Place vs. Stricture in Spanish Nasal Assimilation*

Alexei Kochetov and Laura Colantoni
University of Toronto

1. Introduction

In this paper we investigate patterns of place and stricture assimilation of Argentine Spanish nasals in order to test two competing models of phonological representations of place and stricture features (or tract variables). Electropalatographic (EPG) data from four speakers of Buenos Aires Spanish reveal that nasal assimilation before coronals within words (e.g. in /kanta/, /kansa/, /anʧa/) involves changes in both place and stricture. While place assimilation is found to be overwhelmingly obligatory and categorical, stricture assimilation is optional and gradient, seemingly dependent on speaking rate and/or style. These results partly support the models that assume dependency between place and stricture features, while pointing to some problems with the traditional feature geometric and gestural representations. Building on the current results, we provide a preliminary analysis of Spanish nasal assimilation that employs modified gestural representations manipulated by faithfulness and gestural coordination constraints.

2. Background

Models of phonological representations disagree on the status of the features encoding place of articulation and stricture (continuancy). In most feature geometry models, place and stricture are seen as fully independent, represented by separate 'sister' nodes. This is, for example, how these features are organized in Clements & Hume's model (1995) (1a). In other approaches, specifically in Padgett's (1995) feature geometry model, stricture is a dependent of the place node (1b). The dependency between place and stricture is also expressed in gestural representations of Articulatory Phonology (Browman & Goldstein 1989), as both are represented as constriction location (CL) and constriction degree (CD) variables of articulatory gestures (e.g. the tongue tip gesture for [t], (1c)).

(1) a. Supralar
[Place] [cont]

b. Supralar
[Place]
[cont]

c. Tongue Tip
CL [alveolar] CD [closed]

Some important evidence for the dependency between place and stricture comes from nasal assimilation processes. As Padgett (1995) observes, languages tend to avoid assimilation of nasals to fricatives. This is done in a number of ways, with the nasal assuming a default place of articulation value (as in Polish, (2a)), deleting altogether (as in Zoque, (2b)), or assimilating to and hardening the following fricative (as in Zulu (2c)) (data from Padgett, 1995: 39-42, 54). These different repair

* The authors would like to thank the audience of WCCFL 28 for helpful comments and suggestions, and Daniel Recasens for valuable advice on data analysis. Thanks also to Bojana Radovanovic for assistance with labeling EPG data. All errors are the authors' responsibility. The work is supported by a University of Toronto Connaught Grant to the first author. For more information on the project, please see http://utlinguistics.blogspot.com/2010/02/phonetic-work-on-argentine-and-cuban.html or email *al.kochetov@utoronto.ca* and *laura.colantoni@utoronto.ca*.

strategies are seen as closely related under the place-stricture dependency approaches (1bc), but do not follow directly from the place-stricture segregation approach (1a).

(2)	a.	Polish		
		szansa	[ʃaw̃sa]	‘chance’
		konflikt	[kow̃flikt]	‘conflict’
		cf. *blond*	[blond]	‘blond’
		cf. *bank*	[baŋk]	‘bank’
	b.	Zoque		
		/N-sʌk/	[sʌk]	‘my beans’
		/N-faha/	[faha]	‘my belt’
		cf. /N-tatah/	[ndatah]	‘my father’
		cf. /N-pama/	[mbama]	‘my clothing’
	c.	Zulu		
		/iziN-fudu/	[izimpfudu]	‘tortoises’
		/iziN-sizi/	[izintsizi]	‘sorrows’

In a few rare cases, assimilation does result in nasal-fricative clusters. Such clusters are found among the well-known patterns of assimilation in Spanish (3) (data from Padgett 1995: 50; cf. Harris, 1969; Piñeros, 2006; Bakovi, 2007). At a first look, the presence of nasals (which are by default [-continuous]) before fricatives (which are [+continuous]) suggests that assimilation in Spanish affects place but not stricture, thus supporting the segregation approach. Yet, as Padgett argues (p. 50-51), the nasals in these cases are likely to be [+continuous], having a reduced constriction degree. These segments are thus assimilated in both place and stricture, and can be narrowly transcribed as shown on the right in (3a). The absence of considerable oral airflow or frication in such nasals is apparently due to the reduced air pressure in the oral cavity resulting from lowering of the velum (Ohala, 1975), not due to the purported presence of an oral closure.

(3)	a.	*manso*	[ns]	or	[s̃s]	‘gentle’
		ánfora	[ŋf]	or	[f̃f]	‘amphora’
		ajenjo	[nx]	or	[x̃x]	‘wormwood’
	b.	cf. *manto*	[n̪t̪]			‘cloak’
		cf. *mancho*	[nʲʧ]			‘I stain’
		cf. *campo*	[mp]			‘country’
		cf. *manco*	[ŋk]			‘one-handed’

The prediction that nasals should have reduced constriction degree before fricatives receives some support in the descriptive literature on Spanish nasal assimilation. While most descriptions of the phenomenon focus on place assimilation only (Harris, 1969; Quilis, 1993; Hualde, 2005), Navarro Tomás (1918) notes some differences in stricture. According to him, nasals before some fricatives (i.e. /f/, /θ/, and /x/) have no complete closure, yet produce no perceptible frication (§89, 95, 130). In contrast, nasals before stops and affricates appear to be fully occluded (§87, 104, 122, 130).

Some articulatory evidence for stricture, as well as place assimilation was obtained by Honorof (1999). He collected electromagnetic midsagittal articulometer (EMMA) data from four speakers of Peninsular Spanish producing various /n/ + consonant sequences both within and across words. The results revealed that the constriction location and degree of the syllable-final nasal was indeed similar or identical to the constriction location and degree of the following obstruent. Before non-coronals (/p f k x/), assimilation was categorical: a complete deletion of the tongue tip gesture and extension of the lip or tongue body gesture (either having a stop- or fricative-like constriction: *ca*[mp]*ar* ‘to wander around’, *ca*[f̃f]*ar* (nonsense word)). Before the coronals (/t θ s/), assimilation was apparently gradient, with the nasal showing intermediate values in constriction location and degree (i.e. gestural blending: *ca*[^{n}n̪t̪]*a* ‘to sing’, *ca*[^{n}s̃s]*ar* ‘to weary’). Honorof interpreted the results as evidence for a representational approach where place and stricture features are dependent on each other (1b and 1c), and specifically for the gestural representations of Articulatory Phonology. Honorof’s findings with

respect to stricture assimilation before coronals, however, may not be fully conclusive, as the EMMA method does not provide clear information about the tongue-palate contact. With respect to place assimilation before coronals, the results are also limited, since the set of contexts used in the study did not include the palato-alveolar /ʧ/, which is known to substantially back or palatalize the nasal (Navarro Tomás, 1918; Quilis, 1993; see also Martínez Celdrán & Fernández Planas, 2007 for EPG evidence from Peninsular Spanish).

The goal of this study is to further investigate Spanish within-word nasal assimilation before coronal obstruents using electropalatography (EPG), a technique that provides relatively precise information about constriction degree and location in the alveolar/palatal region. The speech variety investigated is Spanish spoken in Buenos Aires, Argentina, which is similar to Peninsular Spanish in some relevant respects, such as the default alveolar realization of the coda nasal and the general patterns of nasal assimilation (Quilis, 1993). Our focus is on articulatory properties of the nasal (which is assumed to be an apical alveolar /n/) before three coronals: the laminal dental stop /t/, the (apico-laminal) alveolar fricative /s/, and the laminal palato-alveolar affricate /ʧ/. If place and stricture are indeed inter-dependent, we would expect to find consistent place assimilation before /t/ (a fronted and/or more laminal constriction) and /ʧ/ (a backed and more laminal or palatalized constriction), as well as consistent stricture assimilation before /s/ (a constriction lacking a complete closure). Given Honorof's findings, we would also expect that both place and stricture assimilation be gradient, showing partial fronting, backing, and de-occlusivization.

3. Method

Four female speakers from Buenos Aires (A1-A4), who at the time of the experiment resided in Toronto, Canada, were recruited for the study. The materials consisted of six words with /n/ followed by /t/, /ʧ/, and /s/, with the nasal in a stressed and an unstressed syllable (4). The words were presented in a carrier phrase *Diga __ otra vez* ('Say ___ once again'), together with other items, and produced by each speaker six times at a comfortable speaking rate. This resulted in 144 tokens (6 items x 6 repetitions x 4 speakers).

(4)

Stressed		Unstressed	
canta	's/he sings'	*cantó*	's/he sang'
cansa	's/he tires out'	*cansó*	's/he tired out'
ancha	'wide'	*planchar*	'to iron'

A WinEPG system (Wrench et al., 2002) was used for data collection, with EPG data sampled at 100 Hz, acoustics at 22,050 Hz. Artificial palates with 62 electrodes were custom-made for each participant. For the purposes of the study, the focus is on the first five rows of electrodes on the palate corresponding to the alveolar/post-alveolar constriction, as shown in Figure 1.

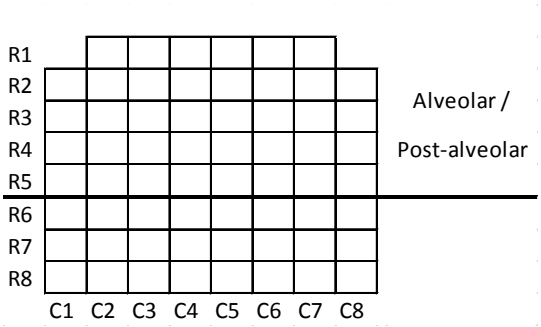


Figure 1. The palate phonetic zoning

Measurements of the tongue-palate contact were made at two points: at the midpoint of the nasal portion of the cluster (C1, determined based on the waveform and spectrogram) and at the midpoint of the following obstruent (C2, taken as the midpoint of the stop/affricate closure or fricative noise).

These measurements were converted to the following two indices corresponding to the relative front/back position of the alveolar constriction and the degree of its central occlusion (see Fontdevila, Pallarès, & Recasens, 1994 for details):

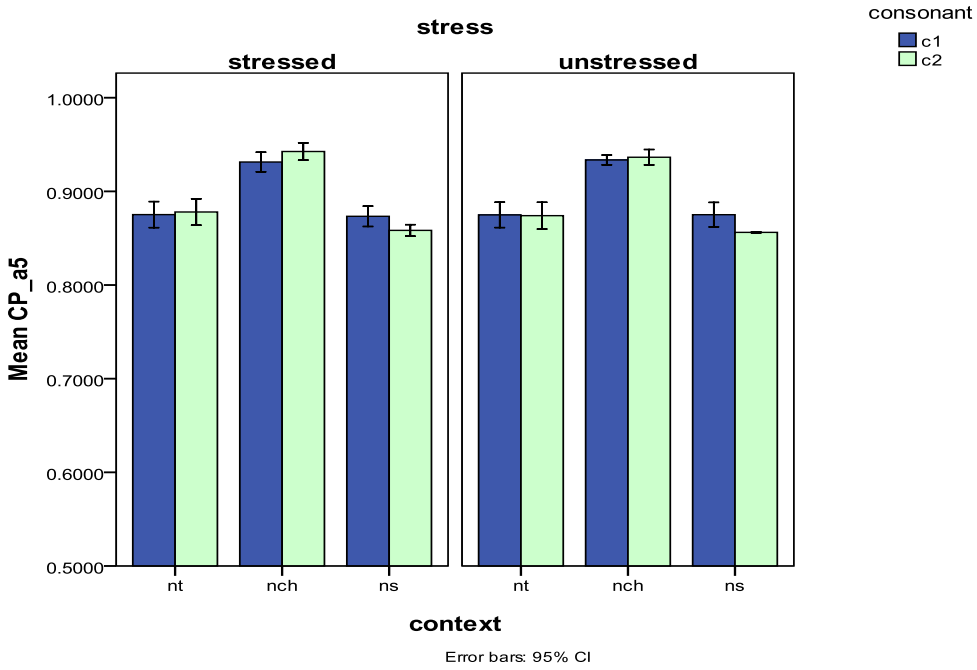
- Contact Posteriority for the alveolar region (CPa): the backmost position of the constriction in the first 5 rows, with higher values corresponding to a more posterior or more laminal constriction.
- Contact Centrality for the alveolar region (CCa): the degree of central occlusion in the 5 central columns of the first 5 rows, with higher values corresponding to a greater central occlusion.

CPa was expected to be higher before /ʧ/ (i.e. more back) than before /t/ and /s/; CCa was expected to be lower before /s/ (i.e. less centrally occluded) than before /t/ and /ʧ/. (These differences were established in an analysis of single consonants of Argentine Spanish: Kochetov & Colantoni, 2009). A lack of significant differences in CPa or CCa between the nasal (C1) and the following consonant (C2) was interpreted as categorical assimilation in place or stricture. Presence of significant differences between C1 and C2 was interpreted as partial assimilation or no assimilation (depending on the degree of the observed differences). In addition to the analysis based on CPa and CCa indices, we also examined individual linguopalatal contact profiles for the presence or absence of complete coronal closure before /s/.

4. Results

Figure 2 plots mean C1 and C2 values representing relative frontness/backness (CPa) and degree of central occlusion (CCa) in three clusters and two stress conditions, averaged for 4 speakers. As expected, CPa values for the nasal before /ʧ/ were higher than before /t/ and /s/, corresponding to the more posterior constriction of the former. Stress did not seem to influence the relative posteriority of constrictions. Also as expected, CCa values for the nasal before /s/ were substantially lower than before /t/ and /ʧ/, corresponding to the less centrally occluded constriction for the former. In addition, the nasal before /ʧ/ was more centrally occluded than before /t/. Interestingly, the CPa and CCa values for the nasal were hardly different from those for the following obstruent, except when the following obstruent was /s/. In the latter case, the differences were particularly notable in stricture (CCa), with the nasal having an intermediate value between the fully occluded nasals before /t/ and /ʧ/, and the fricative-like constriction of /s/. Note also that that reduction in CCa for C1 was greater in the stressed condition. Overall, this can be interpreted as gradient, partial assimilation before /s/ in stricture. In contrast, assimilation before /t/ and /ʧ/ was seemingly categorical, complete.

An examination of individual results revealed some important differences across speakers in context-specific realization of the nasals. Figure 3 presents linguopalatal profiles taken at the midpoint of nasal consonants in all six words (averaged over 6 tokens) separately for each speaker. The color of the cells in the profiles ranges from white (no contact in any of the tokens) to black (contact in all 6 tokens). The nasals before the stop and the affricate show consistently complete closures in the alveolar/post-alveolar region (in rows 1-4), somewhat more posterior and/or having greater palatal side contact before /ʧ/ than before /t/. In contrast, only one of the speakers, A1, shows a complete closure before /s/ (notably less extensive than in the other two contexts). Speaker A2 shows fricative-like constriction with a central groove in all 6 tokens. Speakers A3 and A4 show variable realization of the nasal in this context, either with or without closure. Note also that A2, A3, and A4 show less central contact before /s/ in the stressed condition, compared to the unstressed one (e.g. *canso* vs. *cansó*). Counts across both stress conditions showed that the overall rate of closure retention varied considerably across speakers: 100% for A1 (12 out of 12 tokens), 17% for A2, 67% for A3, and 17% for A4.



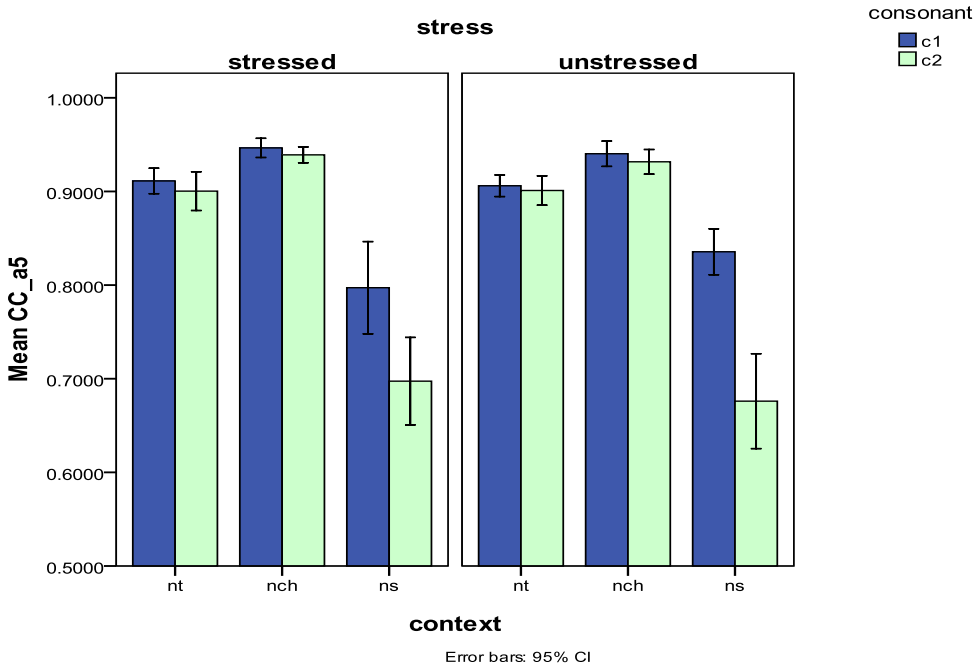


Figure 2. Mean C1 and C2 values of Contact Posteriority (top) and Contact Centrality (bottom) in the alveolar region by context (nt, ntʃ, ns) and stress condition (ˈVnCV and VnˈCV). Results averaged for 4 speakers over 6 repetitions.

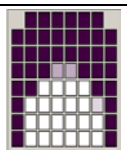
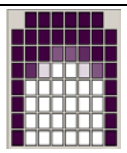
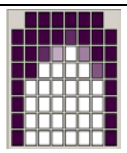
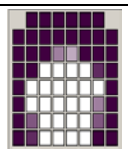
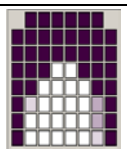
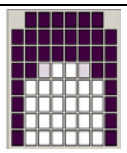
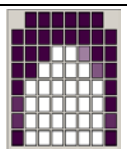
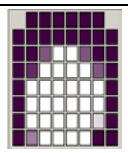
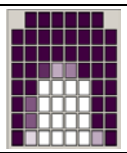
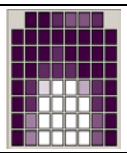
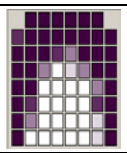
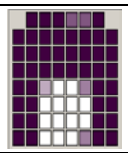
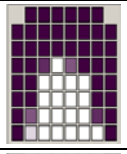
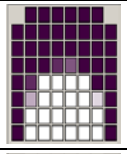
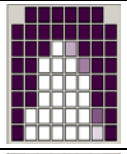
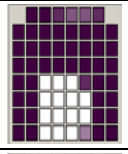
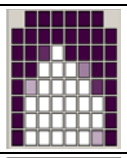
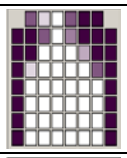
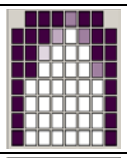
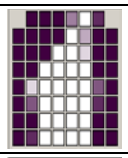
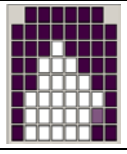
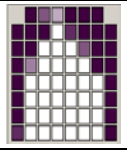
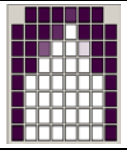
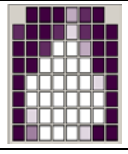
Context	Stress	A1	A2	A3	A4
_t	Stressed				
	Unstressed				
_tʃ	Stressed				
	Unstressed				
_s	Stressed				
	Unstressed				

Figure 3. Mean linguopalatal contact of nasals before three consonants in two stress conditions, separately for 4 speakers (see Figure 1 for the palate zoning)

To further determine whether nasals were articulated with the same or different place and stricture as the following obstruent, we performed paired samples t-tests comparing C1 and C2 in terms of constriction posteriority and centrality. The results are summarized in Table 1 by CPa and CCa, indicating whether the differences were significant ($p \leq .01$), as well as the direction and amount of significant differences. In terms of place assimilation, no significant differences were obtained between C1 and C2 in any of the three clusters, except for A1 who showed a more posterior constriction for the nasal before /s/ (cf. Figure 3), and for A4 who showed some posteriority differences between C1 and C2 in the /nt/ and /ntʃ/ clusters. In terms of stricture, the nasal was not significantly different from the following stop or affricate, except for A4, where /n/ was somewhat less constricted than the following /t/. There was considerably more inter-speaker variability in stricture assimilation: Speakers A2 and A4 showed no significant difference between the nasal and /s/ in CCa, whereas for A1 and A3 the nasal was significantly more occluded than /s/. It should be noted that the CCa differences here were quite substantial, compared to the above-mentioned CCa and CPa differences, even for the speakers who showed no significant effect. These statistical results confirm the inter-speaker variation in the presence/absence or degree of nasal occlusion before /s/ noted above.

Table 1. Results of paired-samples t-tests comparing C1 and C2 in terms of Contact Posteriority (CPa) and Contact Centrality (CCa) in the alveolar region in three clusters, separately for each speaker

Cluster	CPa (place)				CCa (stricture)			
	A1	A2	A3	A4	A1	A2	A3	A4
/nt/	n.s.	n.s.	n.s.	* (c1<c2, 0.004)	n.s.	n.s.	n.s.	* (c1<c2, 0.036)
/nʧ/	n.s.	n.s.	n.s.	* (c1>c2, 0.018)	n.s.	n.s.	n.s.	n.s.
/ns/	** (c1>c2, 0.058)	n.s.	n.s.	n.s.	** (c1>c2, 0.147)	n.s.	** (c1>c2, 0.124)	n.s.

**p<.001, *p<.01, n.s. = not significant (p≥.01); df = 11

5. Discussion

The results of the study show that nasals in Argentine Spanish tend to share constriction location with following coronal obstruents occurring within words. Both consonants in /nʧ/ are more posterior than the corresponding consonants in /nt/ or /ns/; the consonants in /nt/ also have a more extensive (i.e. laminal) front-to-back constriction than the consonants in /ns/. This is suggestive of consistent and largely categorical place assimilation in word-internal clusters. Further, nasals also share constriction degree and shape with the following non-continuant consonants, /t/ and /ʧ/. The same, however, does not always hold before the continuant /s/, where most speakers show values for the parameter intermediate between the fully occluded and the fricative-like constriction (also affected by stress). This suggests that assimilation in stricture is somewhat different from assimilation in place, being, at least under the current conditions, optional, gradient, and restricted to certain clusters.

The finding that nasals assimilate in both place and stricture is consistent with Honorof's (1999) results, as well as with Navarro Tomás' (1918) informal observations and Padgett's (1995) theory-based predictions. At the same time, our finding that place and stricture assimilation is largely categorical, apart from the /s/ context, is in contrast with Honorof's conclusions (although consistent with his original predictions for word-internal clusters). This discrepancy can be due to dialect differences (e.g. unlike in Argentine, /s/ in Peninsular Spanish is apical alveolar or retroflex), to the set of consonants used, and/or to the methods employed in both studies. Recall that Honorof's study did not include palato-alveolars, which in our case showed consistent backing of preceding nasals (cf. Martínez Celdrán & Fernández Planas, 2007). His study also used EMMA, which provides valuable information about the special position of various articulators, but does not provide precise information about the tongue/palate contact.

It is reasonable to assume that the variable and gradient application of nasal stricture assimilation is related to degrees of gestural overlap, which, in turn, depend on speaking rate and style (Browman & Goldstein, 1989). This predicts that stricture assimilation is more likely to occur or to have a greater extent in faster and more casual speech. We do have some preliminary data that confirms this prediction. As part of the preparation for the experiment, the same speakers read a text, which contained three instances of the word *entonces* 'then'. This task presumably involved less formal or faster speech than reading of the short utterances analyzed earlier. As seen in Figure 4, three out of four speakers (A1, A2, and A4) produced a considerably less constricted /n/, compared to the similar stressed sequence in Figure 3. The degree of de-occlusivization is particularly striking for A1 and A2. It should be noted that the latter speaker showed a very short nasal (acoustic) component of the cluster and a strongly nasalized vowel – the properties indicative of a tendency to vocalization of the nasal before fricatives (cf. Navarro Tomás, 1918; Quilis, 1993).

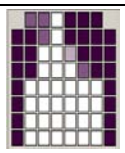
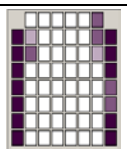
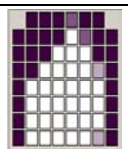
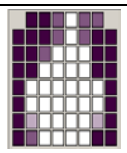
Context	A1	A2	A3	A4
ˈo_s				

Figure 4. Mean linguopalatal contact at the midpoint of the nasal before /s/ in the word *entonces* produced in a reading passage by 4 speakers (3 tokens each)

6. Implications

The results of the study have some important implications for the models of featural or gestural organization. Specifically, the similar (obligatory and categorical) patterning of place and stricture in some contexts and their somewhat different (optional and gradient) patterning in other contexts suggests that the two features or tract variables are partly dependent and partly autonomous. The first observation is consistent with models of place-stricture dependency (1bc), favoring them over models of place-stricture segregation (1a). The second observation, however, points to the limitation of the dependency models, where the relations between features or gesture variables are 'all or nothing'. The categorical and near-obligatory status of assimilation in place further suggests that it is in some sense primary, while stricture assimilation is secondary. In other words, stricture assimilation implies place assimilation. This is predicted by Padgett's (1995) feature geometry model, where stricture is subordinated to place, yet does not quite follow from Browman & Goldstein's (1989) gestural model where constriction degree and location have an equal status. At the same time, the apparently gradient and rate/style-dependent status of stricture assimilation is not compatible with the inherently categorical nature of feature geometry model of Padgett (1995). In contrast to the latter model, the gestural representations of Articulatory Phonology are capable of modeling both gradient and categorical realizations of assimilation. Our observation that stricture assimilation may turn into nasal vocalization (deletion of the nasal consonant and nasalization of the vowel) as the speech rate increases or becomes more casual is interesting, as it provides evidence for a link between the two processes. In fact, these processes can be viewed as two steps in the direction of eliminating the highly marked nasal-fricative clusters, as predicted by the place-stricture dependency approaches (Padgett, 1995; cf. Piñeros, 2006; Baković, 2007; see also Hajek 1997 on the historical development of nasal-obstruent clusters).

A detailed formal analysis of Spanish nasal assimilation is beyond the scope of this paper. It is worth, however, to outline a preliminary proposal building on the current experimental findings. One possible way to capture the autonomous status of place and stricture is to assume that tract variables of the traditional gestural representations (Browman & Goldstein, 1989; see 1c) are decoupled from each other. In other words, the variables [constriction location] (CL) and [constriction degree] (CD) are given an autonomous status (cf. Gafos 1999 on the autonomy of CL and CD in consonant harmony). The partial dependency and implicational relations between the two, however, can be captured by Optimality Theoretic faithfulness constraints to CL and CD that are harmonically ranked (fixed): IDENT(CD) » IDENT(CL). These constraints enforce the realization of CD and CL identical to the input representations (e.g. CD [closed], CL [alveolar] for /n/). The fixed higher ranking of IDENT(CD) over IDENT(CL) reflects the higher priority of maintaining the original stricture configuration over the original place configuration, thus limiting the possible patterns of assimilation to those involving either place (CL) or both place and stricture (CL and CD). Following Gafos (2002), we assume that many phonetic/phonological processes affecting clusters, such as assimilation, deletion, and epenthesis, are triggered by constraints on consonant-to-consonant gestural coordination. These constraints refer to different gestural landmarks, for example, requiring the release of the first consonant (C1) to be timed at the target achievement of the second consonant (C2), or the center of C1 to be timed at the target achievement of C2 (see Gafos, 2002 for details), as illustrated in (5). As such, these constraints effectively produce different degrees of gestural overlap, as representative of different speaking rates and styles. All being equal, greater gestural overlap is assumed to induce assimilation, as gestural specifications of the two consonants have conflicting targets for constriction location and/or

constriction degree. Given the fixed ranking of faithfulness constraints discussed above, a smaller degree of overlap is predicted to induce place assimilation, but not stricture assimilation, while a larger degree of overlap should result in assimilation in both place and stricture. Stricture assimilation without place assimilation is not possible under this account. The constraint rankings responsible for the two patterns, presumably associated with two different speaking rates or styles, are shown in (6). Gradient realization of stricture assimilation would follow from rates and styles intermediate between the slow/formal and fast/casual extremes. In sum, this proposal correctly captures the observed partial dependence and autonomy of place and stricture in Spanish nasal assimilation, setting the stage for a more comprehensive account of nasal assimilation and place/stricture interactions in general.

(5) a. C1 release to C2 target b. C1 center to C2 target

(6) a. place assimilation at slow rate and/or formal style
IDENT(CD) » CC-COORD$_{RELEASE}$ » IDENT(CL)
b. place and stricture assimilation at fast rate and/or casual style
CC-COORD$_{CENTER}$ » IDENT(CD) » IDENT(CL)

References

Baković, Eric. (2007). Local assimilation and constraint interaction. In Paul de Lacy (ed.), *The Cambridge handbook of phonology* (pp. 335-352). Cambridge: Cambridge University Press.

Browman, Catherine P. & Goldstein, Louis. (1989). Articulatory gestures as phonological units. *Phonology, 6*, 201-252.

Clements, G. Nick & Hume, Elizabeth. (1995). The internal organization of speech sounds. In John Goldsmith (ed.), *A handbook of phonological theory* (pp. 245-306). Oxford: Blackwell.

Fontdevila, Jordi, Pallarès, Maria Dolors, & Recasens, Daniel. (1994). The contact index method of electropalatographic data reduction. *Journal of Phonetics, 22*, 141-154.

Gafos, Adamantios. (1999). *The articulatory basis of locality in phonology*. New York: Garland. [1996. Baltimore, MD: Johns Hopkins University Ph.D. dissertation.]

Gafos, Adamantios. (2002). A grammar of gestural coordination. *Natural Language and Linguistic Theory, 20*, 269–337.

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

Harris, James. (1969). *Spanish phonology*. Cambridge: MIT Press.

Honorof, Douglas. (1999). Articulatory gestures and Spanish nasal assimilation. Ph.D. dissertation, Yale University.

Hualde, José Ignacio. (2005). *The sounds of Spanish*. Cambridge: Cambridge University Press.

Kochetov, Alexei & Colantoni, Laura. (2009). Articulatory characteristics of coronal consonants in Argentine Spanish: An electropalatographic study. *Journal of the Acoustical Society of America 126*. 2222.

Martínez Celdrán, Eugenio & Fernández Planas, Ana Ma. (2007). *Manual de fonética española*. Barcelona: Ariel.

Navarro Tomás, Tomás. (1918 [1970]). *Manual de pronunciación española*. Madrid: CSIC.

Ohala, John J. (1975). Phonetic explanations for nasal sound patterns. In C. A. Ferguson, Larry M. Hyman, & John J. Ohala (eds.), *Nasalfest: Papers from a symposium on nasals and nasalization* (pp. 289-316). Language Universals Project, Department of Linguistics, Stanford University.

Padgett, Jaye. (1995). *Stricture in Feature Geometry*. Stanford, CA: CSLI Publications.

Piñeros, Carlos-Eduardo. (2006). The phonology of nasal consonants in five Spanish dialects. In Martinez-Gil, Fernando & Sonia Colina (eds.), *Optimality-theoretic studies in Spanish Phonology* (pp. 146-171). Amsterdam: John Benjamins.

Quilis, Antonio. (1993). *Tratado de fonética y fonología españolas*. Madrid: Gredos.

Wrench, A. A., Gibbon, F. E., McNeill, A. M., & Wood, S. E. (2002). An EPG therapy protocol for remediation and assessment of articulation disorders. In J. H. L. Hansen & B. Pellom (eds.), *Proceedings of ICSLP-2002*. 965- 968. Denver, USA.