COARTICULATION AND CONTRAST: NEIGHBORHOOD DENSITY CONDITIONED PHONETIC VARIATION IN FRENCH

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ABSTRACT

Phonological neighborhood density (ND) conditions variation in a number of acoustic phonetic properties of words. For example, previous research has shown greater hyperarticulation and greater nasal coarticulation in high-ND English words than in low-ND words. Here, we investigate the effects of ND on vowel hyperarticulation and vowel nasality (coarticulatory and contrastive) in French. Acoustic analysis of elicited French data revealed some ND patterns that paralleled those reported for English, but also some language-specific patterns. In particular, we found greater hyperarticulation for oral vowels in Hi-ND vs. Lo-ND words, but greater centralization for nasal vowels in Hi-ND vs. Lo-ND words. However, we did not find ND effects for vowel nasality in either coarticulatory or contrastive contexts. We discuss both the ND effects found and the apparent lack of others in terms of the language-specific relationship between oral and nasal vowels and between coarticulatory and contrastive nasality in French.

Keywords: neighborhood density, vowel nasality, hyperarticulation, coarticulation, French

1. INTRODUCTION

Phonological neighborhood density (ND), or the number of words that are phonologically similar to a given word, has been shown to be related to systematic word-specific variation along a number of acoustic phonetic dimensions. For example, words with many phonological neighbors (Hi-ND) are generally produced with greater hyperarticulation [21, 15, 18, though cf., 9], increased vowel-to-vowel and nasal coarticulation [18, 17), and increased VOT in voiceless initial stops [2].

Neighborhood density is well known to affect lexical perception as well. Hi-ND words are perceived more slowly and less accurately than Lo-ND words, as demonstrated in a range of tasks from word naming to lexical decision [13, 14, 20]. Such effects can be explained in terms of the process of spoken word recognition, which involves picking out a target word from among its competitors in the lexicon, all of whose lexical representations are simultaneously activated by an acoustic-phonetic input [e.g., 13, 14]. Words with more neighbors face greater competition and are thus perceptually harder.

These perception effects suggest a possible explanation for the effects in production: namely, that the production effects might be accommodations that help compensate for the difficulties encountered by listeners due to ND effects in lexical access [e.g., 21]. The phonetic variants found in Hi-ND words (those that would be "harder" in lexical access) tend to be perceptually beneficial: vowel hyperarticulation increases vowel discriminability and overall talker intelligibility [5]; increased VOT in voiceless stops enhances their contrast with voiced stops; increased coarticulation provides cues for the coarticulatory source segment – e.g., coarticulatory vowel nasality serves as a cue to an upcoming (or just past) nasal consonant [1, 4]. We expect that similar effects might be found across other features and other languages as well, but that they should be shaped by feature-specific and language-specific perceptual patterns.

The current study investigates the effects of phonological neighborhood density on the realization of hyperarticulation and vowel nasality (coarticulatory and contrastive) in French. We expect to find hyperarticulation effects that parallel those found in English, where Hi-ND words are hyperarticulated relative to Lo-ND words. With respect to nasality, however, we expect that neighborhood density may have different effects for contrastive than for coarticulatory nasality. In particular, while contrastive nasality may be increased in Hi-ND words, coarticulatory nasality may be unaffected or even reduced in Hi-ND words, since increased nasality (as found in English Hi-ND words) could lead to confusion with contrastively nasal vowels.

2. METHODS

2.1. Speech materials

The corpus for this experiment includes 184 disyllabic French words with a contrastively nasal vowel (/ɛ̃, ã, ɔ̃/) (N=40) or a coarticulatorily nasalized vowel (/i, y, ɛ, a, ɔ, u/) (N=144) in the final syllable. The words in the coarticulation set contained a nasal consonant in either the onset (N=72) or coda (N=72) of the final syllable, while the words in the contrast set had no nasal consonants in the final syllable.

The test words were of two types with respect to their lexical properties: words with few neighbors or words with many neighbors. Neighborhoods were modeled on a single-edit phonemic basis [10; see also 13, 15, 21, 18], where all words differing from the target word by the addition, deletion, or substitution of a single phoneme are considered to be neighbors of that word. Neighborhood density was frequency-weighted, calculated as the summed log frequencies of the neighbors. Neighbors and lexical frequencies were determined from the Lexique 3 lexical database [16].

Words were selected for inclusion in the study on the basis of having frequency-weighted neighborhood densities in the top third (Hi-ND) (e.g., *bouchon, agent*) or bottom third (Lo-ND) (e.g., *buisson, agence*) of the range of NDs for disyllabic French words. Target word frequency was also controlled and balanced across ND conditions.

2.2. Participants and procedure

Eight speakers (4 males and 4 females) recorded the materials for this study. All were native speakers of French from France, living in the United States. Recordings took place in a sound-attenuated booth using a microphone with a flat low-frequency response, which was positioned directly in front of the speaker's nose and mouth. Words were uttered two times each in the carrier sentence 'Dites __ s'il vous plaît'. Speakers were naïve to the purpose of the study and were paid for their participation.

2.3. Measurements

2.3.1. Hyperarticulation

Hyperarticulation was measured as the degree of dispersion within the vowel space for the final vowel of each word [5, 15, 21, 18]. F1 and F2 measurements were taken at the midpoints of all test vowels and bark transformed. The Euclidean distance from the center of the vowel space was then calculated, where the center of the vowel space was defined by the mean of all instances of /i/ and /a/ for F1 and /i/ and /u/ for F2, for each talker. The duration of each test vowel was also measured.

2.3.2. Nasality

Nasality in each test vowel was measured from the acoustic signal. Nasalized vowels show the presence of extra spectral peaks, including a low-frequency peak below the first formant (P0), accompanied by a reduction in the amplitude of the first formant spectral peak (A1). Vowel nasalization may be quantified, then, as the relative amplitudes of nasal and oral peaks, specifically A1–P0 [7]. Lower A1-P0 indicates greater nasality. A1 and P0 were measured from FFT spectra generated with a 50 ms Hamming window. Measurements were made at four timepoints: at vowel onset and 25%, 50%, and 75% into the vowel. (Endpoints were excluded due to observed unreliability of measurements immediately adjacent to a following consonant.)

3. RESULTS

3.1. Hyperarticulation

The midpoint Euclidean distances from vowel space center were modeled using linear mixed effects regression (LMER) with fixed factors of ND (Lo-ND or Hi-ND) and Vowel Nasality (oral or nasal), and random intercepts for Speaker, Word, and Vowel and by Speaker random slopes for ND, as summarized in Table 1. The model showed a significant effect for ND (Hi-ND words were generally further from the center than Lo-ND words), as well as a significant ND by Nasality interaction. The ND by Nasality interaction was elucidated via post-hoc LMERs for oral and nasal vowels separately, showing that while oral vowels from Hi-ND words were more peripheral in the vowel space (i.e., more hyperarticulated) than oral vowels from Lo-ND words (as shown previously in English) [ND: est.=-0.13, t=-2.01], the pattern was reversed for nasal vowels, where the vowels in Hi-ND words were instead centralized, relative to those in Lo-ND words [ND: est.=0.16, t=2.07], as shown in Figs. 1 and 2.

Table 1: Summary of linear mixed-effects model for Euclidean distance from V space center.

	Estimate	Std.Err	t
(Intercept)	2.33	0.37	6.25
ND=Lo-ND	-0.19	0.08	**-2.28**
V Nas=oral	0.37	0.45	0.81
Lo-ND:oral	-0.32	0.09	**-3.72**

Figure 1: Euclidean distance from V space center (in Bark) in Lo- vs. Hi-ND words, by Vowel Nasality.

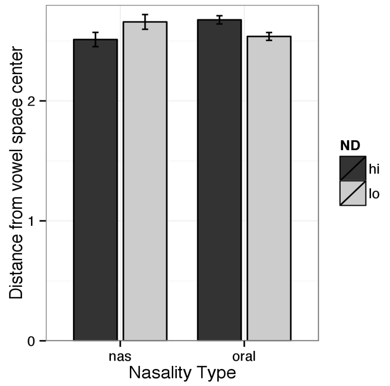
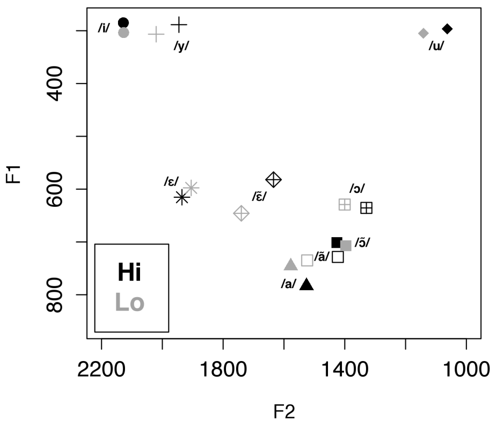


Figure 2: Hyperarticulation by Vowel, by ND.



Vowel duration was also analyzed in a linear mixed effects model with the same effect structure as described above. There were no significant main effects or interactions.

3.2. Coarticulatory nasality

The acoustic nasality measures (A1-P0) from non-high vowels in nasal coarticulation contexts were also modeled using linear mixed effects regression, this time with fixed factors of ND, Coarticulation type (anticipatory-VN or carryover-NV), Timepoint, and F1 Frequency (in Hz – to account for predicted effects of vowel height on nasality), as well as random intercepts and slopes as above. See the model summary in Table 2. (Recall that A1-P0 decreases as nasality increases, so negative estimates indicate increases in nasality.) The model showed significant effects for Coarticulation, Timepoint, and F1 Frequency, but crucially, no significant effect for ND or the interaction with ND. In other words, we find no evidence that nasal coarticulation increased or decreased as a function of the ND of the word.

Note that the Coarticulation, Timepoint, and F1 Frequency main effects indicate that the overall nasality patterns were as expected for this data. In particular, carryover (NV) coarticulation was stronger than anticipatory (VN) [also 8]; nasality generally increased across the vowel (due to a relatively flat NV profile and increasing nasality in VNs) [also 8]; and nasality increased with F1, showing that lower vowels (higher F1) were more nasal [also 3].

Table 2 Summary of linear mixed-effects model for Coarticulatory nasality (dB A1-P0).

	Estimate	Std.Err	t
(Intercept)	5.42	1.10	4.93
ND=Lo-ND	-0.23	0.60	-0.38
Coartic=VN	2.32	0.54	**4.34**
Timepoint	-0.38	0.05	**-7.91**
F1 Freq	-0.003	0.001	**-5.25**
Lo-ND:VN	-1.06	0.76	-1.40

3.3. Contrastive nasality

Finally, the acoustic nasality measures (A1-P0) from contrastively nasal vowels were modeled using linear mixed effects regression; the model was identical to the coarticulatory nasality model, except without the Coarticulation type factor. The model showed significant effects for Timepoint (nasality increases across the vowel) and F1 Frequency (nasality is greater in lower vowels), but again, no significant effect for ND. In other words, we find no evidence that ND affects the nasality of nasal vowels in French.

Table 3 Summary of linear mixed-effects model for Contrastive nasality (dB A1-P0).

	Estimate	Std.Err	t
(Intercept)	5.20	1.20	4.32
ND=Lo-ND	-0.52	0.70	-0.74
Timepoint	-1.05	0.08	**-13.60**
F1 Freq	-0.004	0.001	**-5.00**

4. DISCUSSION

An investigation of neighborhood-conditioned variation in French has yielded a number of observations. First, the data show the expected effect of ND on hyperarticulation for oral vowels in French: oral vowels in Hi-ND words were more hyperarticulated (i.e., more peripheral in the vowel space) than those in Lo-ND words, as seen previously in English [21, 15, 18]. Such hyperarticulation might be interpreted as enhancement of the vowel contrasts in the oral vowel space in words that would otherwise be perceptually more difficult.

Interestingly, there was a reversal of this hyperarticulation effect for contrastively nasal vowels: nasal vowels in Hi-ND words were systematically *centralized* relative to those in Lo-ND words. We suggest that this, too, though, could be viewed as enhancement of these vowels: nasal vowels in general tend to be centralized (especially with respect to F1) relative to their oral counterparts [11, 3, 6], so this Hi-ND centralization could be seen as an enhancement of the vowel quality of the nasal vowels. Furthermore, this centralization enhances the pairwise contrast between these nasal vowels and their oral counterparts. Carignan, Shosted and colleagues [19, 6] posit similar oral enhancement of contrastive nasalization in Hindi.

With respect to nasality, however, no effects of ND were found. For nasal coarticulation, these results for French are different from those found for English [18], where an increase in nasal coarticulation has been found in Hi-ND words. However, this difference is not surprising in light of the difference in phonological status of nasality in French versus English. Whereas in English, vowel nasality always co-occurs with a nasal consonant, and is therefore predictive of that nasal consonant (with no other phonological role), vowel nasality in French may either be of this co-occurring (coarticulatory) type or it may be contrastive. Since vowel nasality is thus potentially ambiguous in French, possibly indicating an oral vowel adjacent to a nasal consonant, or possibly a contrastively nasal vowel, its enhancement in coarticulatory contexts is potentially confusing, rather than potentially helpful as in English. Furthermore, we expect that vowel nasality in French may be interpreted by listeners as contrastive nasality by default, as was the case for Bengali listeners presented with both truncated CVN and truncated CṼC Bengali words [12]. Thus, the potential usefulness of coarticulatory nasality is constrained in French by the contrastive role that nasality plays.

This discussion of the relation between coarticulation and contrast leaves open the possibility that nasality could be enhanced in *contrastively* nasal vowels in Hi-ND words in French. However, no ND effect on nasality was found for nasal vowels either. We suggest two possible explanations for this lack of effect. One is that nasal vowels may already be produced at or near a nasality ceiling, in order to maximize the contrast between nasal and oral vowels in general. If so, there may be no greater degree of nasality that is articulatorily or acoustically possible and/or that could be perceptually useful. (We looked for neighborhood-conditioned differences in extent as well as in degree of nasality, but still we found no effects.) A second possible explanation for the lack of ND effect on contrastive nasality is that nasality may simply not be "available" for low-level manipulation in French due to its phonological or representational status. (Though we note that both VOT and V-space hyperarticulation, which have shown ND-conditioned variation, involve contrastive features. Thus, the crucial difference for vowel nasality in French would seem to be its dual status.) It is relevant to recall that despite the fact that we do not see ND-conditioned enhancement of nasality itself, we do see oral cavity enhancement of nasal vowels, in terms of centralization of nasal vowels in Hi-ND words.

5. CONCLUSIONS

The current study has shown neighborhood density conditioned phonetic variation in French. In particular, greater hyperarticulation was observed for oral vowels in Hi-ND words than for oral vowels in Lo-ND words. At the same time, greater centralization was observed for nasal vowels in Hi-ND words than for nasal vowels in Lo-ND words. Both findings were interpreted as enhancement of vowel contrasts, with hyperarticulation leading to greater dispersion or greater space between oral vowels and centralization leading to greater pairwise distance from oral vowel counterparts, as well as enhancement of natural nasal vowel centralization patterns. No effects of ND were found, though, for vowel nasality in either coarticulatory or contrastive contexts. The lack of such effects may be explicable in terms of the relation between coarticulation and contrast.

We take both the ND effects found and the seeming absence of others to point toward a role for perception in ND effects in production. The difference in hyperarticulation patterns for nasal and oral vowels supports a more nuanced contrast-driven interpretation of ND-conditioned "hyperarticulation". And the constraints on ND effects on nasality that seem to arise from the potential for confusion between coarticulatory and contrastive nasalization support the idea that these ND effects may have a perceptual, or listener-directed, basis.

6. REFERENCES

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