Articulatory Evidence for Nasal De-occlusivization in Castilian

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ABSTRACT

The literature on intervocalic consonants in Spanish attests to the spirantization of voiced *oral* stops except in absolute initial position and immediately following certain homorganic consonants. Surprisingly, in the present investigation, analysis of magnetometer data from multiple native speakers of Castilian suggests that voiced singleton *nasal* stops may also de-occlusivize generally, including in those environments reported elsewhere for the spirantization of /b, d, g/. Implications for theories of intrinsic and extrinsic timing are discussed.

1. INTRODUCTION

In all varieties of Spanish, voiced stops (/b, d, g/) "spirantize" (that is, weaken, lenite, de-occlusivize). In Castilian [1:§100], as in and most Spanish accents, these stops spirantize in all but the following environments:

1. Absolute initial position; and
2. When preceded by a homorganic consonant made with a complete midsagittal occlusion (potentially nasals and, for dentals, /l/).

In other contexts, these consonants are articulated with a more open *stricture* (or, in the sense of [2], *manner* of articulation) than expected for stops. Thus they may be classed as continuants, though it has been argued that these continuants are relatively shorter in duration and more intense than fricatives and unaccompanied by turbulent airflow despite a constriction as occluded as that for a fricative, at least in Andalusian [3]. Following [3], therefore, such spirantized sounds will be referred to here as approximants.

Within a feature-and-node-based phonological framework, /b, d, g/ are expected to participate in a natural class; in minimal, generic terms, they are voiced non-nasal consonants. Thus all three voiced stops might be expected to participate in a single phonological pattern to the exclusion of /n/ which is [+nasal]. In a gesture-based theory of extrinsic timing such as Articulatory Phonology [4], however, the predictions are sometimes different. When phonological patterns involving /d/ are explained in terms of increases in overlap or reduction in gestural magnitude, for example, one expects the same pattern to obtain for /n/, all other things being equal. /n/ should behave like /d/ in such cases because both involve a single midline closure on the oral tier, and, in fact, both involve part of the tongue tip-blade complex (though, in Spanish, /n/ is alveolar and /d/, dental). Thus, if spirantization of /b, d, g/ is represented as a reduction of gestural magnitude [3], one would predict that the tongue-tip gesture for /n/ will also reduce in gestural magnitude under analogous conditions.

Unfortunately, impressionistic transcriptions of Spanish and classic descriptions of Spanish phonology agree in the assertion that /n/ does not de-occlusivize in intervocalic environments, (though some reduction of stricture is noted in assimilation of /n/ to /f/ or /θ/ by Navarro Tomás [1:§89, §95]). However, in the course of collecting pilot data for a more extensive magnetometer study of Castilian nasal place assimilation [5], it became apparent that /n/ was de-occlusivized between vowels. As all /n/s in the data set occurred in intervocalic position, the pilot data lacked crucial information about the canonical place and stricture of an ideally articulated alveolar nasal. Therefore a nasal juncture geminate was added to the stimulus set in hopes that de-occlusivization would be blocked. That is, with the addition of /n#n/ to the stimulus set, it became possible to ask whether an orthogonal set of native speakers of Castilian de-occlusivize /n/ intervocalically but not in juncture geminates.

2. METHODS

Participants. Three speakers of Castilian participated in the present study. None reported having any speech, hearing, language or communication disorders. Although all had learned to speak English fluently as a foreign language, and although all had learned other languages as well, Castilian was the primary language spoken in childhood for all three talkers.

Participant One (*P1*) was a 25 year-old female who had lived in Madrid on and off for most of her life and whose parents and grandparents where all from Madrid. She believes that her own accent is typical of a 'madrileña', an assertion confirmed by Participant Two who was familiar with her speech.

Participant Two (*P2*) was a 25 year-old male from Madrid, where he had lived virtually all his life. The participant spoke only Castilian in the home as a child, and considers his native accent to be Castilian from Madrid. He reported a one-centimeter long flat clip of an unspecified metal in his right shoulder. The shoulder remained outside the

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center of the magnetic field during data collection.

Participant Three (*P3*) was a 35 year-old male from Salamanca, where he had lived until relocating to the United States to teach the Spanish language in his mid-thirties. He reported that he is a native-speaker of Castilian.

Materials. Non-contrastive coronal nasal consonants were examined in four intervocalic positions: a) within a word (*a canar,* 'to go gray'), b) before a word boundary (*digan haga,* "say [form. pl.] 'haga'" where the 'h' is not pronounced), c) after a word boundary (*diga naja,* "say [form. sg.] 'naja'"), and, as a control condition, d) within a juncture geminate (*digan naja,* "say [form. pl.] 'naja'"). Stimuli were cast in one or the other of a pair of felicitous, parallel carrier phrases. For the VnV tokens (*a canar*) the carrier phrase was "*Di _______ más alto*" ("Say _______ more loudly.") For the three word-boundary conditions (*digan#haga*, *diga#naja* and *digan#naja*), the carrier phrase used was simply "*_______ alto*" ("_______ loudly"), where the word "say" was actually part of the target material. Stimuli were presented in pseudo-random order. Approximately 14 repetitions were collected for each talker blocked by two self-selected speaking rates.

Procedure. Articulometry (specifically the EMMA system [6]) was employed to transduce articulator movement into measurable digital data while the talker read the stimuli aloud with the explicit goal of using a reasonably "non-read" speaking style. The set-up involved affixing an electromagnetic transducer coil approximately 1.5 mm in diameter to the midline of the superior surface of the tongue as close to the tip as practical (5-9 mm behind the outstretched apex as estimated using calipers). For purposes not relevant to the present work, three other coils were affixed to the superior surface of the tongue and one to the vermilion border of each lip. Standard reference coils were also used.

Movement of the articulator-coils within the electromagnetic field was sampled 625 times per second. After voltage-to-distance conversion, the kinematic data were fed through a triangular low-pass filter (-3 dB gain, 17 kHz frequency cutoff). After the fact, it was discovered that the maxillary head reference coil became unglued for P3 during the start of the fast block, so only the slower tokens were analyzed for P3.

Data analysis. Results are presented in Tables 1 and 2 for algorithmic measurements made on absolute peak vertical displacement of the tongue tip during the nasal interval. For reference, Figure 1 shows tongue tip movement paths (that is, trajectories through Cartesian space) derived from averages across all tongue tip vertical (*TTY*) and tongue tip horizontal (*TTX*) displacement curves. Conceptually, curves represent the region between achievement and release of tongue tip constriction for the nasal or nasals. Achievement and release of target were determined by an automatic zero-crossing algorithm applied to tongue tip constriction degree (*TTCD*) curves (smoothing: 24 ms

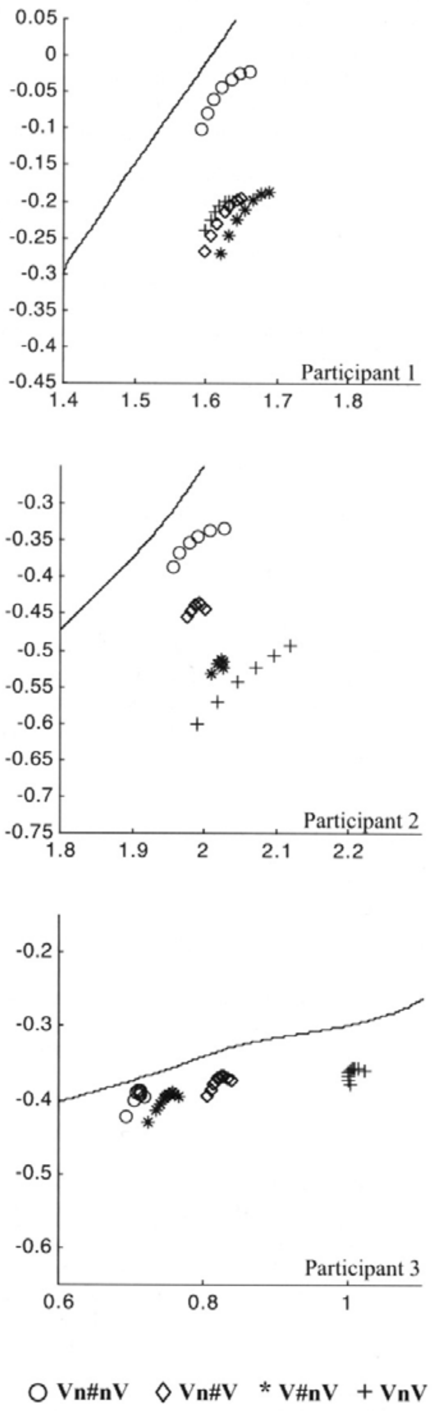

Figure 1: Averaged tongue-tip movement paths into and out of TTCD plateau for /n/, /n#/, /#n/ and /n#n/ in the context of /a/ with translated palate trace segments. Scale is in centimeters.

triangular). TTCD curves were derived as described in [7], and represent relative approximation of the tongue tip coil to an anterior segment of the palate trace. The event–marking algorithm identified zero-crossings into and out of the TTCD plateau using a spatial noise level of 10% of TTCD range. Once TTCD plateau were labeled, corresponding segments of "raw" TTY and TTX curves were temporally normalized by cubic interpolation so that each segment came to have the same number of samples as the longest-held TTCD plateau for each utterance type for each talker. The segments were then averaged point-by-point, and corresponding two-dimensional movement paths were plotted using one symbol for each nth sample in the derived curves (where n is between 4 and 10 and varies by subject according to figure-readability). No measurements were made on averaged data. Also plotted are the alveolar/post-alveolar segments of smoothed midsagittal traces of each talker's palate translated so as to fit in the display window. The reader should bear in mind that, due to the slightly posterior placement of the tongue tip coil relative to the apex of the tongue, it may not always touch the palate when the tongue tip touches despite potential compression of soft tongue tissues upon palatal contact.

3. RESULTS

Results from univariate ANOVA run in BMDP under VMS (Table 1) support the observation that there are significant differences in stricture among /n/ environments for P1 and P2 at the instant of absolute peak in TTCD, though tests do not reach significance for P3. Comparisons were made where significant results obtained, that is, for P1 and P2 only. Although the investigation of stricture in intervocalic versus juncture geminate nasals followed from the specific hypothesis that the juncture geminates would be produced with a tighter tongue tip constriction at the alveolar ridge, because there was no a priori assumption about patterning among nasals in the three intervocalic environments, and because the hypothesis itself was not the inspiration for the experiment but was stumbled upon accidentally, these comparisons are treated as post hoc. The Tukey Studentized Range Method was used. Results for the post hoc comparisons are reported in Table 2.

	Source	SS	*df*	MS	*F*
P1	**Between**	0.1352	3	0.0451	9.43*
	Within	0.2439	51	0.0048	
	Total	0.3791	54		
P2	**Between**	0.3121	3	0.1040	7.47*
	Within	0.7240	52	0.0139	
	Total	1.0361	55		
P3	**Between**	0.0492	3	0.0164	1.62†
	Within	0.2028	20	0.0101	
	Total	0.2520	23		

*$p < .01$; †$p < 0.2166$

Table 1: ANOVA Summary

For P1, only and all the comparisons involving Vn#nV achieve significance at an alpha level of 1%. For P2, two of three comparisons involving Vn#nV achieve significance at an alpha level of 1%. For both participants, Vn#nV means are the lowest indicating the tightest constriction among the four utterance types.

Although the ANOVA for P3 did not reach significance (p < 2.166), the means indicate a trend in the same direction (VnV=-0.82; V#nV=-0.72; Vn#V=-0.74; Vn#nV=-0.70), that is, the mean for the juncture geminate nasal suggested a position closest to the palate.

If we are willing to accept a less conservative alpha level ($p < .05$), post hoc analysis indicates that absolute initial /n/ may be more tightly constricted than intervocalic /n/ within a word for P2.

4. DISCUSSION

Overall, ANOVA and post-hoc comparisons confirm the hypothesis that, between vowels, singleton /n/ is less tightly constricted than is the juncture geminate /n#n/.

Measurements from the third participant also showed a consistent trend in the direction of more de-occlusivization for singletons, but tests did not achieve significance. This latter speaker's 'fast' tokens were un-analyzable. It may be that nasal de-occlusivization is strong only at faster speaking rates, a hypothesis deserving further investigation.

For singletons, the presence of a word boundary on either side of /n/ is not sufficient in and of itself to block de-occlusivization, though, given a less conservative significance level, it appears that absolute initial /n/ is less de-occlusivized than word medial, intervocalic /n/ for P2. Extension of such a finding over a larger pool of talkers would bring the pattern of /n/ de-occlusivization further into alignment with the observed pattern of /b, d, g/ spirantization.

The present results, though based only on the speech of three talkers (plus one pilot participant run under slightly

***P1: n* = 13, 14** ***P2: n* = 14**	***DIFFERENCES BETWEEN PAIRED TREATMENT MEANS***			
Participant 1	***Vn#V***	***V#nV***	***VnV***	***Vn#nV***
MEANS	**-1.45**	**-1.43**	**-1.42**	**-1.32**
***Vn#V* = -1.45**	—	.02	.03	.13*
***V#nV* = -1.43**		—	.01	.11*
***VnV* = -1.42**			—	.10*
***Vn#nV* = -1.32**				—
Participant 2	***VnV***	***Vn#V***	***V#nV***	***Vn#nV***
MEANS	**-1.76**	**-1.72**	**-1.64**	**-1.56**
***VnV* = -1.76**	—	.04	.12†	.20*
***Vn#V* = -1.72**		—	.08	.16*
***V#nV* = -1.64**			—	.08
***Vn#nV* = -1.56**				—

*$p < .01$; †$p < .05$

Table 2: Post Hoc Pairwise Comparisons

different conditions), nudge us toward the speculation that spirantization and nasal de-occlusivization are simply two manifestations of the same thing: gestural reduction. In the case of voiced oral stops, reduction of the magnitude of the oral closure gesture produces a sound that lies somewhere between fricative and vowel. However, in the case of /n/, effectively the only canonical nasal and the only canonical alveolar closure in the productive inventory, reduction of the tongue tip closure gesture produces a "hidden" nasal de-occlusivization. The de-occlusivization is not noticed by transcribers or by native speakers because it is overshadowed by the perceptual salience of nasality and because nasal coupling shunts airflow away from the oral constriction, greatly reducing the likelihood of the generation of spirant-like turbulent airflow [8] (which is only relevant insofar as spirantized stops are held long enough to exhibit turbulent airflow anyway; see [3]).

Having recovered from the unexpected finding that /n/ de-occlusivizes, it should be no surprise that de-occlusivization is blocked, essentially, in the same environment in which spirantization is blocked. However, in the terms of traditional operationalist phonology, the structural description of the spirantization rule must be adjusted so that the rule applies to nasals. Such a restatement requires explicitly specifying these [+nasal] segments as [–continuant]. The rule must also be renamed. The percept of spirantization or the lack thereof is merely a low-level consequence of patterns of higher-level gestural organization at play in the phonology; the more general pattern is most elegantly described in gestural terms.

5. CONCLUSIONS

Overall, the present results are consistent with the hypothesis that canonical (voiced, alveolar) nasal (stops) in Castilian de-occlusivize in the same environment as do voiced oral stops, though some inter-talker variability was observed. Thus, it appears that nasal de-occlusivization and spirantization are fundamentally the same thing from a gestural standpoint. The pattern previously attributed to spirantization in process-oriented phonology can perhaps best be viewed as a phonetic outworking of a unified principle of gestural organization and reorganization. Many details of a gestural account of Castilian remain to be worked out. It may be that the principle involved is reduction in gestural magnitude in the context of a specific pattern of V-toV coarticulation. Whatever that principle actually turns out to be, the present results suggest that it may underlie both the well-known phenomenon of spirantization and the newly discovered phenomenon of nasal de-occlusiviation.

Given the very small magnitude of the reduction observed here (around 2 mm), a more intentional study should be undertaken to determine exactly those rates and styles at which de-occlusivization occurs, and along which parameters it varies, if at all.

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