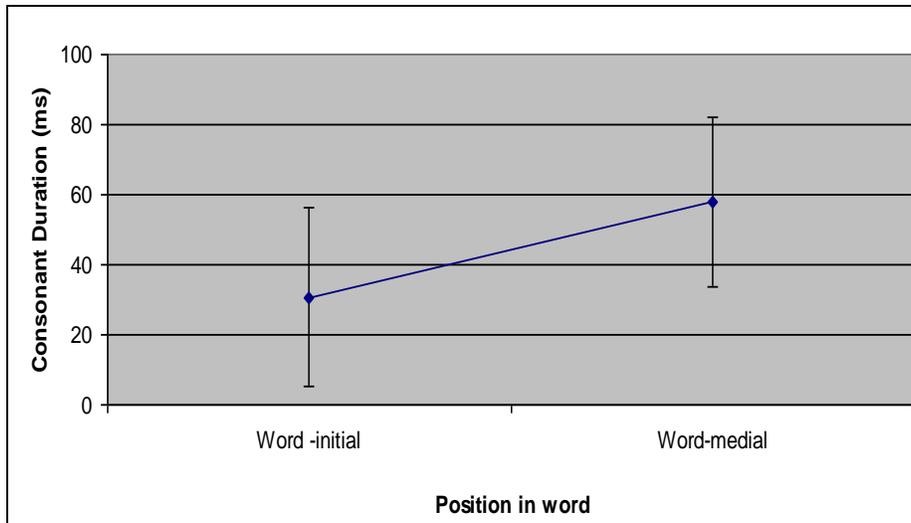

Figure 7. Mean values consonant duration (CD) in (ms) of word-initial and word-medial (intervocalic) /b d g/.

5.3.2. The effect of position in word on RMS measure

Figure 8 illustrates mean RMS values (in decibels) of word-initial and word-medial (intervocalic) stop consonants. The figure shows that mean RMS measure drops significantly for word-medial consonants. This means that intervocalic segments have more energy than word-initial stops and this is indicative of more lenition. In other words, there is higher energy difference between the vowel and the consonant word-initially, (i.e., no lenition) while intervocalic stops have less difference in RMS energy between the consonant and the vowel (i.e., more lenition). The ANOVA analysis was performed to see the effect of position of consonant in word on energy measurement. The results obtained show that the position of consonant in word has a highly significant effect on RMS of the consonant $[F(1) = 8.6898, p < 0.01]$.
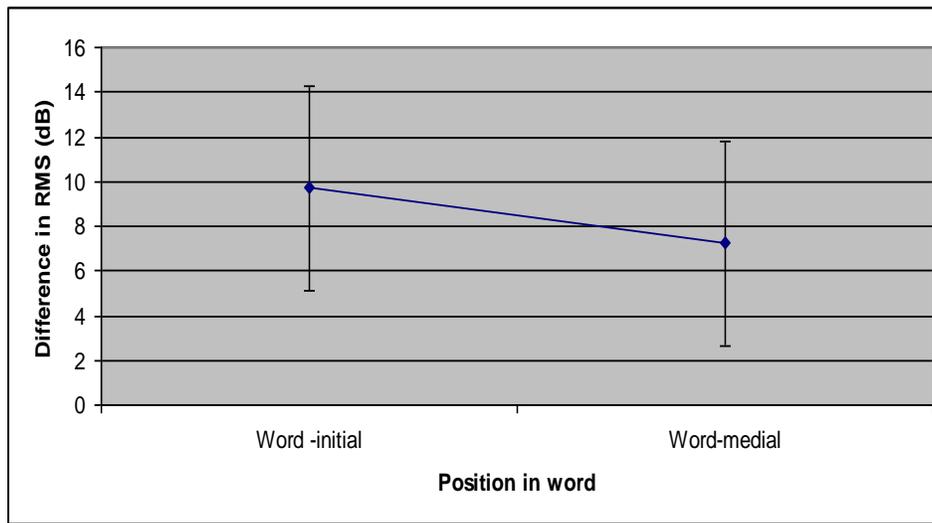

Figure 8. Mean value of Root Mean Square (RMS) in (dB) in word-initial and word-medial (intervocalic) /b d g/.

5.3.2. The effect of position in word on release bursts

Release bursts were measured on a scale of 0 (not present) and 1 (present). Release bursts were present word-initially and absent intervocalically.

6. Discussion

In the results section above, we find compelling evidence in support of the aforementioned hypotheses. First, there is an undeniable proof that

lenition is a gradient process that is affected by speech tempo or articulation rate: lenition increases with faster speech. This has been attested by looking at various acoustic correlates: consonant duration (CD), Root Mean Square (RMS), and release bursts. Second, quantification of several acoustic correlates, ones that are thought of as valid for measuring lenition, contributes to further our understanding of the nature of lenition. Specifically, CD and RMS measures of intervocalic voiced stops are affected by speech tempo or articulation rate. CD represents the duration of the target segment intervocalically from the offset of V1 to onset of V2. Boundaries of the target segment were determined by looking at the waveform and listening to the speech file. CD becomes smaller with faster speech which is indicative of more lenition.

The results obtained from testing the effect of speech tempo or articulation rate on the degree of lenition follows the expected pattern in that faster speech results in a higher degree of lenition. One of the primary reasons for lenition is articulatory reduction or speech economy and, since faster speech requires faster movement of the articulators, we expect a direct effect on the lenited segment resulting in a steady decrease in CD as speech tempo or articulation rate moves from slow to normal to fast. Indeed, CD has a highly significant effect on speech tempo or articulation rate and this shows that it is a good measure of intervocalic weakening of voiced stops.

The second hypothesis expects a relationship between RMS value as a measure of acoustic energy and the degree of lenition. Again, we find that as speech tempo or articulation rate becomes faster energy increases. Statistical analyses show a highly significant effect between speech tempo or articulation rate and acoustic energy in lenited stops. /b d g/ are realized as their allophonic fricativized segments [β ð γ] respectively. The closer RMS values between the consonant and vowels in intervocalic positions suggest that there is minimum or less articulatory displacement between vocalic and consonantal gestures.

In line with previous research, absence of burst release in intervocalic segments indicates that the articulators did not achieve a complete seal in the supralaryngeal cavity and therefore interpreted to be an advanced stage of lenition than pbones produced with release bursts (Lewis 2001).

It is known that VOT increases as place of articulation moves further back in the oral cavity. Accordingly, the longest values are associated with the velar stop. Previous research reports that labial stops have lower duration values than dental and velar ones (Lewis 2001). This is attributed to greater amount of air in front of the velar closure contributing to longer

VOT value. On the other hand, labial stops have the lowest values since there is no trapped air in front of the closure. /g/ occurs with longer duration because air flow over the glottis diminishes leading to termination of phonetic voicing as air tends to accumulate in the relatively small cavity behind the velar closure thereby stabilizing supraglottal and subglottal pressure.

The results show that word-initial stops have lower VOTs than intervocalic ones. This seems contradictory to what have been said before in that lenited segments have lower duration values than non lenited ones. Upon careful examination of the data, it was found that slow speech tempo or articulation rate has high VOT values while the values for subsequent speech tempo or articulation rates were very low which contributed to overall low VOT values and more specifically lower than the ones in word-medial positions. In particular, VOT values were found to be very low in normal and fast speech. This can be attributed to rapid speech in which shorter temporal window (between stop release and the onset of vocal fold vibration) results in lower VOT values. In less formal speech the consonant loses its syllabic affiliation which is evidence of weakening (Lewis 2001). However, as expected, difference in RMS energy was lower intervocalically which shows that word-medial segments have more energy than word-initial ones. For word-medial position, the encroachment on the intervocalic stop is bi-directional; meaning that it is affected by preceding as well as following vowels which in turn leads to the loss of the stop consonant's syllabic affiliation to the following vowel (Cole et al. 1999).

7. Conclusion

The present study aimed at investigating the degree of lenition in voiced stops through quantifying acoustic correlates to measure weakening in intervocalic position. Speech tempo or articulation rate, place of articulation, and position in word were found to be significant factors that place lenited phones in different positions along the lenition continuum.

REFERENCES:

Bauer, L. 1988. What is lenition? *Journal of Linguistics* 24, 381-392.

Browman, C. & Goldstein, L. 1991. Gestural structures: distinctiveness, phonological processes, and historical change. In Ignatuus G. Mattingly and Michael Studdert-Kennedy (eds.), *Modularity and the Motor Theory of Speech Perception: Proceedings of a Conference to Honor Alvin M. Liberman* (pp. 313-338). Hillsdale, NJ: Lawrence Erlbaum Assoc.

Byrd, D. 1994. *Articulatory Timing in English Consonant Sequences*, Doctoral Dissertation, UCLA.

Cardona, G. 1965. *AGujarati Reference Grammar*, Philadelphia: University of Pennsylvania Press.

Cole, J., Hualde, J.I. and Iskarous, K. 1999. Effects of prosodic and segmental context on /g/ lenition in Spanish. in O. Fujimura (ed.), *Proceedings of the Fourth International Linguistics and Phonetics Conference.* Columbus, OH, October 1998. Charles University Press: Prague.

Dalcher, C. 2007. Statistical methods for quantitative analysis of multiple lenition components. *ICPhS* XV1.

Ewen, C. 1995. In J.A. Goldsmith (ed.) *Handbook of Phonological Theory*. Oxford: Blackwell. 570-585.

Harris, J. 1969. *Spanish Phonology*. Cambridge, MA: MIT Press.

Harris, J. 1990. Segmental complexity and phonological government. *Phonology* 7:2, 255-300.

Hsu, C. 1995. Aerodynamic evidence of preconsonantal stop lenition in Taiwanese (A). *The journal of the acoustical society of America* 98 (5) pp. 2891-2892.

Hualde, J. 1993. Topics in souletin phonology, in G*enerative Studies in Basque Linguistics*, John Benjamins, Amsterdam.

Kahn, D. 1976. *Syllable-Based Generalizations in English Phonology*, Doctoral Dissertation, MIT.

Kohler, K. 1991. The phonetics/phonology issue in the study of articulatory reduction. *Phonetica* 48, 180-192.

Lewis, A. 2001. *Weakening of Intervocalic /p, t, k/ in Two Spanish Dialects: Toward the Quantification of Lenition Processes*. Doctoral Dissertation, University of Illinois at Urbana-Champaign.

Lisker, L. & Abramson A.S. 1964. A cross-language study of voicing in initial stops: acoustical measurements. *Word* 20, 384-422.

Mitterer, H. & Ernestus, M. 2006. Listeners recover /t/s that speakers reduce: Evidence from /t/-lenition in Dutch. *Journal of Phonetics* 34, 1 pages 73-103.

Penny, R. 1991. *A History of the Spanish Language*. Cambridge University Press.

Romero, J. 1996. *Gestural Organization in Spanish: an Experimental study of Spirantization and Aspiration* , Doctoral Dissertation, University of Connecticut.

Soler, A. and Romero, J. 1999. The role of duration in stop lenition in Spanish. Paper presented at the annual meeting of the international congress of the phonetic sciences. San Francisco, California.

Watson, K.. 2006. Lenition and segmental interaction: evidence from Liverpool English (and Spanish). *Glossa-An Ambilingual Interdisciplinary Journal* 1 (1). Or from http://www.lancs.ac.uk/staff/watsonkd/watson2006glossa.pdf

Zwicky, A. 1972. On Casual speech, *CLS* 8.