NASAL CORATICULATION IN THE FRENCH VOWEL /i/:
A PHONETIC AND PHONOLOGICAL STUDY

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ABSTRACT

ABBY SPEARS: Nasal Coarticulation in the French Vowel /i/:
A Phonetic and Phonological Study
(Under the direction of Elliott Moreton)

In this paper, I use acoustic phonetic data to examine the phenomenon of nasal coarticulation in French. Previous work describes French as a language with very little vowel-nasal (VN) coarticulation, presumably due to the oral/nasal contrast in vowels (Cohn 1990). However, I found that the high vowel /i/, which has no nasal counterpart in French, exhibits a high degree of coarticulation This finding supports the proposal that contrast and coarticulation are inversely correlated (Manuel 1990), adding the insight that this correlation is observable even within a language.

Based on this finding and a typological survey of VN coarticulation, I propose an underspecification account in an Optimality Theoretic framework to capture the patterns of VN coarticulation. In this OT account, the interaction of markedness constraints driving orality and minimizing effort and a faithfulness constraint protecting the feature [+ nasal] provides an explanation for the French data and produces the attested typology.

For Ms. Elizabeth Dobbs, who got this ball rolling.

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So many people have supported me in this work.

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My family (of origin and of choice) were kind enough to listen to me talk about my research, even when it was largely linguistic mumbo-jumbo.

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CHAPTER 1

INTRODUCTION

1.1 The Big Question

The idea of universally operating phonetic processes is an enticing one. Having a set of universal phonetic principles based on the human speech apparatus and the aerodynamics of its use, both of which should be constant cross-linguistically, seems a reasonable proposition. However, even very basic effects or seemingly obvious consequences of the way the vocal tract works appear not to apply universally. For example, when speakers produce voiced stops, the larynx lowers to increase the volume of the oral cavity. This allows a pressure difference across the vocal folds, and thus voicing, to be maintained longer. It also lengthens the oral cavity, which lowers the pitch of the sound produced. This effect is present in English, but substantially suppressed in Yoruba (Ohala 1993). Similarly, gradient coarticulatory effects, often explained as simple instances of mistimed movements due to limitations on how precisely humans can move their articulators, are present to a much lesser degree in some languages than in others. For example, Cohn (1990) describes a great difference in the degree of nasal coarticulation in French and in English, and Clumeck (1967) notes that among Hindi, Swedish, Amoy Chinese, and Brazilian Portuguese, in addition to French and English, some languages show significantly higher levels of coarticulation than others. Thus, even where we might expect to see universal phonetic effects in play, we do not. Must we, then, abandon the idea of universal phonetic principles altogether? One pattern that seems to emerge from these and other examples of thwarted phonetic universals, which will be discussed further in Chapter 2, is that the phonetic effects are often suppressed in cases where they would threaten a language's phonemic contrasts (Manuel 1990).

Based on this pattern, I argue that we may be able to salvage something of the phonetic universal. I propose that patterns of the attestation of potential phonetic universals as described above can be accounted for in the interplay of phonetics and phonology. Specifically, I argue that these phonetic tendencies operate in all cases *except when explicitly prohibited by the phonology.* My model of this phonological control of phonetic effects uses an Optimality Theory account of underspecification in which a segment's surface specification, or lack thereof, is determined by the phonology. Phonetic tendencies are allowed to emerge in segments that leave the phonology with no specification. Thus, we can account for why the potential phonetic universals are sometimes not active, and the utility of these supposed universals is not entirely lost.

4.2 The Interesting Case of French /i/

The French vowels offer an ideal case for examining the way that the phonology operates on the phonetics. First, for such an inquiry, we need a clear case of the restriction of a phonetic tendency. The suppression of nasal coarticulation in French is well-attested (Clumeck 1967, Cohn 1990, Rochet & Rochet 1991). These studies, however, tend to focus on the French vowels that have nasal counterparts, [ɛ ɔ a œ]. If preserving the oral/nasal contrast is the reason that nasal coarticulation is suppressed in French, as these studies (especially Cohn 1990) suggest, then the high vowels, [i y u], which have no nasal contrast, are an excellent place to test the workings of the phonology's influence on the phonetics.

Looking to the high vowels, we ask if, in environments where the reason for suppressing a phonetic tendency is lost, the tendency is allowed to emerge, even in a language where it was previously thought to be absent. My results suggest that indeed, when lacking the preservation of a contrast as a motivation to limit coarticulation, even French allows this phonetic tendency to happen. Although the theory presented here includes all high vowels in French, this study focuses on the vowel /i/. This is because measuring nasalization acoustically is tricky in the best of situations, so in order to avoid the potentially confounding factor of rounding, nasalization of /u/ and /y/ were not investigated.

1.3 The Organization of This Paper

In Chapter 1, I have presented a general overview of the question being investigated as well as an explanation of the reasons behind the particular focus of the study. Chapter 2 will present a review of the relevant literature. Chapter 3 describes in detail the phonetic experiment that provides the data supporting my analysis. In Chapter 4, an OT analysis of nasal underspecification based on a typology of nasal coarticulation is advanced, with special attention to the new findings presented in Chapter 3. Finally, Chapter 5 sums up the conclusions drawn from the previous chapters, explores their implications, and suggests some avenues for future research.

1.4 A Note About Phonetics and Phonology

Because this study focuses on the interplay between phonetics and phonology, a brief explanation of what exactly I mean by these terms is necessary. I closely follow Hale & Kissock (to appear), who base their model on Keating (1988). In this model, *phonology* involves the mapping of an underlying form to a surface form, *within the same representational format*, here a featural representation. That is to say, the phonology does not output specific gestural instructions to the phonetics. The translation of featural information into gestures is the job of the *phonetics*. Thus, the phonology hands down a set of instructions (i.e., output forms) to the phonetics, where these instructions are interpreted as articulatory gestures. For example, the phonology might take an input form of a vowel that includes the feature specification [+ nasal] and map it to an output form [+nasal]. The job of the phonetics, then, is to turn this [+ nasal] featural representation into an actual set of movements, like "lowered velum." My claim is that by producing instructions with varying degrees of specificity, the phonology can allow varying degrees of freedom in the phonetic interpretation.

CHAPTER 2

BACKGROUND

2.1 Limitation on Phonetic Variation

2.1.1 Introduction

That speakers do not produce a phoneme exactly the same way every time is obvious. Many factors, like volume and rate of speech, stress placement, and phonetic environment can affect how a phoneme is realized. The tendency for variation to occur in the translation of phonological outputs into realized gestures is well-documented (see e.g., Ohala 1993 and Clumeck 1967). For example, vowels tend to nasalize in the environment of nasal consonants, but these vowels are not necessarily categorically nasal (Cohn 1993). Cohn characterizes a phonemically nasal vowel as one that has a categorically high level of nasal airflow, as opposed to the gradient (i.e., increasing steadily over the course of the segment) nasal airflow of phonetically nasalized vowels. This phonetic variation is often explained as a consequence of human physiology (Ohala 1993). For example, coarticulatory effects like vowel nasalization or the intervocalic voicing of voiceless consonants can be explained as gestural mistiming. Effects not involving simple assimilation may also be explained away phonetically, like the tendency for vowels to lower in pitch before voiced obstruents, attributed to a lowering of the larynx in preparation for maintaining voicing during an oral closure (Ohala 1993). However, these effects cannot be entirely uncontrolled accidents of physics and anatomy because, while aerodynamics and human articulatory apparatus are the same cross-linguistically, this phonetic variation can occur differently in different languages (Clumeck 1967, Ohala 1993, Cohn 1990, 1993) . The rest of this section will present examples of this variation.

2.1.2 French nasal vowels

The case of French nasal vowels will serve as a crucial example throughout this work. Cohn (1990) found that French vowels show much less nasalization before nasal consonants than English vowels do. Note that in modern French, vowel nasality is phonemically contrastive, but in English, it is not. The case of nasal vowels in French is particularly interesting when considering the phonetics/phonology interface because of their historical development. In Latin and Old French, there were no phonemically nasal vowels. Presumably, much as in modern English, vowels were nasalized before nasal consonants, and the nasal consonants were always pronounced:

(1)	*vin* [vĩn] 'wine'	*en* [ẽn] 'in'	(Old French)

According to Ohala (1993), the articulation of the nasal consonant was weakened, and the nasalization came to be interpreted as a property of the vowel. The conditioning nasal consonants were then deleted.

(2)	*vin* [vĩ]	*en* [ɛ̃n]	(transitional period)

All vowels nasalized before nasal consonants initially, and the higher nasal vowels lowered and eventually merged with the four nasal vowels that still exist in modern French, [ɛ̃ ɔ̃ ã œ̃] (Ayers-Bennett 2001).

(3) *vin* [vɛ̃] *en* [ã] (Modern French)

Thus, the phonemically nasal vowels in French are thought to arise from the same phenomenon of vowel-nasal coarticulation that is observed in many languages, like English, which does not have contrastive nasality in vowels. The phonetic phenomenon (here, a tendency for vowels to become nasalized before nasal consonants) that gave rise to the phonological contrast (here, an oral/nasal vowel contrast) seems to be suppressed once it is phonologized. That is, it seems that once oral and nasal vowels became contrastive, vowels stopped undergoing coarticulatory nasalization before nasals. Cohn (1990) suggests that the phonetic variation is constrained in order to preserve the oral/nasal contrast.

2.1.3 Yoruba tone

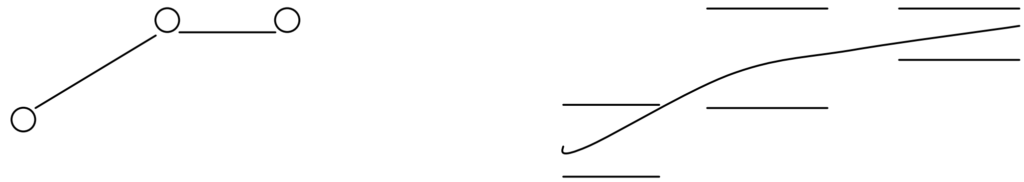
The tendency of phonemic contrast to restrict phonetic variation is not limited to cases of assimilatory coarticulation. Other phonetic phenomena may also be involved. Hombert et al. (1979) describes a similar tendency involving tones in Yoruba, a language in which tone is phonemically contrastive. Like the nasal vowels of French, the phonemic tones of Yoruba are thought to have originated with phonetic pitch lowering before voiced stops (Ohala 1993). Also, like the case of nasalized vowels, the same tendency for a vowel's pitch to be lower before a voiced stop is observed, non-contrastively, in English and Hindi (Ohala 1993). Both Yoruba and French seem to illustrate the same phenomenon. In both languages, a phonetic effect is present in an older version of the language, but is suppressed once it becomes incorporated into the phonology as a phonemic contrast. Thus, both seem to be examples of the presence of a contrast causing coarticulation to be suppressed.

2.1.4 Yoruba vowel height and backness

The described restriction on phonetic variation is not, however, limited to cases of phonologization, in which the contrast arose from the variation. Manuel (1990) describes findings similar to those of Cohn (1990) and Hombert et al. (1979) in a study of three dialects of Yoruba, in which she shows that the dialect with more contrastive vowels has less variation in realization of its vowels than those with fewer. She compares the F1 and F2 frequencies of [ɑ] when followed by syllables with other vowels and notes that speakers of the dialects with less contrast (a 5-vowel system, [i e ɑ o u]) tended to exhibit much more anticipatory vowel-to-vowel coarticulation than speakers of the dialect with more contrast ([ɛ ɔ] in addition to the 5-vowel system). A crucial difference here is that unlike the cases of the French nasals and Yoruba tone, the lax mid vowels in Sotho, the Yoruba dialect with more contrast, are not a result of the phonologization of varying productions of [ɑ]. I claim, then, that the language-specific suppression of phonetic phenomena is a widely-occurring process, not simply a side-effect of phonologization.

2.2 The Window Model of Coarticulation

One way of formalizing the specificity of phonological outputs is Keating's (1987) window model. Keating proposes that the articulatory realization of adjacent segments is not a matter of connecting the dots of segmental targets, but rather a process of interpolating between acceptable ranges for each segment. Figure 2.1 illustrates this difference. Note that the middle segment is the same as the last segment in the illustration on the left, but not on the right.



Interpolating between segment target points

Interpolating between segment ranges

Figure 2.1
Two Models of Interpolation

How wide or narrow the window is allowed to be is phonologically determined and is language-specific. The differing degrees of allowed variation described above are consistent with the window model. Manuel (1990) proposes a similar model, which involves two dimensions of window, one for vowel height and one for backness, instead of proposing separate windows for each feature.

2.3 Underspecification

2.3.1 A general overview of underspecification

One common account of the varying specificity of phonological output involves the presence or absence of specification for a particular feature. For example, in the English vowel nasalization case, English would be considered not to have a specification for the feature [nasal] (Cohn 1990). This lack of information regarding a particular featural value is known as underspecification. Underspecification was commonly used to account for gradient assimilatory effects in non-OT analyses, as in Keating (1988, 1990) and Cohn (1990, 1993). Other analyses (e.g., Clements 1981, Avery and Rice 1989) use underspecification to account for assimilatory processes that do not explicitly involve gradient effects. Recalling that our model of phonology involves the mapping of an input form to an output form, we find two possible forms of underspecification. One involves an underspecified input that is supplied with all featural specifications in the process of mapping to an output form (see e.g., Inkelas 1994, Itô, Mester & Padgett 1995, and Mustafawi 2006). Such a model would account for the English vowel nasalization case by proposing that in the underlying form, English vowels are unspecified for the [nasal] feature, and a phonological process applies a [+nasal] specification to vowels followed by nasal consonants and a [–nasal] specification elsewhere.

Cohn (1990) argues against this model using articulatory data to show that nasal airflow is not at a continuously high level in English nasalized vowels, but French nasal vowels have a high nasal airflow throughout. This is the basis for the distinction she proposes between the phonologically nasal French vowels and the phonetically nasalized English vowels. Her data for English is consistent with the other possible kind of underspecification, in which both the input and output forms can be unspecified, leaving the realization of the underspecified features entirely in the hands of the phonetics. The study of tone provides much evidence for surface underspecification. Interpolation between a few specified tones seems the best account for the realization of tone in English (Pierrehumbert 1980), Japanese (Pierrehumbert and Beckman 1988), Northern Mandarin (Davison 1992), and Chichewa (Myers 1999). Other evidence for surface underspecification comes from English consonant place of articulation (Keating 1988), nasalization of Yoruba /r/ (Huffman 1993), vowel features in Dutch (van Bergem 1994), and obstruent voicing in several languages (Steriade 1999).

2.3.2 Underspecification in OT

Because Optimality Theory is an output-focused system, whether or not the underlying form is specified or not is less of a concern than in generative phonology. Because of the principle of Richness of the Base, an OT account of underspecification needs to be able to handle any input form. While Inkelas's (1994) optimization of the input purports to determine the "correct" input form, such an effort seems counter to the spirit of OT, and, as will be shown in Chapter 4, is not necessary in this analysis. In order to allow for Richness of the Base, my account will allow for both specified and unspecified segments in the input. In my analysis, outputs, too, can bear either specification or be unspecified, as in Steriade (1999) and Mustafawi (2006). Other current work in underspecification in OT includes Flemming (1997) and Meyers (1998), which will be discussed in conjunction with my own phonological analysis in Chapter 4.

CHAPTER 3

EXPERIMENTAL EVIDENCE

3.1 Introduction

The experimental portion of this study involved recording native French speakers' productions of the vowel [i] followed by a nasal consonant and using spectral analysis of these recordings to measure the degree to which French speakers nasalize [i]. For comparison, tokens containing [ɛ] before a nasal consonant and [ɛ̃] were also recorded, as well as tokens in which [i] and [ɛ] were followed by oral stops.

3.2 Participants

The participants were seven native French speakers currently working or in school at the University of North Carolina at Chapel Hill. Their ages ranged from 21 to 38 years. All speakers were born in France and spent the majority of their lives there. Several of the speakers were from the south of France and exhibited characteristics of the Southern French accent, but none produced the denasalized vowels associated with this regional dialect. Many of them did, however, exhibit another common feature of the *accent du Midi*, the insertion of [ə] after word-final stops. This did not seem to have any systematic effect on the results, but it did affect speakers' syllabification of the final consonants. Possible effects of this will be discussed in greater detail in section 3.6.

3.3 Methods

Speakers were recorded using Praat v. 4.4.13 on a Mac G4 PowerBook running OS

10.3.9. All recordings were made using a Labtec Verse 704 USB microphone. Speakers read the sentences off of notecards that were shuffled before each session to produce a random order. Items were recorded in groups of six sentences with a short break between each group. If a speaker made a mistake in production, that sentence was repeated correctly without stopping recording. Speakers were told before being recorded that the study concerned the sounds in French words, but they were not informed of the specific topic of the research.

3.4 Materials

The data recorded consists of words read in a frame sentence "Dites _____ deux fois" ([dit _____ dø fwa], 'Say _____ two times."). This is the frame used in Cohn (1990). Using the same sentence frame for each word helped to control for stress and intonation. The words of interest all had two syllables, and the vowel of interest was always in the second syllable. In all of the words, this final syllable began with a voiceless stop and had one of three vowels: [i], [ɛ], or [ɛ̃]. The [i] and [ɛ] tokens all had closed final syllables, with either nasal or oral stops as the syllable coda.

$$\begin{Bmatrix} p \\ t \\ k \end{Bmatrix} + \begin{Bmatrix} i \\ \varepsilon \end{Bmatrix} + \begin{Bmatrix} m \\ n \\ p \\ t \\ k \end{Bmatrix} \qquad \text{OR} \qquad \begin{Bmatrix} p \\ t \\ k \end{Bmatrix} + \tilde{\varepsilon}$$

Figure 3.1
Structure of Experiment Tokens' Final Syllables

This yielded five different types of words which will subsequently be referred to as [iN] (e.g., *tartine*), [iT] (*petite*), [ɛN] (*certaine*), [ɛT] (*coquette*), and [ɛ̃] (*destin*) tokens. Twelve words of each type were recorded for a total of sixty items per speaker[1]. A complete word list can be found in the Appendix.

3.5 Analysis

3.5.1 Determining the criteria for judging vowel nasality

Using spectral analysis to investigate nasalization is a notoriously tricky endeavor. Past work on the acoustic correlates of nasalization in vowels contains a substantial amount of disagreement. Durand (cited in Delattre 1966) claims that nasal vowels are characterized by high frequency formants around 7500 Hz. Delattre (1966) rejects this claim for several reasons, including the fact that nasals are perceptible over the telephone, but sounds higher than about 3500 Hz are not. He also cites his own phonetic experiments, which involved synthesizing nasal vowels and transforming oral vowels into nasal vowels by increasing or reducing the intensity of sound at particular frequencies. He was able to do both without using this formant at 7500 Hz. He found that nasality has a greater effect in the lower frequencies. The primary indicators of nasality that he found were a weakened first formant and two nasal formants at around 250 and 2000 Hz. Maeda (1993) reports that the weakening of the first formant does not occur in vowels with an F1 below the first critical frequency of the nasal tract (about 400 Hz in a male speaker). He mentions in particular the French vowels [i], [y], and [u]. Additionally, his calculations of nasal formant peaks for [ĩ] based on a nasal coupling model predict the appearance of a nasal formant peak between F1 and F2. Other possible indicators for nasality that I explored included F1 bandwidth, which has been successful in other experiments (e.g., Coleman & King 2003), and a sharp drop in

[1]One speaker, who was recorded as part of a pilot study, has only ten words of each type, for a total of 50 words.

F3 and rise in F4, which Delattre found to occur in nasal vowels, but not as a crucial perceptual cue. A wide bandwidth of F1 in the [i] tokens did not seem to be a reliable indicator of nasality. Praat reported unusually low F1 bandwidths (15- 40 Hz) throughout the [i] vowels, and these measurements were drastically different from my own bandwidth estimates based on spectral slices. The sharp fall of F3 and rise of F4, which were present in many of the [iN] tokens, also appeared occasionally in vowel to consonant formant transitions in the [iT] tokens, even where a rising F3 was expected and where there was no nasalization. Because they were not reliably distinguishable from normal vowel to consonant formant transitions, I chose not to include a sharply falling F3 and rising F4 as an indicator of nasality.

Lacking F1 bandwidth and changes in F3 and F4 as reliable indicators of nasality, I relied only on the formant-like band between F1 and F2 predicted by Maeda (1993) as an indication of nasality in the vowels. The fact that these bands always continued unbroken into the nasal consonant and never occurred before non-nasal consonants suggests that they are in fact correlates of vowel nasality. Additionally, as figure 3.2 shows, spectrograms of my own production of [ĩ] contained this band (at about 1460 Hz), while productions of [i] do not. The specific process of identifying and measuring this band in the French data will be discussed in the following section.

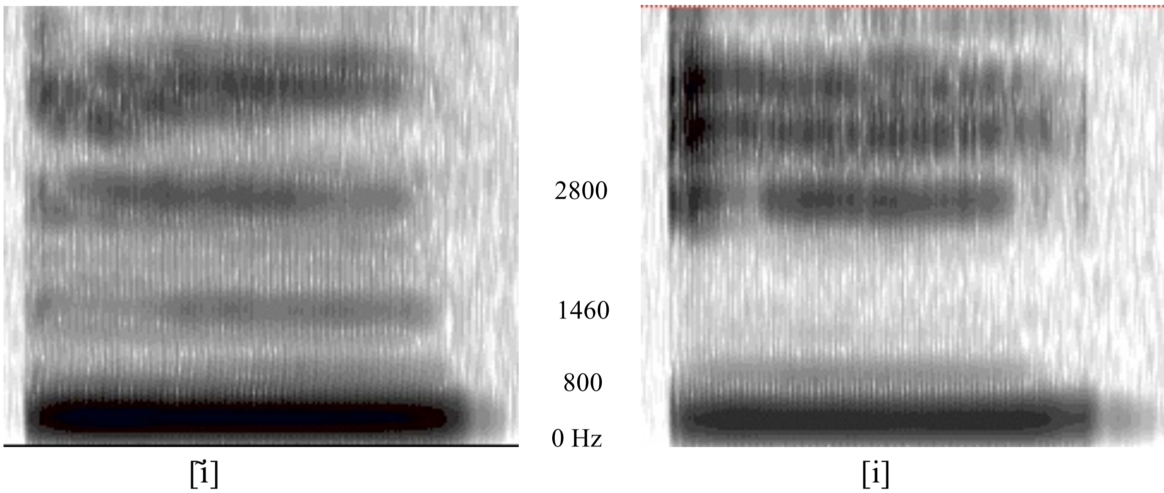


Figure 3.2
Spectrograms of [ĩ] and [i]

3.5.2 The process of analyzing the data

To make my measurements, I typically used spectrograms set to a slightly smaller view range (0 to 3000 Hz) and a longer window length (up to 0.01s) than Praat's default settings. I used the default dynamic range of 50 dB. These settings allowed me to distinguish the nasal band between F1 and F2 that served as my indicator of nasality from prominent harmonics between F1 and F2 (discussed below). Each speaker's data was analyzed using the following process. First, I measured the duration of each vowel. I marked the beginning point of each vowel, where the sound became periodic following the voiceless onset, and the end of the vowel, where the formants either disappeared or dropped drastically to a lower frequency. If the formants were disrupted at different times, I listened to the part of the syllable after each point of disruption and chose the boundary that sounded least like it placed traces of the vowel in the nasal consonant. A segmented [iT] syllable is shown below in Figure 3.3. See Figure 3.4 for segmented [iN] and [ɛN] syllables.

critique [kʀitik]

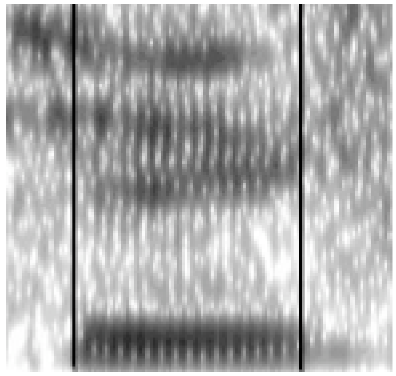


Figure 3.3
Segmented [iT] Syllable

Next, I looked for nasal bands. Because of the somewhat subjective nature identifying these bands, I coded the tokens blind. I extracted 75 ms tokens from the end of each [i] and [ɛ][2], using the endpoint of the vowel found by the process described above. I used tokens of a fixed length rather than looking at the full vowel so that vowel duration would be eliminated as a possible cueing factor. These token clips were each randomly assigned a unique number, and labeled only with this number. The key that matched tokens and numbers was kept in a separate file. For each clip, I looked for a formant-like band between F1 and F2 that appeared during the vowel and continued strongly through its end.

The reason for the criterion of having a clear beginning point during the vowel was to distinguish the nasal band from another kind of band between F1 and F2. A pilot study had shown that some tokens, both [i] and [ɛ], contained a prominent harmonic between F1 and F2 that was clearly not an indicator of nasality. Figure 3.4 places the two kinds of bands next to each other for comparison.

[2] Because the [ɛ̃] tokens were recorded only as aids in finding acoustic correlates of nasality, and were not useful to compare to [iN] and [iT] tokens, they were not included in the process of data analysis described here.

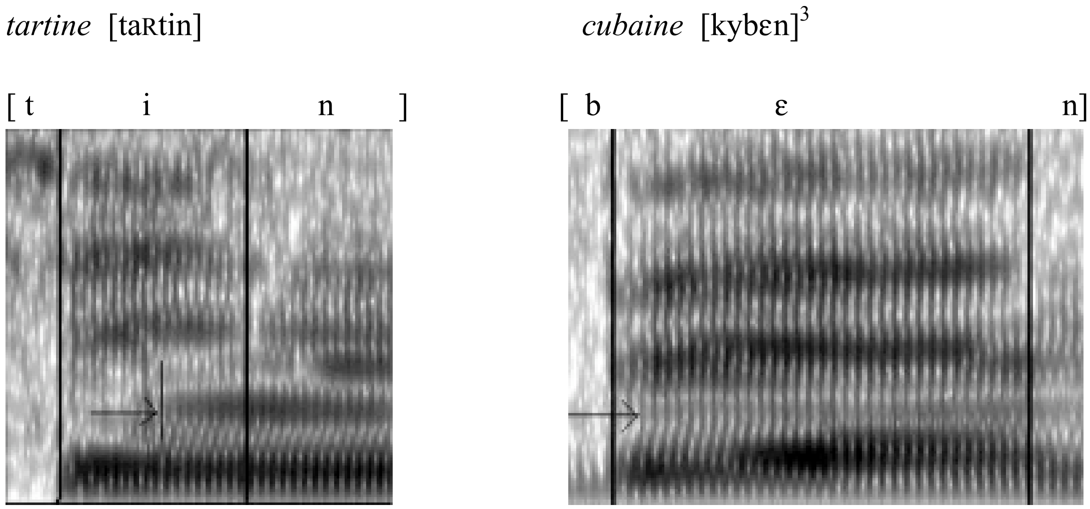


Figure 3.4
Comparing a Nasal Band and a Prominent Harmonic

The spectrogram for *cubaine* shows one of these prominent harmonics. It differed from the nasal band in that stayed constant during the whole duration of the vowel and, in many tokens, appeared anytime there is voicing, including in vowels before oral consonants. It also tended to be fainter than the nasal bands, but since intensity of tokens varied greatly, no objective standard of band intensity was possible. Therefore, if a band seemed very faint as compared to F1 and F2 and stayed constant throughout the clip's duration, I deemed it to be simply a prominent harmonic. Because I was looking at only part of the vowel in most clips, this may have led to some elimination of what truly were nasal bands, but most of the vowels were not substantially longer than 75ms. Additionally, I chose to err on the side of not identifying nasal bands that were there rather than seeing a nasal band where there was none so that bias, if there were any, would be against the results I was looking for. Using this method, I coded each clip as having a nasal band (+) or not having a nasal band (–).

After the initial round of coding, I checked the full token of each vowel I had coded

[3] These spectrograms were taken from the pilot study, which used some tokens not used in the final study. They are representative of the findings in this study.

as + to be sure that the supposed nasal band passed continuously from the vowel to the nasal consonant, as in the [iN] token in Figure 3.4. Praat's formant tracker usually did not detect these bands, so I used spectral slices taken from near the end of the vowel and near the beginning of the nasal to check the visual impression that the bands continued unchanged into the nasal. No tokens failed this check.

After identifying the tokens with nasal bands, I measured the duration of nasality in each vowel that had it. I marked the beginning of the nasal band as the point at which it began to continue unbroken through glottal pulses. The duration from this beginning point to the end of the vowel was recorded as both a duration in milliseconds and as a percent of the total vowel length.

3.6 Results

Overall, I found that more of the [iN] tokens show signs of nasal coarticulation than do the [ɛN] ones, and the duration of the nasalization is longer and is present in a greater

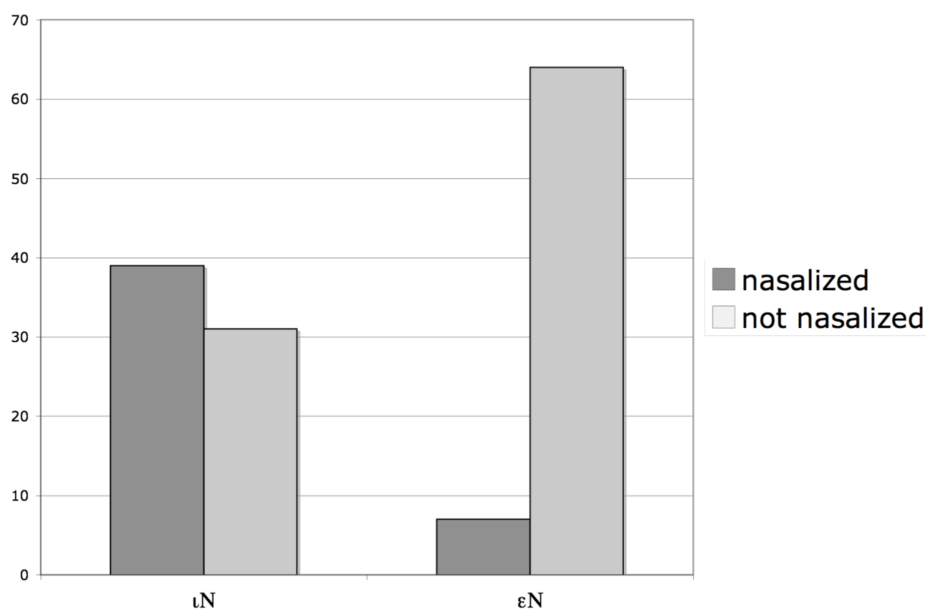


Figure 3.5
Number of [iN] and [ɛN] tokens nasalized

percentage of the vowel. Figure 3.5 compares the number of tokens whose vowels had a nasal band. There are significantly more nasalized [iN] tokens ($p < 0.0001$, by Fisher's Exact Test). Table 3.6 compares mean durations of nasalization in milliseconds and as a percentage of vowel duration among tokens that had a nasal band.

Type	Mean duration nasalized	Mean % nasalized
iN	38.69 ms	52.09%
εN	11.79 ms	10.26%

Table 3.6
Mean Durations of Nasalization

The nasalized [iN] tokens are nasalized for a significantly greater percentage of the vowel length than the nasalized [εN] tokens ($p=0.0002$, by Satterthwaite's test of unequal variances). Additionally, the [iN] tokens showed much more variation in both the duration of nasalization and the percentage of vowel nasalized than did the [εN] tokens. The variance in percentage of vowel nasalized for [εN] tokens was 0.002, while the variance for the [iN] tokens was 0.391, almost 200 times as great. Beyond showing that vowel nasalization is not suppressed in [iN] tokens, this difference in variance also suggests that vowel nasalization is less controlled in the [iN] tokens.

There was no significant effect of speaker gender or dialect. One factor that sometimes seemed to affect degree of nasalization was the syllabification of the nasal consonant following the vowel. This effect was most noticeable in Speaker 6's data, in which all of the [iN] tokens that did not show any signs of nasalization had a very brief (about 10 ms) pause between the vowel and the nasal consonant, which appeared as a slice of white in the spectrogram. Other speakers did not show such a systematic distribution of the nasalization or did not have such a distinct indication of how the word was syllabified. The idea that a nasal consonant would have a greater effect on the preceding vowel as its coda than as the onset of the next syllable is consistent with the findings of Laeufer (1992), who noted that syllable structure affects voicing-conditioned vowel length in French. That I did not find as clear a dependency on syllable structure as Laeufer did is not terribly surprising because of the highly variable nature of that final syllable. Even the speakers who seemed to produce the nasal consonant in a separate syllable produced the vowel that followed it with varying degrees of strength, from a fully vocalic [ə] to a voiceless [ə] to something that seemed more like a strong consonant release. Thus, the syllabic status of the final Nə syllables in my data was less clear than the syllables in Laeufer's study, so the fact that they behave less predictably is not unusual.

3.7 Conclusions

The results of this experiment show that a greater amount of nasal coarticulation occurs in [i] than in [ɛ]. Because Cohn (1990) found a similar amount of nasal coarticulation in [ɛ] as in the other vowels with an oral/nasal contrast, it is reasonable to posit that [i] shows more coarticulation than all the vowels with that contrast. A possible explanation of this is that within French, the same relationship exists between contrast and allowable coarticulation as Manuel (1990) found among dialects of Yoruba. That is, the lack of a nasality contrast in the high vowels allows a greater degree of coarticulation. In this way, the phonology—specifically, the phoneme inventory—governs an aspect of the phonetic realization of these sounds.[4]

[4] That this process distinguishes between high and non-high vowels in French is a new finding, but the possibility that the phonology is sensitive to lack of contrast within certain classes of sounds is not unique to this study. In simultaneous work, Campos-Astorkiza (2006) found a similar effect on vowel length in Lithuanian, which lacks a length contrast in mid vowels and exhibits more variation in the duration of these vowels than in the high or low vowels.

CHAPTER 4

PHONOLOGICAL ANALYSIS

4.1 Introduction

4.1.1 What this chapter is about

This chapter will propose a phonological analysis in Optimality Theory to account for the data described in the last chapter as well as the cross-linguistic typology of nasal coarticulation. I will begin by accounting for the typology described in the literature without consideration for variation within a language such as I found in French. This analysis will draw heavily from non-OT work in underspecification, most notably from Cohn (1990) and Keating (1990). I will then introduce the modification that accounts for my own findings and discuss the implications of this modification on current understanding of nasal coarticulation, as well as the typological predictions it makes.

4.1.2 What this chapter is not about

My analysis is concerned only with nasal coarticulation as a phonetic effect. Cohn (1993) describes the distinction between phonetic and phonological effects as being dependent on how the effect is manifested in the segment. A phonological effect occurs categorically, while phonetic effects are gradient. The fact that nasal coarticulation, a phonetic effect, appears to different degrees in different languages leads me to propose that it is not simply an uncontrolled accident of the timing of velar movement. Rather, I suggest, following Keating (1998), that languages allow a degree of variation within language-specific limits defined in the phonology. This analysis is not intended to apply to phonologically governed nasal assimilation, as is found, for example, in Sundanese nasal spreading (Cohn 1990). This includes any cases in which the assimilated feature is assigned by the phonology, identifiable by the categorical nature of the assimilation. Additionally, I have limited this study to vowels followed by nasal consonants. Possibilities of broader application of this analysis will be addressed in Chapter 5.

4.2 A Typology of Nasal Coarticulation

4.2.1 Two parameters and what they predict

For the purposes of this study, I propose two basic parameters for classifying languages with regard to nasal coarticulation, each with two possible settings:

(1) Nasal Contrast parameter[5]
- (a) contrast: language has a nasal/oral contrast in vowels
- (b) no contrast: language has no nasal/oral contrast in vowels

(2) Nasal Coarticulation parameter[6]
- (a) strict: minimal coarticulation allowed
- (b) sloppy: coarticulation not restricted

The second parameter refers to the findings of Cohn (1990), Rochet & Rochet (1991), and Clumeck (1967) that some languages show significantly more nasal coarticulation than others. The first two studies focus on French and English.[7] Clumeck examines several

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[5] For now, this parameter will refer to whether or not a feature (here, [nasal]) is constrastive in an entire language. Section 4.4 will address the possibility of languages in which some vowels show this contrast and some do not.

[6] For ease of reference, and not implying any value judgment, the values of this parameter will be referred to as strict and sloppy articulation.

[7] Cohn also looks at Sundanese, which shows evidence of phonological nasal spreading and is thus not relevant to this study.

languages and finds that French, Hindi, Swedish, and Amoy Chinese have substantially less nasal coarticulation than American English and Brazilian Portuguese. These two parameters, each with two options, combine to predict the following four language types:

(I) no contrast, sloppy articulation
(II) no contrast, strict articulation
(III) contrast, sloppy articulation
(IV) contrast, strict articulation

We see each of these language types attested. English serves as a well-studied example of type I (Cohn 1990, Rochet & Rochet 1991, Clumeck 1967). Spanish, as described in Walker (2000), belongs to type (II). Type (III) covers languages that have an oral/nasal contrast in vowels that is neutralized before nasal segments, like Brazilian Portuguese (Clumeck 1967) and Bengali (Ferguson and Chowdhury 1960). French as described in Cohn (1990) is an example of type (IV), as is Amoy Chinese (Clumeck 1967).

4.2.2 A closer look at Brazilian Portuguese and Bengali

Type III seems to be a marginal language type. Brazilian Portuguese (BP) and Bengali are the only languages with substantial phonetic data of this type. I classify both as Type III languages because both languages have oral and nasal vowels in unpredictable (i.e., contrastive) distribution, and both are reported to have partial nasalization before nasal consonants. However, the classification for both these languages is disputable. Cagliari (1967) claims that BP doesn't have a nasality contrast in vowels at all. He attributes nasal vowels to the presence of an archiphoneme that is sometimes realized as a segment and sometimes as nasalization on a preceding vowel. However, his discussion of how the archiphoneme is not regular enough to attribute to a phonological process. His "rules" for how the archiphoneme is realized (as nasalization of a preceding vowel or as a nasal consonant) includes qualifiers like "sometimes" and "usually." Additionally, his measurements of nasal airflow show some indication of categorically high nasal airflow in nasal vowels, suggesting phonologically nasal vowels. Thus, I conclude that BP does have contrastive nasality in vowels. Clumeck's (1976) study shows that nasalized vowels in BP are not categorically nasal, so BP is a legitimate Type III language.

That Bengali has contrastive nasal vowels is not controversial. Lahiri and Marslen-Wilson (1991) identify Bengali as a language with a nasality contrast in vowels that is neutralized before nasal segments. However, they attribute the neutralization to phonological nasal spreading, a situation not treated in this work. However, they also say that vowel nasalization in English is due to a phonological spreading process, which Cohn (1990) shows not to be the case. Similarly, Flemming (2001) refers to the nasalization in Bengali as a phonological process, citing Ferguson and Chowdhury (1960). Their study, however, makes no mention of whether the nasalization is phonological or phonetic. In fact, they describe vowels that occur before nasals as "somewhat nasalized," which suggests the kind of partial nasalization that is consistent with an underspecified segment. Lacking phonetic data that would show whether the nasalization is gradient or categorical, I accept this description as sufficient evidence that nasalization in Bengali is a phonetic coarticulatory process. Thus, I conclude that both BP and Bengali are indeed examples of Type III languages.

4.3 An OT Analysis

4.3.1 The big picture

As described in Chapter 2, one way to account for this kind of typology is by underspecification, as in Cohn (1990) and Keating (1990). An underspecification approach seems well-suited to accounting for the strict/sloppy parameter, which can correspond directly to having fully specified or underspecified segments, respectively. Much of the current work on underspecification in OT involves underspecified inputs that produce specified outputs (Inkelas 1994, Itô, Mester & Padgett 1995). That is, the process of assigning specification is handled by the ranked constraints. Instead, I follow Meyers (1998) and Mustafawi (2006) in proposing the possibility that *outputs* can be underspecified, leaving the details of the underspecified segments to the phonetics, to be worked out in the segments' production. However, my analysis follows Cohn (1993) in applying surface underspecification to segmental features, where Meyers's deals only with tone. This approach seems best suited to accounting for the kind of partial assimilation described by Cohn (1990, 1993) and occurring in my findings in Chapter 3; that is, a partially nasalized segment is not the same phonetically as a specified nasal segment.

The difference between a phonetically nasalized underspecified vowel and a phonologically nasalized vowel, as characterized in Cohn (1993) shows that our account should have a possible specified and underspecified outputs, but one must also ask whether the nasal specification is simply [nasal], or if it is binary, [± nasal], with a possibility of carrying a nasal or oral specification. In Meyer's analysis of Chichewa tone, he claims that in Chichewa, tone can be specified high or unspecified, with no possibility of specified low. He does mention the possibility of specified high and low targets in other languages and cites phonetic data to propose this system for English tone. Similarly, the phonetic data from French speakers described in Chapter 3 suggests that both nasal and oral specifications must be possible. Without the possibility of specified oral vowels, we cannot account for the strictly articulated oral vowels that show very little coarticulation when followed by nasal consonants (Cohn 1990). Thus, a segment can bear nasal ([+]) or oral ([–]) specifications, or be unspecified[8] ([Ø]) (Cohn 1990.) Similarly, Steriade (1999) argues that in order to account for patterns of obstruent voicing neutralization, all three possible specifications are necessary. Still, as in Meyers (1998), my analysis allows that languages may or may not make use of all possible specifications. In fact, different subsets of these possible specifications match neatly to the four types of languages described above:

(I) {Ø}: no contrast, sloppy articulation
(II) {–}: no contrast, strict articulation
(III) {+,Ø}: contrast, sloppy articulation
(IV) {+,–}: contrast, strict articulation

Other combinations seem to be unattested. This is in part because of the typological universal that any language that has nasal vowels will also have oral vowels (Maddieson 1984). Thus languages with only phonemically nasal vowels and no oral vowels ({+}), and languages with an oral/nasal contrast that is neutralized before oral stops ({–, Ø}) seem unlikely. The final possibility, {+, –, Ø}, will be revisited in section 4.3.4, but for now, it will suffice that the typology described above has languages with strict articulation and languages with sloppy articulation, but not languages with both. Nonetheless, tentatively rejecting the idea of a phonemic contrast between all three seems reasonable because [–] and [Ø] would be indistinguishable in oral environments, as would [+] and [Ø] in nasal environments. Since there is no environment in this case in which [Ø] is distinctive, having such a three-way contrast seems unlikely. It is with this general understanding of underspecification of vowel nasality that we proceed into an OT analysis.

4.3.2 Constraints

Three constraints are needed to give us the typology described above. These

[8] For ease of reference, I will henceforth refer to a lack of specification as having [Ø] specification.

constraints will refer to the [+], [–], and [Ø] specifications described above. The first reflects the unmarked nature of the oral vowel:

ORAL – vowels are specified oral.
Assign one * for each vowel segment that is [+] or [Ø].

The next constraint reflects the tendency toward efficiency of movement. While it reflects a similar goal as Kirchner's (1998) LAZY constraint, it operates more neatly within OT by having the constraint specify how to be lazy (by being underspecified) so as to allow a normal categorical assignment of violations and avoid a scalar model of candidate evaluation:

UNSPEC – be underspecified.
Assign one * for each vowel segment that is [+] or [–].

Both the constraints above are consistent with the markedness of nasal vowels. The final constraint also makes use of the markedness of nasal vowels:

ID[+ nasal] – do not change a nasal specification.
Assign one * for each segment with correspondents in the input and the output for which one correspondent has a [+] specification and the other does not.

I use this constraint for nasal faithfulness rather than a more typical ID[nasal] constraint because the attested languages suggest that a [+ nasal] specification can be preserved in cases where [– nasal] is not, even when the context is not responsible. This suggests that such protection is afforded by a faithfulness constraint. ID[+ nasal] has precedent in deLacy's (2002) scale-referring faithfulness constraints that more marked segments are more protected, so that for any markedness hierarchy *X » *Y » *Z, there are corresponding faithfulness constraints ID{X} » ID{X,Y} » ID{X,Y,Z}, such that the most marked segment is also the most protected by faithfulness constraints. Using this constraint instead of ID[nasal] prevents the phonology from producing an unattested language type with possible specifications {–, Ø}. Under DeLacy's model, this implies the existence of another constraint ID[+, –] that exists in a fixed hierarchy ID[+] » ID[+, –]. Only one ranking exists where ID[+, –] produces a different language type than those mentioned above and accounted for in the next section. This problematic ranking will be discussed in section 4.3.4.

4.3.3 Ranking

A factorial typology of the possible rankings of these constraints gives us precisely the four language types described above. These rankings are presented below, numbered to correspond with the language types, along with the set of output specifications they allow.

(1)	UNSPEC » ORAL, ID[+] :	{Ø}
(2)	ORAL » UNSPEC, ID[+] :	{–}
(3)	ID[+] » UNSPEC » ORAL :	{+, Ø}
(4)	ID[+] » ORAL » UNSPEC :	{–, +}

Note that in both (1) and (2), the ranking of the lower two constraints is unimportant, so for each, two possible ranking collapse into one language type. In (1), the top-ranked UNSPEC forces all outputs to have [Ø] specification, so this produces a language like English with no contrast and sloppy articulation, as shown in the following tableaus[9].

Tableau Set 4.1: UNSPEC » ORAL, ID[+]

(a) For specified oral inputs:

/–/		UNSPEC	ID[+]	ORAL
	+	*!		*
	–	*!		
☞	Ø			*

[9] Tableaus will be given using feature specification as input and output. Because all of the proposed constraints apply to individual segments, and because this analysis focuses on nasal specifications of vowels, this representation should suffice to stand for full lexical inputs and outputs. Each vowel segment in an input would be evaluated as shown by the tableaus here.

(b) For specified nasal inputs:

	/+/	UNSPEC	ID[+]	ORAL
	+	*!		*
	–	*!	*	
☞	Ø		*	*

(c) For unspecified inputs:

	/Ø/	UNSPEC	ID[+]	ORAL
	+	*!		*
	–	*!		
☞	Ø			*

Top-ranked ORAL operates the same way in (2), forcing all outputs to be specified [–], as in Spanish, which has no contrast and strict articulation:

Tableau Set 4.2: ORAL » UNSPEC, ID[+]

(a) For specified oral inputs:

	/–/	ORAL	UNSPEC	ID[+]
	+	*	*!	
☞	–		*!	
	Ø	*		

(b) For specified nasal inputs:

	/+/	ORAL	UNSPEC	ID[+]
	+	*!	*	
☞	–		*	*
	Ø	*!		*

(c) For unspecified inputs:

	/Ø/	ORAL	UNSPEC	ID[+]
	+	*!	*	
☞	–		*	
	Ø	*!		

In (3) and (4), top-ranked ID[+] ensures that all input [+] segments retain their specification, and the ranking of UNSPEC and ORAL determines the fate of input segments with [–] or [Ø] specification. If UNSPEC » ORAL, non-[+] segments are all [Ø] in the output, giving us a language with a contrast and sloppy articulation, like Bengali:

Tableau Set 4.3: ID[+] » UNSPEC » ORAL

(a) For specified oral inputs:

	/–/	ID[+]	UNSPEC	ORAL
	+		*!	*
	–		*!	
☞	Ø			*

(b) For specified nasal inputs:

	/+/	ID[+]	UNSPEC	ORAL
☞	+		*	*
	–	*!	*	
	Ø	*!		*

(c) For unspecified inputs:

	/Ø/	ID[+]	UNSPEC	ORAL
	+		*!	*
	–		*!	
☞	Ø			*

Finally, if ID[+] » ORAL » UNSPEC, all nasal specifications are preserved, and all other segments become specified [–] in the output. This produces a language with a contrast and strict articulation, such as Amoy Chinese (Clumeck1967):

Tableau Set 4.4: ID[+] » ORAL » UNSPEC

(a) For specified oral inputs:

	/–/	ID[+]	ORAL	UNSPEC
	+		*!	*
☞	–			*
	Ø		*!	

(b) For specified nasal inputs:

	/+/	ID[+]	ORAL	UNSPEC
☞	+		*	*
	–	*!		*
	Ø	*!	*	

(c) For unspecified inputs:

	/Ø/	ID[+]	ORAL	UNSPEC
	+		*!	*
☞	–			*
	Ø		*!	

The proposed constraints can produce all and only the patterns attested if we assume that all the vowels in a language have the same contrast and strictness settings. However, because the data presented in the previous chapter suggests that these settings can vary within a language, some modification of this basic analysis is in order. First, though, let us return to the issue of the ID [+, –] constraint implied by the existence of ID[+].

4.3.4 Dealing with the ID[+, –] constraint

As the following tableaus show, the existence of the ID[+, –] constraint predicts the existence of a fifth language type, one with a three-way {+, –, Ø} contrast.

Tableau Set 4.5: ID[+] » ID[+,–] » UNSPEC » ORAL

(a) For specified oral inputs:

	/–/	ID[+]	ID[+,–]	UNSPEC	ORAL
	+		*!	*	*
☞	–			*	
	Ø		*!		*

(b) For specified nasal inputs:

	/+/	ID[+]	ID[+,–]	UNSPEC	ORAL
☞	+			*	*
	–	*!	*	*	
	Ø	*!	*		*

(c) For unspecified inputs:

/Ø/		ID[+]	ID[+,–]	UNSPEC	ORAL
	+			*!	*
	–			*!	
☞	Ø				*

This is the most weakly dismissed language type in section 4.3.1, and the possibility of its existence is an interesting path for future research. This possibility rests on the feasibility of distinguishing unspecified vowels from specified ones, which is undetermined and needs further work. For the present analysis, I will suppose that such a distinction is not distinctive enough to support a contrast (cf. Flemming 2004). If we accept the initial state proposal (Smolensky 1996) that infants begin with all markedness constraints outranking all faithfulness constraints, and we suppose that the difference between [Ønasal] and [–nasal] is imperceptible before oral segments, as is that between [Ønasal] and [+nasal] before nasals, then an language-acquiring child would never have the motivation to promote ID[+, –] over ORAL separately from ID[+]. Should this distinction turn out to be perceptible, it is not fatal to my model; the model simply gains a fifth language type and loses the neatness of two binary parameters.

4.4 Formalizing Intra-Language Variation

4.4.1 An additional constraint

Recall that the French data suggests a possible link between contrast and coarticulation within a language, and Manuel (1990) demonstrated similar effect between languages among Yoruba dialects for vowel height. If lack of contrast is correlated with a higher degree of coarticulation, we would prefer that a single constraint be responsible for both. Indeed, we find that the promotion of a single constraint can both eliminate contrast within the high vowels and allow them to have sloppy articulation:

UNSPEC(hiV) – High vowels should be underspecified.
Assign one * for each high vowel segment that is [+] or [–].

Ranking this constraint above ORAL and ID[+] creates the following ranking:

(4') UNSPEC(hiV) » ID[+] » ORAL » UNSPEC

Note that for high vowels, this is like the ranking in (1), but for nonhigh vowels, it is like the one in (4). Thus the high vowels show no contrast and a high degree of coarticulation, and the nonhigh vowels show contrast and a low degree of coarticulation.

The existence of this constraint suggests that full specification is somehow marked in high vowels. It is certainly the case that [+ nasal] specification is more marked in high vowels. High nasal vowels are more rare typologically, and they tend to lower when nasalized, as is the case, historically, in French. Because so few accounts of languages' phoneme inventories consider the possible differences between [– nasal] and underspecified segments, further work is needed to make any typological statement about the occurrence of specified [– nasal] vowels. Other support for this constraint comes from acoustic data. As Delattre (1967) reports, many of the acoustic features of nasality are less salient in high vowels. Thus, making the oral/nasal contrast in high vowels requires more effort, and there is less gain for effort made.

From this constraint follows the claim that marked, "difficult" segments like nasal high vowels neutralize to unspecified forms, not to specified, less marked forms. This claim echoes Flemming's (2001) analysis of the neutralizing of /u/ and /y/ between coronals in Cantonese. The contrast neutralizes to /y/ not because /y/ is less marked but because it involves very little movement to produce between coronals. The data reported is consistent with an underspecification account.

One might propose instead that instead of having two UNSPEC constraints, one might just as well split the ID[+] constraint, adding a constraint

> ID[+](loV) - do not change the nasal specification of a nonhigh vowel. Assign one * for each low vowel segment that has a [+] in one correspondent and not in the other.

However, no possible ranking with this constraint gives the observed situation. One must either have ID[+](loV) » ORAL » UNSPEC » ID[+], which produces specified oral or nasal low vowels and specified oral high vowels, or ID [+](loV) » UNSPEC » ORAL » ID [+], which gives contrasting, sloppy (Portuguese-like) low vowels and non-contrasting, sloppy (English-like) high vowels. Additionally, to have any effect at all, this constraint must go against deLacy's (2002) proposed scale-referring faithfulness constraints, as the less marked nasal low vowels would have a higher faith requirement than the more marked nasal high vowels. Thus we see that the UNSPEC(hiV) is the best choice for an added constraint to simultaneously account for both the lack of contrast and the high degree of coarticulation in French high vowels.

4.4.2 Typological predictions

The addition of a new constraint UNSPEC(hiV) produces a new factoral typology to consider. Only five of the twenty-four possible rankings produce different language types than the original four. One of these five is the one used above to account for the French data in Chapter 3. Two of the remaining four rankings produce the same language type. The three new language types predicted are

(a) UNSPEC(hiV) » ID[+] » UNSPEC » ORAL
{Ø} in high V; {+, Ø} elsewhere

(b) UNSPEC(hiV) » ORAL » UNSPEC, ID[+]
{Ø} in high V; {–} elsewhere

(c) ID[+] » UNSPEC(hiV) » ORAL » UNSPEC
{+, Ø} in high V; {+, –} elsewhere

The attestation of these language types is uncertain because of a lack of work that makes the three-way distinction of possible specifications, but certainly none of these predicted types seems outlandish. For example, Spanish could plausibly be of type (b), or Portuguese of type (a). Further phonetic research is needed to determine whether these types are actually attested.

4.5 Conclusions

The phonological analysis presented here proposed three possible nasality specifications for vowels: {+, –, Ø}. All three specifications may occur in both input and output forms. An unspecified output leaves nasality of the unspecified segment in the hands of the phonetic production, functioning like a wide window in Keating's (1990) window model. The single constraint UNSPEC(hiV) accounts for the French data presented in Chapter 3 and reflects the correlation between contrast and strict articulation. However, it allows for vowels without a nasal/oral contrast to bear a [-nasal] specification just as languages without this contrast may still exhibit a low degree of coarticulation, as in Spanish.

The typological predictions from this analysis offer the potential for further work. Because traditional accounts of vowel nasality seldom consider the possibility of three different specifications, this work opens the possibility of revisiting the status of nasality even in well- studied languages. For example, any of the languages discussed in this chapter might actually exhibit different degrees of strictness in the articulation of high and low vowels, as I have shown that French does.

While my findings and the cases discussed in Chapter 2 support Manuel's (1990) claim that some negative correlation exists between contrast and coarticulation, the existence of type III languages like Brazilian Portuguese and Bengali suggests that this tendency is not universal. Where the examples above show coarticulation being suppressed in order to preserve contrast, BP and Bengali instead lose the contrast in environments before nasal consonants. This does not entirely undermine the analysis presented, however. It merely demonstrates that languages may find different solutions to the tension between efficient production and salient perception of sounds. If we take coarticulation to be the universally default state, we must account for why it *does not* happen. Here, the goal of preserving a contrast may, but does not necessarily, supercede the tendency to nasalize vowels before nasal consonants.

Why, if there is some motivation for contrast to suppress coarticulation, does it fail to happen in some languages? I propose an explanation that does not rely on some fundamental fact about underspecification, but instead considers what typology a reasonable set of constrains could produce. That is, a typology that only allows languages with {Ø} or {+, –} as possible specification sets is impossible to produce with normal constraints. No constraint set made of basic relevant markedness and faithfulness constraints[10] produces just this two-member typology. Essentially, given the markedness of nasal vowels, we can assume that some faithfulness constraint (**F**) is necessary to allow {+,–} as a possible specification set. If some other ranking gives an English-like language with [Ø] as the only possible specification, then **F** can be promoted to the top of this ranking to allow at least {Ø, +}, and (depending on the nature of **F**) possibly {Ø, –} and {Ø, +, –} as possible specification sets. Thus it seems that any constraint set that captures the markedness of nasal vowels and allows languages with nasal vowels at all must also allow {Ø, +} as a possible specification set.

[10] That is, markedness constraints of the form *[feature specification] and faithfulness constraints MAX[feature specification], DEP[feature specification], and ID[feature specification].

Thus,the attested patterns are simply a consequence of the typology produced by a set of uncontroversial constraints.

By allowing that the link between contrast and strict articulation is not absolute, we lose the predictive power of this link. We cannot say that a language with a contrast will necessarily have strict articulation, as BP and Bengali prove; nor, given type I languages like Spanish, can we conclude that any language with strict articulation must have a contrast.[11] Nonetheless, the many examples of the correlation between coarticulation and lack of contrast suggest that some link exists, even if it is not always active. We may at least say that preserving contrast *may* motivate the phonology to suppress coarticulation, perhaps even that it commonly does. This is reflected in my model by the fact that a top-ranked UNSPEC both eliminates contrast and allows a high degree of coarticulation. However, top-ranked ORAL can also eliminate contrast, allowing for the possibility that lack of contrast may not be linked with coarticulation.

[11] Manuel (1990) describes a situation similar to Spanish (no contrast, strict articulation) in Shona, one of the five-vowel Yoruba dialects. She concludes “minimally, phonemes must have some audible, distinctive output, and that languages are free to restrict the output of particular phonemes even further” (1294).

CHAPTER 5

CONCLUSIONS

5.1 Summary and Review

Let us begin with a brief review of what has been concluded in previous chapters, from most specific to broadest. First, the phonetic experiment described in Chapter 3 has shown that in French, the vowel /i/, when followed by a nasal consonant, shows significantly more nasalization than is found in /ɛ/, both in terms of number of nasalized tokens and in amount of the vowel nasalized. Based on this finding, I conclude that French /i/ (and probably the other high vowels /y/ and /u/) behave as English vowels, with no contrast and sloppy articulation. This data forces us to revise Cohn's (1990) description of French as a language with very little coarticulation overall. This difference between /i/ and the vowels that Cohn studied, /ɛ ɔ a/, reinforces the idea that some link exists between contrast and coarticulation, and shows that lack of contrast can result in less strict limits on coarticulation, as found in Manuel (1990).

The novel proposal here is that lack of contrast *within a language* can allow more coarticulation in that part of the language. This complements Manuel's finding that differences in contrasts between languages correlates with differences in the degree of coarticulation allowed. Thus, if we revisit the Contrast and Coarticulation parameters proposed in Chapter 4, we must now grant that these parameters are assigned values (or at least, they have the potential to be assigned values) on a segment-by-segment basis. This principle of contrast limiting coarticulation does not just operate between languages and dialects, which is what previous work has focused on.

I have also concluded, following Cohn (1990) and Keating (1990), that sloppy articulation is a reflection of underspecified segments. My findings add to the body of evidence cited by Myers (1998) for surface underspecification, in which the phonology outputs underspecified forms to the phonetics. I argue that in this case, we see evidence that universal phonetic tendencies, like the tendency for VN coarticulation, are allowed to emerge when the phonology allows freedom in the phonetic implementation of a segment by failing to specify that segment in the output form.

5.2 Implications

5.2.1 Universal phonetics

The analysis presented here offers the possibility that despite the fact that nasal coarticulation may not be operative in all possible environments in all languages, it may still be considered a universal phonetic tendency. Beyond the simple satisfaction of collecting universals of language, phonetic universals are useful in some concrete ways. First, much of the work in OT phonology is grounded in the idea of cross-linguistic phonetic naturalness. Appealing to phonetic naturalness when proposing a constraint is, in an oblique way, appealing to the idea of phonetic universals. Similarly, work in child language acquisition regarding the order of acquisition of phonemes and the cross-linguistic phonological tendencies of language-acquiring children also makes reference to the idea that certain phonetic tendencies, especially those concerning markedness, are universally present.

Another very appealing consequence of the existence of universal phonetic tendencies is greater simplicity in our model of the mental grammar. Our model has to provide some way to go from phonological outputs to actual, realized sounds. The complexity of this part of the model is greatly reduced if we can appeal to some sort of universal phonetics to fill in the blanks left by the phonology. Otherwise, we are left demanding that the phonology specify exact muscle movements, or we must invent a whole system for determining how the phonetics take phonological surface forms as input and produces sounds as output. The model proposed here says that, barring other orders from the phonology, the phonetics does the same thing all the time in all languages. This is not intended, however, to oversimplify the phonetic processes. As the wide variation in how the [iN] tokens were nasalized suggests, the way that the phonetics fills in the blanks when realizing a string of sounds is probably not very simple, straightforward interpolation. This finding echoes that in Meyers' (1998) work with tones. Nonetheless, figuring out a single default process is a much less daunting task than figuring out a whole system of processes.

5.2.2 Underspecification

The set of constraints proposed in Chapter 4 offers a simple, workable way to handle underspecification in OT. This is unique in that the constraints that allow for surface underspecification of segmental features are explicitly defined, grounded, and able to assign violations categorically. These constraints are shown to account for one particular case of surface underspecification, vowel nasalization before nasal consonants. This analysis is particularly pleasing because it accounts for underspecification without bending the rules of OT, unlike, for example, Inkelas's (1994) analysis that requires "optimization of the input" to limit Richness of the Base. Although this model certainly requires more testing with other phenomena than nasalization, it has promise to be able to bring past work in underspecification into OT.

5.2.3 Feature Specification

This work offers support for the idea that features like [nasal] carry binary specifications in the phonology, along with a third possibility of no specification at all, as proposed by e.g., Cohn (1990, 1993) and Steriade (1999). Contrary to proposals that nasal segments have a [nasal] specification and oral segments lack this specification entirely, the data from Chapter 3 supports Cohn's (1990) analysis that both specified nasal and specified oral segments behave differently from segments that lack a feature specification. The support for the idea that the [nasal] feature can bear both [+ nasal] and [– nasal] specifications also suggests that other features in dispute, like [voice], may also have binary specifications.

5.3 Avenues for Future Research

5.3.1 The phonetics of nasalization

The finding that French does not behave phonetically the way it is described in prior analyses opens up the possibility that other languages also show different phonetic behavior in different segments or groups of segments. Because my analysis predicts that lack of contrast does not require underspecification, nor is it the only way to have underspecified segments, even languages without a vowel system like French, where some vowels have an oral/nasal contrast and some don't, are candidates for investigation. Two immediately obvious places to begin to investigate are Spanish and Portuguese, as mentioned in section 4.4.2. An experiment similar to the one described here, perhaps investigating more vowels, would serve as a good beginning point to such an investigation. Such an investigation would seek to discover whether or not the additional language types predicted in 4.4.2 were actually attested and to see if the prediction that the split between different possible specification sets is always between high and non-high vowels, as it is in French.

Additionally, more work is needed in French to strengthen the support for the nasal band between F1 and F2 as a correlate of nasality. Perception tests would be particularly helpful, both comparing the perceived nasality of actual recorded sounds with and without this nasal band, and synthesizing [ĩ] by adding s nasal band to an oral [i], as Delattre (1966) did with other vowels and other acoustic correlates of nasality.

Another area where perception is of great interest is in determining how perceptible the difference between specified and unspecified nasal segments is. That is, can a listener tell the difference between [+ nasal] and [Ø nasal] before a nasal consonant or between [– nasal] and [Ø nasal] before an oral consonant? My analysis supposes, based on the attested patterns, that listeners cannot hear the difference, but experimental evidence supporting or refuting this supposition would be interesting, especially in terms of the feasibility of acquiring a language with all three possible specifications for the same vowel set.

5.3.2 Contrast and coarticulation involving other features

If vowels that have a nasal/oral contrast may behave differently than vowels that do not in the same language, might we see the same kinds of differences in other features? In a language where voicing is contrastive in some segments and not in others, do we see differences in the occurrence of intervocalic voicing? Whether or not voicing (and other features that are sometimes contrastive and sometimes not) follow the same pattern as French VN coarticulation would be an interesting path of research, and might similarly unearth other universal phonetic tendencies.

5.3.3 Expanding the OT analysis to other features

As is always the case when a new set of constraints is proposed, my OT analysis raises many questions about the possibilities of where this analysis might aptly account for attested patterns and where it might not. One particular area of interest is how well it can be adapted to other features like voicing or tone. Does it make the same predictions, and if so, are they similarly borne out? This work could be done in conjunction with that described in the previous section, beginning with a project much like this one.

5.4 Final Remarks

In this work, I have created an underspecification model in OT based on patterns of phonetic nasalization in French. Using phonetic data, I have shown that French high vowels, unlike other French vowels, undergo phonetic nasalization before nasal consonants. I account for this phonetic nasalization using underspecified outputs. I have proposed a constraint that drives underspecification (UNSPEC) and that, as a family of constraints, can refer to specific classes of segments (e.g., UNSPEC(hi)). This results in different patterns of coarticulation in different segments within a language, demonstrated here with French high vowels. Because this constraint is partly responsible for eliminating contrast, it accounts for the patterns of contrast and coarticulation described by Manuel (1990), but since other constraints are at work, this correlation is not absolute, as exemplified in Brazilian Portuguese and Bengali.

APPENDIX

Token List

[In] tokens

cantine
centime
copine
epine
estime
glutine
latine
ratine
routine
taquine
tartine
victime

[It] tokens

boutique
cantique
caustique
critique
équipe
gotique
hittite
mystique
otite
pépite
petite
typique

[εN] tokens

antenne
baptème
centaine
certaine
cheftaine
empenne
fontaine
futaine
lointaine
patène
scorpène
système

[εT] tokens

casquette
coquette
croquette
franquette
jaquette
jupette
perpète
pipette
quartette
raquette
répète
trompette

[ɛ̃] tokens

certain
copain
destin
lapin
latin
lutin
matin
patin
pépin
sapin
satin
tatin

WORKS CITED

Avery, Peter and Keren Rice. 1989. Segment structure and coronal underspecification. *Phonology* 6.2: 179–200.

Ayers-Bennett, Wendy. 2001. Problems and perspectives: studies in the modern French language. Harlow: Longman.

Bergem, D. R. van. 1994. A model of coarticulatory effects on the schwa. *Speech Communication* 14: 143–162.

Cagliari, Luis. 1977. *An experimental study of nasality with particular reference to Brazilian Portuguese.* Ph.D. dissertation. Edinburgh University.

Campos-Astorkiza, Rebeka. 2006. Lithuanian vowel length and the voicing effect. 14th Manchester Phonology Meeting (handout).

Clements, George N. 1981. Akan vowel harmony: a nonlinear analysis. Harvard Studies in Phonology, vol. II. Bloomington, IN: Indiana University Linguistics Club, 108-177.

Clumeck, Harold. 1967. Patterns of soft palate movement in six languages. *Journal of Phonetics* 4: 337-351.

Cohn, Abigail. 1990. Phonetic and phonological rules of nasalization. Ph.D dissertation, UCLA.

Cohn, Abigail. 1993. Nasalisation in English: phonology or phonetics. *Phonology* 10: 43-82.

Coleman, Malissa and Katie King. 2003. American English vowel nasalization and lexical boundaries. LING 120 final project, UNC-CH..

Davison, Deborah. 1992. Parametric variation in pitch realization of ‘ neutral tone ’ syllables in Mandarin. *BLS* 18 : 2. 67–79.

De Lacy, Robert. 2002. The formal expression of markedness. Ph.D dissertation. U Mass, Amherst.

Ferguson, Charles and Munier Chowdhury. 1960. The phonemes of Bengali. *Language* 36 (1): 22-59.

Flemming, Edward. 1997. Phonetic detail in phonology: evidence from assimilation and coarticulation. In Suzuki, K. and D. Elzinga (eds.) Southwest Workshop on Optimality Theory: Features in OT (SWOT), Coyote Papers.

Flemming, Edward. 2001. Scalar and categorical phenomena in a unified model of phonetics and phonology. *Phonology* 18: 7-44.

Flemming, Edward. 2004. Contrast and perceptual distinctiveness. In Hayes, B., R. Kirchner, and D. Steriade (eds.) *Phonetically-Based Phonology*. Cambridge: Cambridge U P, 232-276

Hale, Mark & Madelyn Kissock. To appear. The Phonetics-Phonology Interface and the Acquisition of Perseverant Underspecification. In Ramchand, G. and C. Reiss (eds.) *Handbook on Interface Research in Linguistics.* Oxford University Press.

Hombert, Jean-Marie et al. 1979. Phonetic explanations for the development of tones. *Language* 55(1): 37-58.

Huffman, Marie. 1993. Phonetic patterns of nasalization and implications for feature specification. In Marie Huffman and Rena Krakow (eds), *Nasals, nasalization, and the velum.* San Diego : Academic Press. 303–327.

Inkelas, Sharon. 1994. The consequences of optimization for underspecification. UC Berkely, manuscript.

Itô, Junko, Padgett, Jaye and Mester, Armin. 1995. Licensing and underspecification in Optimality Theory. *Linguistic Inquiry* 26(4):571-614.

Keating, Patricia. 1988. The window model of coarticulation: articulatory evidence. UCLA Working Papers in Phonetics 69: 3-29.

Keating, Patricia A. 1990. The window model of coarticulation: articulatory evidence. In Kingston, J. and M. E. Beackman (eds.) *Papers in laboratory phonology I: Between the grammar and physics of speech*. Cambridge: Cambridge UP, 451-470.

Kirchner, Robert. 1998. *An effort-based approach to consonant lenition*. Ph.D. Dissertation. UCLA.

Lahiri, A and W. Marslen-Wilson. 1991. The mental representation of lexical form: a phonological approach to the recognition lexicon. *Cognition* 38(3): 245-94.

Maddieson, Ian. 1984. *Patterns of sounds*. Cambridge: Cambridge University Press.

Maeda, Shinji. 1993. Acoustics of vowel nasalization and articulatory shifts in French nasal vowels. In Huffman, M.K. and R.A. Krakow (eds.) *Nasals, nasalizaton, and the velum*. New York: Academic Press, 147-167.

Manuel, Sharon. 1990. The role of contrast in limiting vowel-to-vowel coarticulation in different languages. *Journal of the Acoustical Society of America*. 88(3): 1286-98.

Myers, Scott. 1998. Surface underspecification of tone in Chichewa. *Phonology* 15:367-91.

Mustafawi, Eiman. 2006. *An optimality theoretic approach to variable consonantal alterations in Qatari Arabic*. Ph.D. dissertation. University of Ottowa.

Ohala, John J. 1993a. The phonetics of sound change. In Jones, C. (ed.) *Historical Linguistics: problems and perspectives*. London: Longman, 237-277.

Pierrehumbert, Janet. 1980. *The phonetics and phonology of English intonation*. PhD dissertation, MIT. Distributed 1987, Indiana University Linguistics Club.

Pierrehumbert, Janet & Mary Beckman. 1988. *Japanese tone structure*. Cambridge, Mass. : MIT Press.

Rochet, A.P. and B.L. Rochet. 1991. The effect of vowel height on patterns of assimilation nasality in French and English. *Proceedings 12th ICPhSc, Aix-en-Provence,* vol.3, 54-57.

Smolensky, Paul. 1996. The initial state and 'richness of the base' in Optimality Theory. Technical Report JHU-CogSci-96-4. Cognitive Science Department, Johns Hopkins University.

Steriade, Donca. 1999. Phonetics in phonology: the case of laryngeal neutralization. *UCLA Working Papers in Linguisitcs* 2: 25-146.

Walker, Rachel. 2000. *Nasalization, neutralization, and opacity effects*. New York: Garland.