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Acoustic investigation of anticipatory vowel nasalization in a Caribbean and a non-Caribbean dialect of Spanish

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Abstract: Spanish dialectology observes that dialects with a preference for velarized variants of /n/ (e.g. Caribbean dialects) include nasalized vocalic allophones in their inventory. Instrumental cross-dialectal comparisons of Spanish anticipatory nasalization, however, remain surprisingly rare. To this end, I compare the time-course of nasality in pre-nasal vowels in Argentine and Dominican Spanish, as well as across a number of linguistic variables described in the phonetic, sociolinguistic and historical literature. Twenty-eight speakers from Santo Domingo and twenty-six from Buenos Aires were recorded with a nasometer, an ideal instrument for data collection in the field. Measurements of nasal energy were extracted to acoustically characterize the time-course of nasality. Results indicate that Dominican speakers present more extensive anticipatory vowel nasalization than Argentine speakers. These findings are consistent with observations of allophonic nasalization (i.e. phonologized) in the Caribbean dialect under study, Dominican Spanish. Regarding the linguistic variables, stressed pre-nasal vowels showed earlier onset of nasalization, particularly among the Caribbean speakers, which further provides support for the phonological differences in vowel nasality.

Keywords: anticipatory vowel nasalization; Argentine Spanish; Dominican Spanish; nasometer

1 Introduction

This article takes up Colantoni's (2011) call to extend empirical coverage of phenomena in Spanish phonetics and phonology, diversify methodological approaches, and compare across dialects of Spanish. To this end, I present a nasometric study of anticipatory vowel nasalization in a Caribbean and a non-Caribbean dialect of Spanish (Santo Domingo and Buenos Aires, respectively), and across a number of linguistic variables.

Two types of anticipatory vowel nasalization have long been recognized (Cohn 1993; Hajek 1997; Sampson 1999; Solé 1992). Most languages exhibit some degree of coarticulatory nasalization in pre-nasal vowels. But, over time, nasalization may become an intended property of the vowel, such that some languages may phonologize it. These two types of sub-phonemic nasalization fit squarely with dialectal differences in Spanish. Spanish anticipatory vowel nasalization has been traditionally described as the mechanical by-product of coarticulation with the nasal consonant (Solé 1992). Based on impressionistic transcriptions, dialects in southern Spain and in the Caribbean region have been reported to exhibit extensive vowel nasalization, arguably interpreted as a property of the vowel (i.e., phonologized, Campos-Astorkiza 2012; Colantoni 2011; Hualde 2014; Lederer 2003; Lipski 2011; Terrell 1975; Trigo Ferre 1988; Vaquero 1996). Despite these long-standing descriptions, instrumental comparisons of vowel nasality across Spanish dialects are scarce. This article fills this void.

As will be discussed in the next section, cross-linguistic phonetic research has established the time-course of nasality as a reliable phonetic cue to said sub-phonemic variation. In this study, I examine the time-course of

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nasalization in two dialects of Spanish, Santo Domingo Spanish (Dominican Republic, Caribbean dialect) and Buenos Aires Spanish (Argentina, non-Caribbean), with equipment well-suited for instrumental research in the field: a nasometer. A nasometer is a split channel set of microphones separated by a removable plate that records oral and nasal signals simultaneously yet separately. Consistent with descriptions of extensive anticipatory nasalization (i.e. phonologized), findings show earlier onset of nasalization in the Santo Domingo data. Regarding the linguistic variables, stressed vowels in this dialect showed earlier onset of nasalization, providing additional support for the phonological differences in vowel nasality.

2 Background

2.1 The phonetics and phonology of anticipatory vowel nasalization

Non-contrastive nasalization (i.e., nasality spreading from a nasal consonant in oral vowels) exhibits considerable phonetic variation, cross-linguistically and even within varieties of a language, which has been probed through cross-linguistic experimental techniques since the 1970s (Clumeck 1976; Cohn 1993; Reenen 1982; Solé 1992, 1995). Given the amount of variation (whether in all or part of the vowel, the degree of nasality, or the rate of increase or decrease), a single language-general rule of allophony is not sufficient to account for language-specific facts regarding anticipatory vowel nasalization. Thus, two types of non-contrastive nasality have been established: coarticulatory and allophonic nasalization (Cohn 1993; Hajek 1997; Sampson 1999; Solé 1992). The key difference between the two is whether nasality is an intended property of the vowel or the result of coarticulation.

The time-course of nasalization has been especially fruitful in showcasing this distinction. In two now seminal studies, Cohn (1993) and Solé (1992) use the time-course to show cross-linguistic phonological differences. A generalization that stems from this work is that in languages in which anticipatory nasalization is coarticulatory, such as French or Spanish, nasal airflow in the pre-nasal vowel remains low for most of its duration. In languages with allophonic nasalization, like English, anticipatory nasalization starts earlier in the pre-nasal vowel, and is arguably aligned with onset of the vowel, as shown by speech rate adjustments in Solé (1992). Such phonetic differences in the time-course of nasalization, thus, reflect differences in the phonological make up of the language.

In addition to cross-linguistic and phonological variation, the phonetic underpinnings of anticipatory vowel nasalization also vary within languages in ways that are sensitive to language-internal factors. For example, the patterns of nasalization are susceptible to the effect of stress. The velum lowering valley has been shown to be longer and lower in stressed environments, at least for English (Krakow 1999; Vaissière 1988). Additionally, numerous studies document covariation of nasalization with vowel height. Low vowels typically exhibit longer duration of nasalization (possibly due to inherently lower velum position, via activation of the palatoglossus muscle, Clumeck 1976; Diakoumakou 2004; Kuehn and Moon 1998). Finally, though not the focus of this study, weakening of the nasal also connects to variation in nasalization– the more weakened the nasal consonant, the earlier onset of nasalization in the pre-nasal vowel (Beddor 2009 and Bongiovanni in preparation explore this relationship). The language-internal facts of variation often find historical correlates (e.g. nasalization has been said to have phonologized first in the context of low vowels, stressed syllables and weakened adjacent nasal consonants), thus indicating that these are environments that may facilitate longer or greater nasalization (Chen 1975; Hajek 1997; Lightner 1973; Schourup 1972, 1973).

2.2 Spanish anticipatory nasalization

The Spanish nasal system is comprised of three consonants that contrast by place of articulation in onset position: the bilabial, the alveolar and the palatal nasals (*ca*[m]*a* 'bed' vs. *ca*[n]*a* 'white hair' vs. *ca*[ɲ]*a* 'sugar cane'). In coda position, the most common nasal consonant is /n/, though word-finally it exhibits a wide range

of regional variation. Dialects of Spanish can be broadly categorized as 'preferring' an alveolar or a velar realization for word-final /n/, or as I will be referring to them, [n]- and [ŋ]-dialects, respectively.

Unlike other Romance languages like French and Portuguese, Spanish does not include nasal vowels in its phonemic system. Nasalized vocalic allophones have been posited when flanked by nasal consonants (e.g., [mãno] <mano> 'hand') or word-initially and adjacent to a coda nasal consonant (e.g., /e/ in [ẽntra] <*¡entra!*> 'come in!'; Piñeros 2008: 161; Schwegler et al. 2018: 35). These (pan-Hispanic) nasalized vowels contrast with dialect-specific nasalization. Dialectal differences in vowel nasality are intertwined with regional variation of word-final nasal consonants. Anticipatory vowel nasalization in Caribbean dialects ([ŋ]-dialects) has been described as "extensive". Whether "extensive" means greater in duration or in degree of nasalization is unsettled. It is clear, however, that anticipatory vowel nasalization in these varieties is unequivocally different from that of [n]-dialects. These descriptions echo the difference between coarticulatory and allophonic nasalization presented in the previous section.

Much work on Spanish anticipatory vowel nasalization originates in the sociolinguistics literature, which focused on [ŋ]-dialects and – understandably – relied on impressionistic coding (Cedergren and Sankoff 1975; D'Introno and Sosa 1988; Haché de Yunén 1981; Hernández 2009; López Morales 1980; Terrell 1975). Only one instrumental study (to the best of my knowledge) has examined dialectal differences (with nasographic data) and has found that, in contrast with Peninsular Spanish (an [n]-dialect), the patterns of anticipatory vowel nasalization in Cuban Spanish (an [ŋ]-dialect) and American English were comparable in terms of the time-course of nasalization (Lederer 2000, cited in Lederer 2003). While these findings indeed point to cross-dialectal differences in the phonetic underpinnings of anticipatory vowel nasalization across Spanish dialects with putatively different phonological interpretations, they are based on the speech of a single speaker of each region. Thus, there is a need for detailed phonetic work regarding Spanish anticipatory nasalization, which this study undertakes.

3 The present study

This study is more extensive than previous ones on the topic in at least four respects: (i) it compares across dialect groups, recorded within their dialectal region, (ii) it surveys a larger participant pool, (iii) it relies on fine-grained acoustic data, and (iv) it employs specialized equipment well-suited for data collection in the field.

Three restrictions narrowed the scope of the present study. First, read speech alone was examined, given the challenge of studying spontaneous speech with this instrument. Second, the articulatory details of the nasal consonant cannot be examined with nasometric (or more generally acoustic) data. Finally, the nasometer is a reliable indicator of velic opening and closing, but it does not allow one to accurately determine greater or smaller opening. For this reason, claims regarding degree of nasalization are limited with this equipment. Within these confines, the aim of this study is to compare anticipatory vowel nasalization in two dialects of Spanish with putatively diverging phonological interpretations of said feature. In addition to the regional comparison, this study incorporates a number of linguistic variables documented in the historical literature to examine within-dialect variation as well.

Santo Domingo (Dominican Republic) and Buenos Aires (Argentina) were chosen as research sites for two reasons. First, dialect-specific production details revealed these two sites as ideal locations. While Dominican Spanish has not been reported as the [ŋ]-dialect with highest rates of nasalized vowels (such as Panama Spanish, Cedergren and Sankoff 1975), it does not exhibit the lowest rates either. Because it occupies an intermediate stage among Caribbean dialects, Santo Domingo Spanish is likely susceptible to a wide range of variation. Argentina was chosen as locale for research because, despite wide dialectal variation, it is located within a region of [n]-dialects. That is, unlike other [n]-dialects (such as Peninsular dialects), the Buenos Aires area – and, broadly, the Southern Cone – is not in contact with other [ŋ]-dialects. The second reason is the relationship of these two cities to their broader regional context. The population and territorial area differences are undeniable, but when the local regional context is considered, Santo Domingo and Buenos Aires are

comparable in terms of their stature as cultural, financial, political, and commercial centers (though not necessarily the only ones).

In order to test phonetic differences in the phonological interpretation of vowel nasality, I examine the time-course of nasalization. Based on previous descriptions of dialectal differences, [ŋ]-dialects exhibit longer temporal extent of nasalization than [n]-dialects. Santo Domingo Spanish is thus expected to exhibit earlier onset of nasalization than Buenos Aires Spanish. I also expect within-dialect variation, consistent with language-internal and historical evidence: the low vowel, stressed syllables and the pre-pausal environment are expected to exhibit earlier onset of nasalization (Colantoni and Kochetov 2012; Krakow 1999; Vaissière 1988).

3.1 Speakers, equipment, and elicitation materials

Participants were 28 native speakers of Santo Domingo Spanish (18 females and 10 males, aged 18–27 years old) and 26 of Buenos Aires Spanish (18 females and eight males, aged 19–28 years old). The research design was aimed primarily at phonetic and phonological aspects of the variation, thus, only one age group was examined, as a starting point. All participants were college students, which allowed the study to control for age group as well as educational background, in order to keep comparability across dialect communities as much as possible. Data were collected with a Glottal Enterprises nasometer (NAS-1 SEP Clinic), in Praat (Boersma and Weenink 2016), and sampled at 44.1 kHz. Supplementary materials include sample spectrogram and waveforms.

The stimulus set included 24 real words, in which the vowel of interest (/a e o/) appeared in various phonological environments: syllable type (CVN and NVN),[1] stress (stressed and unstressed syllables), and non-assimilating contexts (pre-pausal and pre-vocalic). These were embedded in carrier phrases, displayed in Microsoft PowerPoint on the same MacbookPro used for recording. Instead of repetitive 'traditional' carrier phrases (e.g. 'I say [target word] for you'), NPs and VPs (e.g. *La sartén aceitosa* 'the oily skillet', *Digo que tiraron* 'I say they threw') were employed.

3.2 Instrumentation and acoustic measurements

The data were annotated manually in a Praat TextGrid using multiple acoustic events on a token-by-token basis. The separate oral and nasal waveforms provided accurate information to locate the vowel-nasal boundary: a sudden absence of audio in the oral channel and a strong presence of audio in the nasal channel. Spectrographic reading was also employed (e.g. visual presence of an abrupt change and damping of formant frequencies to identify the nasal consonant; see Figure S1 in supplementary materials). A total of 3,888 tokens were extracted, of which 484 were eliminated primarily due to mis-readings.

Amplitude (absolute sound pressure energy) readings were taken at 20 equidistant time points over the course of the vowel and the nasal, and smoothed using a five-point window. To characterize the time-course of anticipatory nasalization, sound pressure energy in the nasal channel was treated as a proxy for the velic gesture – a higher index of nasal energy indicates a lowered velum. Minimum and maximum nasal energy for each individual observation over the 40 time points (i.e., over the span of the vowel-nasal sequence) were located and the range between the two was calculated. Onset of nasalization was operationalized as the time point at which nasal energy crossed a threshold of 15% of the range (cf. Honorof 1999; Solé 1992). That is, the 15% of the range is consistent across participants and dialects, but where the criterion value falls is specific to each observation as it hinges on the range between its maximum and the minimum reading.

1 The protocol also included control items with word-final oral consonants for comparison purposes. See supplementary materials.

4 Results

All visualization in this article were done in R (R Core Team 2019), using the tidyverse suite of packages (Wickham et al. 2019). Onset of nasalization, per dialect group (yellow for Santo Domingo, blue for Buenos Aires), is visualized in Figure 1. For this and all subsequent figures, only the pre-nasal vowel and the first half of the nasal consonant are plotted. Time point zero represents onset of /n/. Thus, all time points corresponding to the pre-nasal vowel bear negative integers. Dashed lines represent the mean and time point zero corresponds to the vowel-nasal boundary.

On average, onset of nasalization was earlier for Santo Domingo ($M = -7.8$, $sd = 4.9$) than for Buenos Aires ($M = -4.3$, $sd = 4.9$), a statistically significant difference, $t(45.9) = 8.1$, $p < 0.001$, $r = 0.94$. These findings confirm the hypothesis that for Santo Domingo the pre-nasal vowel would exhibit earlier anticipatory nasalization. Considering these group differences, dialects will be examined separately in the next two subsections.

4.1 Buenos Aires Spanish

Visual inspection of the Buenos Aires data shows that onset of nasalization took place earlier with CVN syllables than with NVN syllables ($M = -6.4$, $sd = 5.3$, and $M = -1.9$, $sd = 3$, respectively; Figure 2, left panel). I attribute this finding to the operationalization of the onset of nasalization itself (see Section 5, Discussion). Regarding prosodic environment (Figure 2, right panel), the pre-nasal vowel exhibited earlier onset of velum lowering ($M = -3.1$, $sd = 3.8$) when preceding a pause than when preceding a vowel ($M = -5.8$, $sd = 5.6$). Note differences in the spread of variation of each condition, which suggest that the pre-pausal environment is more stable (i.e. less variation). For vowel type (Figure 3, left panel), /o/ exhibited earlier onset of nasalization ($M = -5$, $sd = 5.2$), followed by /e/ and /a/ (/e/, $M = -4.1$, $sd = 4.6$; /a/ = $M = -3.8$ $sd = 4.8$). The effect of stress was not immediately evident (stressed, $M = -4.5$, $sd = 5$; unstressed, $M = -4.1$, $sd = 4.7$; Figure 3 right panel).

To test the statistical significance of the linguistic variables, a linear mixed effects model was constructed using the lmer4 package. Time point was entered as the dependent variable, speaker as random effect, and syllable type, vowel, prosodic environment and stress, as fixed effects. Instead of a fully-fledged model, only one interaction term was included in the model: vowel by stress. Statistical significance was set at $\alpha = 0.05$. The baseline was CVN, stressed and /a/. The mixed effects model (Table 1) showed that syllable type, prosodic environment and vowel type were statistically significant fixed effects. Stress was not statistically significant, though the interaction with vowel type was.

In light of the significant interaction between vowel type and stress, these data were examined further (Figure 4). Across stress conditions, there was great acoustic overlap between vowels. Regarding stress, /o/ remained the vowel type with earliest onset of velum lowering across conditions. However, the relationship between /e/ and /a/ changed. When stressed, /e/ exhibited earlier onset of nasalization ($M = -4.7$, $sd = 5$) than

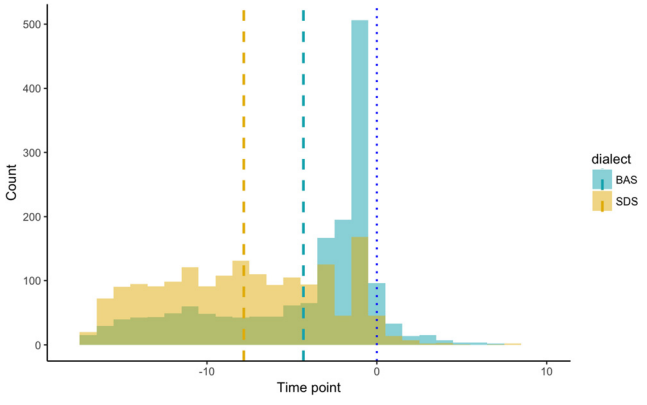

Figure 1: Histogram for onset of nasalization, per dialect.

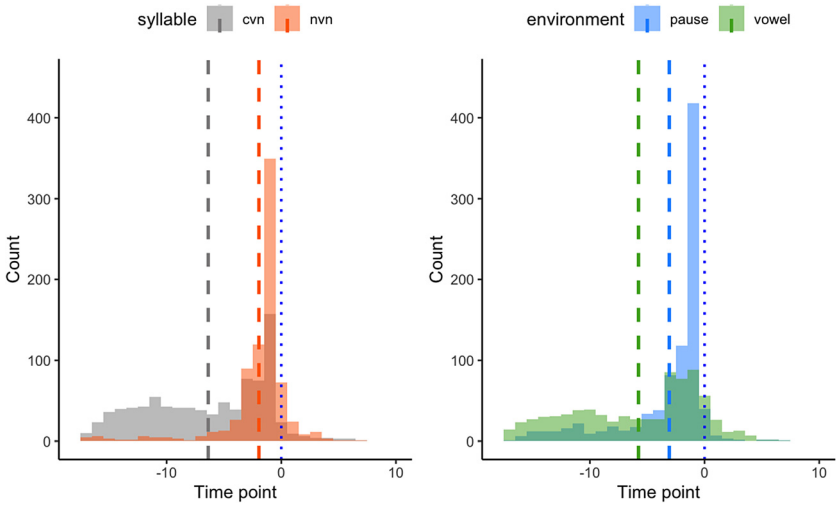

Figure 2: Histogram for onset of nasalization in BAS data, per syllable type (*L*) and prosodic environment (*R*).

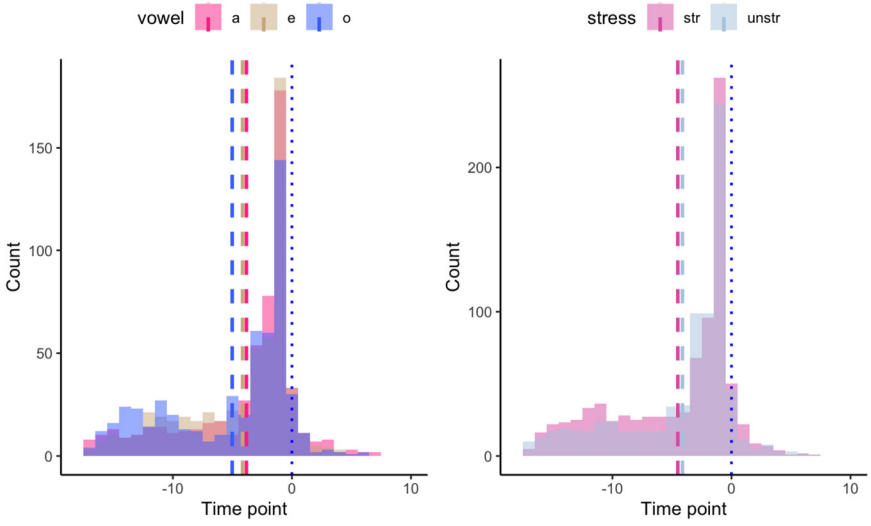

Figure 3: Histogram for onset of nasalization in BAS data, per vowel type (*L*) and stress (*R*).

Table 1: Mixed effects linear regression for the Buenos Aires Spanish speakers.

Fixed effect	Estimate	Std. error	*df*	t-value	*p*
(Intercept)	−4.48	0.35	97.52	−12.59	<0.000001
NVN	−4.32	0.20	1,639.69	21.95	<0.000001
Unstressed	−0.50	0.34	1,638.80	−1.47	Not significant
Vowel /e/	−1.12	0.33	1,638.20	−3.42	<0.000001
Vowel /o/	−1.64	0.33	1,638.65	−4.92	
Pre-vocalic environment	−2.53	0.20	1,640.88	−12.85	<0.000001
Interaction term					
Unstressed /e/	1.90	0.48	1,638.60	3.98	<0.000001
Unstressed /o/	1.07	0.48	1,639.25	2.23	<0.05

/a/ (M = −3.6, sd = 4.5). The opposite trend was found in the unstressed condition, with /a/ showing earlier onset (M = −4.1, sd = 5.2, compared to M = −3.5, sd = 4.1 for /e/). I do not currently have an explanation for this effect. Without a replication, I am hesitant to offer an interpretation.

4.2 Santo Domingo Spanish

For Santo Domingo Spanish, visual inspection of the data indicated that onset of nasalization was also elicited earlier with CVN than with NVN ($M = -9.4$, $sd = 4.8$, and $M = -6$, $sd = 4.3$, respectively; Figure 4, left panel). CVN and NVN syllables showed almost opposite distributions: onset of nasalization clustered towards the right of the histogram whereas for NVN, towards to the left. Regarding prosodic environment, the pre-vocalic condition elicited earlier nasalization ($M = -8.8$, $sd = 4.3$) than the pre-pausal condition ($M = -6.8$, $sd = 5.3$; Figure 4, right panel), though less robustly than in the Buenos Aires data. Vowel types show sizable acoustic overlap (Figure 5, left panel). Concerning stress, nasalization appears to be elicited earlier in stressed than in unstressed syllables ($M = -8.2$, $sd = 5$, and $M = -7.4$, $sd = 4.8$, respectively; Figure 5, right panel).

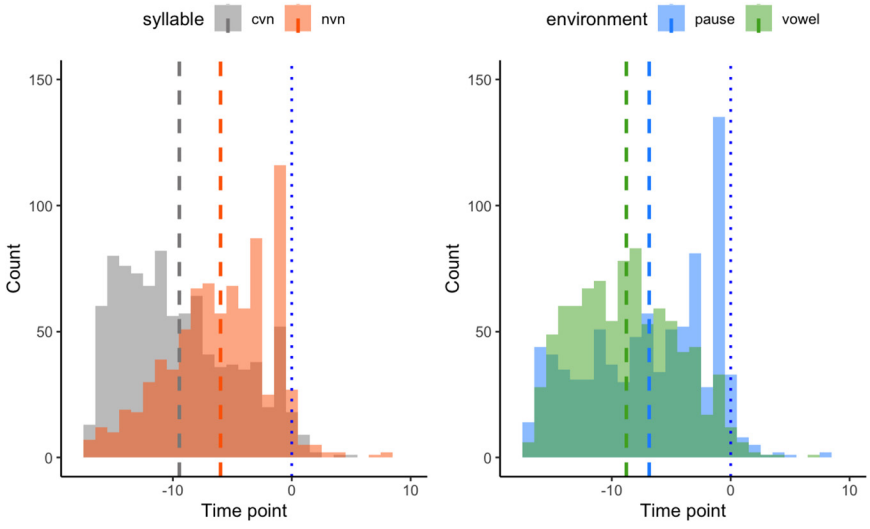

Figure 4: Histogram for onset of nasalization in the Santo Domingo data, per syllable type (*L*) and prosodic environment (*R*).

A linear mixed effects model was constructed (also with the lmer4 package), with onset of nasalization as dependent variable, speaker as random effect and syllable type, stress, environment and vowel as fixed effects. As with the previous model, the only interaction term included was vowel by stress. Statistical significance was also set at $\alpha = 0.05$. The baseline was also CVN, stressed syllables and /a/. The results of the model (Table 2) unveiled statistical fixed effects for stress, syllable type and prosodic environment, but not vowel type. The interaction between vowel type and stress was not statistically significant either.

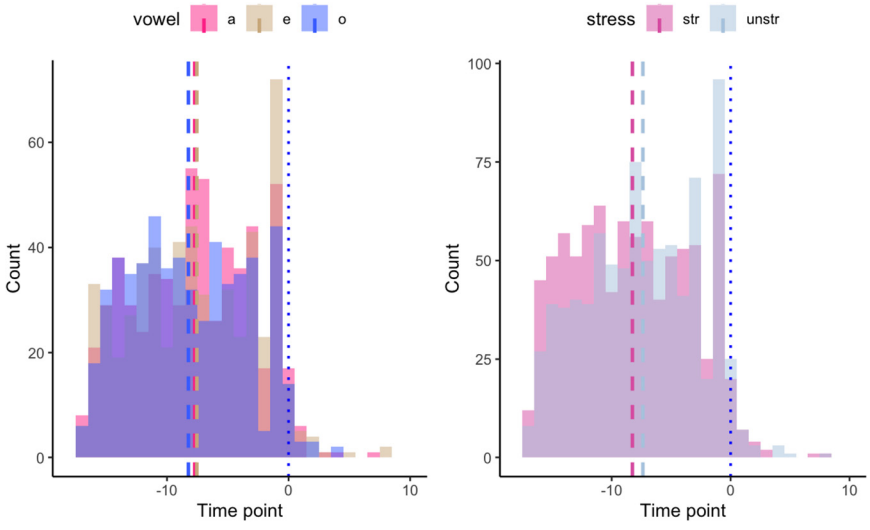

Figure 5: Histogram for onset of velum lowering in Santo Domingo data, per vowel type (*L*) and stress condition (*R*).

Table 2: Mixed effects linear regression for the Santo Domingo Spanish speakers.

Fixed effect	Estimate	Std. Error	*df*	t-value	*p*
(Intercept)	−8.94	0.44	59.96	−20.33	<0.000001
NVN	3.33	0.20	1,699.60	16.74	<0.000001
Unstressed	0.90	0.34	1,698.79	2.68	<0.01
Pre-vocalic environment	−1.85	0.20	1,699.18	−9.34	<0.000001
/e/	−0.01	0.34	1,698.97	−0.005	Not significant
/o/	−0.24	0.34	1,698.48	−0.73	Not significant
Interaction term					
Unstressed /e/	0.29	0.49	1,698.60	0.61	Not significant
Unstressed /o/	−0.326	0.48	1,698.53	−0.65	Not significant

5 Discussion and conclusion

This article presents an acoustic analysis of anticipatory vowel nasalization in a Caribbean and non-Caribbean dialect of Spanish. For this purpose, energy was measured in speech samples recorded with specialized equipment that separates mouth and nose signals, a nasometer. It was expected that Santo Domingo Spanish would exhibit earlier onset of nasalization and this was indeed the finding. Although not a novel observation, the precise quantification offered here is a new contribution.

Consistent with the cross-linguistic evidence, I interpret the phonetic difference in the time-course of nasalization as a cue to phonological differences regarding anticipatory vowel nasalization: while it is coarticulatory in Buenos Aires, it is allophonic in Santo Domingo. In addition to temporal differences in the onset of nasalization, there are several other findings in this study that additionally support this phonological interpretation of phonetic facts.

One such finding is the effect of stress across dialects. Recall onset of nasalization started earlier for stressed than for unstressed syllables, most notably in the Santo Domingo data, where it surfaced as a statistical fixed effect. Since stress functions as a "pointer" by indicating which information in an utterance is most important and linguistically relevant (de Jong 2004), the finding for Santo Domingo suggests that nasality is an intended property of the vowel in this dialect. That is, stress enhanced acoustic differences that were relevant to the phonology in this dialect group. The effect of stress was not completely absent from the Buenos Aires data. It was part of a significant interaction with vowel type. Earlier onset of nasalization was expected with /a/, particularly in the stressed condition. Instead, /o/ exhibited earlier onset of velum lowering in both stress conditions. Why this effect surfaced with /o/ remains unclear and requires replication. The results for vowel type additionally suggest that the critical comparison may not necessarily be low vs. non-low vowels, but rather high vowels vs. non-high vowels (cf. Delvaux et al. 2008).

The effect of prosodic environment may also be interpreted in light of cross-dialectal phonological differences. Briefly summarized, the results for prosodic environment indicated that anticipatory nasalization presented earlier onset in the pre-vocalic environment across dialects; these differences were more robust for Buenos Aires. I presuppose that the prevocalic environment encourages weakening (in magnitude and/or duration) of the nasal consonant, whereas pre-pausally prosodic strengthening is facilitated (Colantoni and Kochetov 2012; Fougeron 2001; Ramsammy 2013; Shosted and Willgohs 2006). I bring this assumption forward because it informs my interpretation of the data: as the nasal consonant weakened, onset of anticipatory vowel nasalization obtained earlier (Beddor 2009). The more robust effects in Buenos Aires Spanish across prosodic environments may suggest low-level articulatory planning (i.e. coarticulatory nasalization). Santo Domingo Spanish could thus be argued to be more resistant to the hypothesized effects of weakening of the nasal consonant, and for this reason the difference between environments is much narrower. It is important to keep in mind that in the absence of data on the nasal consonant, claims as to whether the temporal domain of nasalization has stretched or shrunk are not possible. This still needs to be clarified, though I hypothesize that

the velic gesture may be temporarily stable such that onset is aligned with the nasal consonant (cf. Beddor 2009). Surprisingly, prior instrumental research in Spanish has not analyzed weakening concurrently with anticipatory vowel nasalization even though the theoretical and sociolinguistic work take this relationship as its point of departure (Colantoni and Kochetov 2012; Lederer 2003; Ramsammy 2013). All in all, the data reported here point to the relative importance of strengthening or weakening of the word-final nasal consonant (cf. Beddor 2009). These findings, thus, foreground the need to examine co-variation between the consonant and the pre-nasal vowel, work that is already well under way (Bongiovanni in preparation).

Moving on to the effects of syllable type, the finding that NVN exhibited earlier onset of nasalization may be an artifact of the operationalization itself. To remind the reader, onset of nasalization was established as the first time point at which nasal energy crossed a threshold of 15% of the range between the minimum and the maximum nasal energy reading for that individual observation. Onset of nasalization was thus determined based on each individual token's 15% landmark, and not a speaker-specific threshold. With NVNs, if the velum remains lowered throughout the vowel, this operationalization still finds minimum and maximum energy points. As a result, the 15% landmark threshold establishes an onset of nasalization nonetheless, though potentially an uninformative one. I do not believe this is the case in the present study. While nasal energy traces were undeniably higher for NVNs than for CVNs overall (see Section 4 in supplementary materials), they also showed a sudden increase of nasal energy as the articulatory closure was formed for the nasal consonant (also, in supplementary materials), suggesting that the 15% threshold operationalization is sensitive to said point. Until this finding is replicated, it is better to refrain from overinterpreting this result as evidence of velum raising or lowering gestures. This hesitation should not take from the broader findings: dialectal differences are still robust when only CVNs are examined as well.

On a more descriptive note, there are also many instances of early nasalization in Buenos Aires Spanish, particularly among CVN syllables. Considering that Spanish phonological differences in nasalization have only been discussed in the context of [ŋ]-variants, this finding is noteworthy (and also unexpected). In contrast to existing instrumental research in Spanish anticipatory nasalization (e.g. Lederer 2000, cited in Lederer 2003; Solé 1992), the dialectal comparison across various linguistic environments has unveiled more intra-dialect variability than previously established.

Outside the scope of Spanish phonetics and phonology, the findings herein are important to further establish the sub-phonemic dichotomy itself. It has yet to be addressed whether the patterns observed are language specific or if they can be generalized to the coarticulatory-allophonic distinction. This study underscores the need for additional work across a range of linguistic environments and language/dialect pairs to evaluate which facts are indeed language-specific and which can be attributed to the coarticulatory-allophonic dichotomy.

One final point of discussion relates to the instrumentation employed in this study. The comparative geographic approach highlights how the nasometer could play a more active role in sociophonetic studies, an observation by no means new (Thomas 2010: 247). Nasometry lends itself nicely to data collection outside of laboratory settings and with larger speaker samples. For example, since the variation examined in this study has been well documented in the sociolinguistics literature (as outlined in Section 2.1), a key extension would be to examine variation across speaker groups within a research locale, crucially among speakers of Caribbean dialects. Even though spontaneous speech elicitation (e.g. sociolinguistic interviews) would not be attainable, a variety of speech styles would be. The use of the nasometer certainly promises new and exciting research, in particular for fieldwork.

Returning to Colantoni (2011), this investigation accomplishes each tenet: it explores a domain that has comparatively lagged behind in instrumental work on Spanish (nasality), employs innovative methodology (the nasometer), and compares across dialects (Santo Domingo and Buenos Aires Spanish). In closing, the findings in this study are consistent with observations of phonologized nasalization in the Caribbean dialect under study, Santo Domingo Spanish. In addition to regional variation, the examination of the effect of syllable type, stress, vowel quality and prosodic environment unveils much intra-dialectal variation as well. This study offers empirical support that laboratory-oriented studies can offer critical information on the regional (and arguably social) variation of anticipatory vowel nasalization.

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References

Beddor, Patrice. 2009. A coarticulatory path to sound change. *Language* 85(4). 785–821.

Boersma, Paul & David Weenink. 2016. Praat: doing phonetics by computer version 6.0.16. [Computer program]. http://www.praat.org/ (accessed 5 April 2016).

Bongiovanni, Silvina. In preparation. Covariation between nasal consonant weakening and anticipatory vowel nasalization: Evidence from a Caribbean and a non-Caribbean dialect of Spanish.

Campos-Astorkiza, Rebeka. 2012. The phonemes of Spanish. In José Ignacio Hualde, Antxón Olarrea & Erin O'Rourke (eds.), *The handbook of Hispanic linguistics*, 89–110. Chichester, West Sussex: John Wiley & Sons.

Cedergren, Henrietta & David Sankoff. 1975. Nasals: A sociolinguistic study of change in progress. In Charles Ferguson, Larry Hyman & John Ohala (eds.), *Papers from a symposium on nasals and nasalization*, 67–80. Stanford, CA: Stanford University.

Chen, Matthew. 1975. An areal study of nasalization in Chinese. *Journal of Chinese Linguistics* 3(1). 16–59.

Clumeck, Harold. 1976. Patterns of soft palate movements in six languages. *Journal of Phonetics* 4(4). 337–351.

Cohn, Abigail. 1993. Nasalisation in English: phonology or phonetics. *Phonology* 10(01). 43–81.

Colantoni, Laura. 2011. Laboratory approaches to sound variation and change. In Manuel Díaz-Campos (ed.), *The handbook of Hispanic sociolinguistics*, 9–35. Malden, MA: Wiley-Blackwell.

Colantoni, Laura & Alexei Kochetov. 2012. Nasal variability and speech style: An EPG study of word-final nasals in two Spanish dialects. *Italian Journal of Linguistics/Rivista di Linguistica* 24. 11–42.

de Jong, Kenneth. 2004. Stress, lexical focus, and segmental focus in English: Patterns of variation in vowel duration. *Journal of Phonetics* 32(4). 493–516.

Delvaux, Veronique, Didier Demolin, Bernard Harmegnies & Alaine Soquet. 2008. The aerodynamics of nasalization in French. *Journal of Phonetics* 36(4). 578–606.

Diakoumakou, Evanthia. 2004. *Coarticulatory vowel nasalization in Modern Greek*. Ann Arbor, MI: University of Michigan dissertation.

D'Introno, Francesco & Juan Manuel Sosa. 1988. Elisió de nasal o nasalizaciõ de vocal eŋ caraqueño [Nasal deletion or vowel nasalization in Caracas Spanish]. In Robert Hammond & Melvyn Resnick (eds.), *Studies in Caribbean Spanish dialectology*, 24–34. Washington, DC: Georgetown University Press.

Fougeron, Cècile. 2001. Articulatory properties of initial segments in several prosodic constituents in French. *Journal of Phonetics* 29(2). 109–135.

Haché de Yunén, Ana María. 1981. La /n/ final de sílaba en el español de Santiago de los Caballeros [Syllable final /n/ in the Spanish of Santiago de los Caballeros]. In Orlando Alba (ed.), *El español del caribe*, 143–154. Santiago de los Caballeros: Universidad Católica Madre y Maestra.

Hajek, John. 1997. *Universals of sound change in nasalization*. Oxford: Blackwell.

Hernández, José Esteban. 2009. Measuring rates of word-final nasal velarization: The effect of dialect contact on in-group and out-group exchanges. *Journal of Sociolinguistics* 13(5). 583–612.

Honorof, Douglas. 1999. *Articulatory gestures and Spanish nasal assimilation*. New Haven, CT: Yale University dissertation.

Hualde, José Ignacio. 2014. *Los sonidos del español [Sounds of Spanish]*. Cambridge: Cambridge University Press.

Krakow, Rena. 1999. Physiological organization of syllables: A review. *Journal of Phonetics* 27(1). 23–54.

Kuehn, David & Jerald Moon. 1998. Velopharyngeal closure force and levator veli palatini activation levels in varying phonetic contexts. *Journal of Speech, Language, and Hearing Research* 41(1). 51–62.

Lederer, Jenny. 2003. The diachronic coronal–velar nasal relationship. In Maria-Josep Solé, Daniel Recasens & Joaquin Romero (eds.), *15th International Congress of Phonetic Sciences*, 2801–2804. Barcelona: Causal Productions.

Lightner, Theodore. 1973. Remarks on universals in phonology. In M. Gross (ed.), *The Formal Analysis of Natural Languages. Proceedings of the First International Conference*, 13–50. The Hague: Mouton.

Lipski, John. 2011. Socio-phonological variation in Latin American Spanish. In Manuel Díaz-Campos (ed.), *The handbook of Hispanic sociolinguistics*, 72–97. Malden, MA: Wiley-Blackwell.

López Morales, Hugo. 1980. Velarización de "n" en el español de Puerto Rico [Velarization of "n" in the Spanish of Puerto Rico]. *LEA: Lingüística española actual* 2(2). 203–217.

Piñeros, Carlos Eduardo. 2008. *Estructura de los sonidos del español [Structure of Spanish sounds]*. Upper Saddle River, NJ: Pearson/Prentice Hall.

R Core Team. 2019. *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing.
Ramsammy, Michael. 2013. Word-final nasal velarisation in Spanish. *Journal of Linguistics* 49(01). 215–255.
Reenen, Pierre Th. van. 2011. *Phonetic feature definitions: Their integration into phonology and their relation to speech: A case study of the feature NASAL*. Berlin: de Gruyter Mouton.
Sampson, Rodney. 1999. *Nasal vowel evolution in Romance*. Oxford: Oxford University Press.
Schourup, Lawrence. 1972. Characteristics of vowel nasalization. *Research on Language & Social Interaction* 5(4). 530–548.
Schourup, Lawrence. 1973. A cross-language study of vowel nasalization. *Ohio State University Working Papers in Linguistics* 15. 190–221.
Schwegler, Armin, Juergen Kempff & Ana Ameal-Guerra. 2018. *Fonética y fonología españolas [Spanish phonetics and phonology]*. New York: John Wiley & Sons.
Shosted, Ryan & Beatriz Willgohs. 2006. Nasals unplugged: The aerodynamics of nasal de-occluvization in Spanish. In Manuel Díaz-Campos (ed.), *Selected proceedings of the 2nd conference on laboratory approaches to Spanish phonetics and phonology*, 14–21. Somerville, MA: Cascadilla Proceedings.
Solé, Maria-Josep. 1992. Phonetic and phonological processes: The case of nasalization. *Language and Speech* 35(1–2). 29–43.
Solé, Maria-Josep. 1995. Spatio-temporal patterns of velopharyngeal action in phonetic and phonological nasalization. *Language and Speech* 38(1). 1–23.
Terrell, Tracy. 1975. La nasal implosiva y final en el español de Cuba [Word- and syllable-final nasals in the Spanish of Cuba]. *Anuario de Letras* 13. 257–271.
Thomas, Erik. 2010. *Sociophonetics: An introduction*. Basingstoke, Hampshire: Palgrave Macmillan.
Trigo Ferre, Rosario Lorenza. 1988. *The phonological derivation and behavior of nasal glides*. Cambridge, MA: Massachusetts Institute of Technology dissertation.
Vaissière, Jacqueline. 1988. Prediction of velum movement from phonological specifications. *Phonetica* 45(2–4). 122–139.
Vaquero, María. 1996. Antillas. In Manuel Alvar (ed.), *Manual de dialectología hispanica: El español de América [Spanish dialectology: Spanish in the Americas]*, 51–67. Barcelona: Ariel.
Wickham, H., M. Averick, J. Bryan, W. Chang, L. D'Agostino McGowan, R. François, G. Grolemund, A. Hayes, L. Henry, J. Hester, M. Kuhn, T. L. E. PedersenMiller, S. M. Bache, K. Müller, J. Ooms, D. RobinsonSeidel, V. Spinu, K. Kohske Takahashi, D. Vaughan, C. Wilke, K. Woo & H. Yutani. 2019. Welcome to the tidyverse. *Journal of Open Source Software* 4(43). 1686.

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