

PATTERNS OF ASSIMILATION NASALITY IN ENGLISH AS A FUNCTION OF VOWEL HEIGHT

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ABSTRACT

Assimilation nasality patterns for high, mid and low vowels were studied in two dialects of North American English (Canadian & southeastern American). Native speakers (n=24) produced CVC, NVC, CVN and NVN tokens. The vowel portion of each oral and nasal acoustical signal was transduced by a Nasometer, digitized, and the degree of nasalance established as: % nasalance = nasal rms/(nasal + oral rms) x 100. The high vowels in both dialects exhibited significantly more assimilation nasality than lower vowels in all nasal contexts. In addition, anticipatory nasalization was significantly more extensive than carry-over nasalization for all speakers and all vowels, and significantly more so for the southeastern American speakers than those who spoke Canadian English.

1. INTRODUCTION

The assimilation of nasality onto vowels spoken in the context of nasal consonants has been documented by research using various methods (aeromechanical, acoustical, biomechanical, perceptual) [8, 2, 6, 7, 1, 4]. Previous research on French and English using acoustical analog recording and digital analysis techniques has suggested that differences in degree of assimilation nasality exist among vowels as a function of tongue height, with high vowels exhibiting a higher degree of assimilation nasality than low vowels [6]. The present experiment used similar techniques to quantify and compare assimilation nasality patterns in two dialects of English as a function of vowel height.

2. PROCEDURES

2.1. Subjects/Speech Sample

Subjects were 24 adults, 9 native speakers of southeastern American English (SAE) and 15 of western Canadian English (CE), with normal hearing, voice qualities and articulation patterns. They read aloud words in which high, mid and low English vowels were embedded in the contexts CVC, NVC, CVN and NVN, where V = one of the target vowels, C = a non-nasal obstruent and N = /m/ or /n/. Each word was produced as the terminal item in a carrier phrase, e.g., "A half keen."

2.2. Data Collection/Analysis

The oral and nasal acoustical signals corresponding to subjects' productions of the test words were transduced separately by means of a Nasometer (model 6200; Kay Elemetrics, Inc.). The Nasometer microphone signals were recorded simultaneously on separate channels of a two-channel analog recorder, low-pass filtered at 4.8 kHz and digitized at 10 kHz/12 bit resolution via CSpeech [5]. The vowel portion of the oral and nasal components of each digitized signal was isolated, converted to an rms value, and the degree of nasalance computed by comparing rms amplitudes of corresponding oral and nasal data across the duration of the vowel in 5 ms steps, according to the formula: % nasalance = nasal rms/(nasal + oral

rms) x 100. Data analysis focussed on two dependent measures as a function of vowel height: (1) degree of nasal resonance, using 50% nasalance as an arbitrary threshold, and (2) percentage of the vowel with nasalance values above 50%. Analyses of variance and t-tests were used for within- and between-dialect comparisons.

3. RESULTS

3.1 CVC context

This context served as the control (i.e., non-nasal) environment for degree of nasalance in the utterance sample. Figure 1 illustrates the percentage of CVC cases *without* significant nasalance (i.e., <50%). In both dialects, the nasalance levels for the large majority of vowels in this context never exceeded the arbitrary threshold. Among the tokens on which the nasalance level did exceed the threshold, the high vowels exhibited the most cases (7% in SAE & 4% in CE), and the mid vowels exhibited the fewest (1% in both dialects).

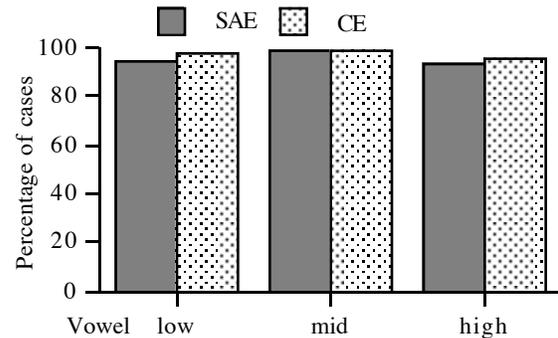


Figure 1. Percentage of CVC cases without significant nasalization (<50%).

3.2 NVC context

Figure 2 illustrates the degree of nasalance above 50% in this

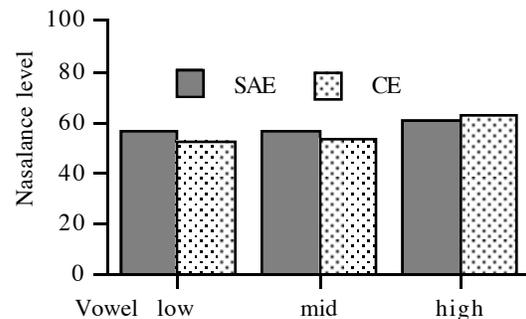


Figure 2. Nasalance level in NVC context

carry-over assimilation nasality context. The high vowels exhibit significantly higher levels of nasalance than the mid or low vowels in both dialects [$p < .0001$]. The difference in degree of nasalance between the mid and low vowels is not significant in either dialect.

With respect to the percentage of the vowel nasalized in the NVC context, two patterns were observed, which are schematized in Figure 3. In pattern 1, only the portion of the vowel adjacent to the nasal consonant was nasalized (i.e., with nasalance $> 50\%$). In pattern 2, the entire vowel was nasalized.

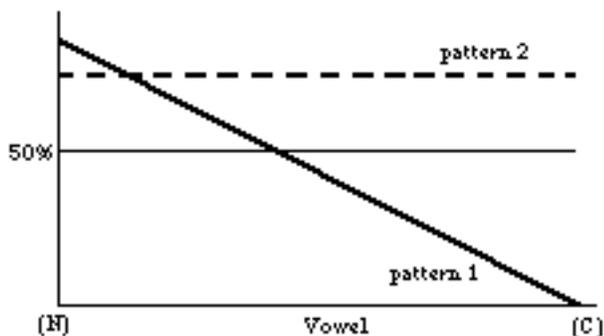


Figure 3. NVC hypothetical nasalization patterns

In SAE, 86% of the tokens followed pattern 1, and 14% followed pattern 2. Of the latter, 94% were high vowels. In CE, 71% followed pattern 1, and 29% followed pattern 2. Of the latter, 94% were high vowels.

Figure 4 shows the percentage of the vowel affected by carry-over nasality in SAE and CE. In both dialects, the percentage of the vowel duration that is nasalized is significantly higher for high vowels [$p < .0001$ for CE; $p < .01$ for SAE] than for mid and low vowels.

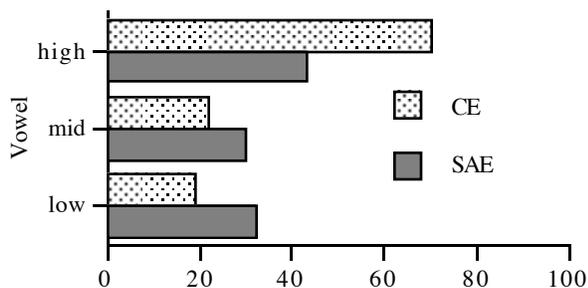


Figure 4. Percentage of vowel nasalized in NVC context

3.3. CVN context

Figure 5 illustrates the degree of nasalance above 50% in this anticipatory assimilation nasality context. The high vowels exhibit significantly higher levels of nasalance than the mid or low vowels in both dialects, although this difference is more distinct for the CE sample [$p < .0001$ for CE; $p < .01$ for SAE]. The difference in degree of nasalance between the mid and low vowels is not significant in either dialect.

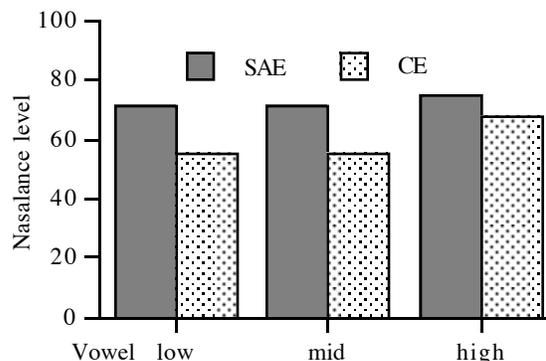


Figure 5. Nasalance level in CVN context

With respect to the percentage of the vowel nasalized in the CVN context, two patterns were observed, which are schematized in Figure 6. In pattern 1, only the portion of the vowel adjacent to the nasal consonant was nasalized (i.e., with nasalance $> 50\%$). In pattern 2, the entire vowel was nasalized.

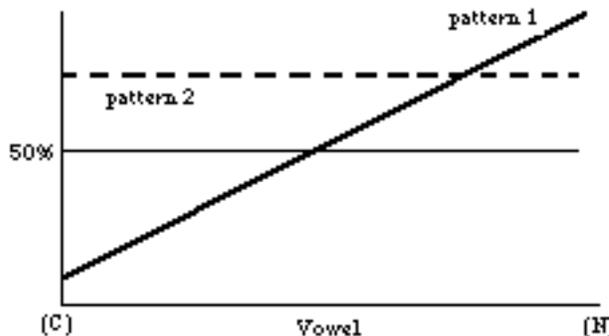


Figure 6. CVN hypothetical nasalization patterns.

For SAE, 25% of the tokens followed pattern 1, and 75% showed nasalization of the entire vowel. Of the latter, 94% were high vowels. In CE, 35% of the tokens followed pattern 1, and 65% showed nasalization of the entire vowel. Of the latter, 72% were high vowels.

Figure 7 represents the percentage of the vowel affected by anticipatory nasality in CE and SAE.

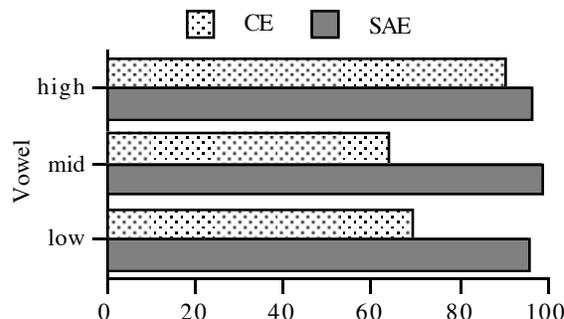


Figure 7. Percentage of vowel nasalized in CVN context

A significantly higher portion of the vowel is nasalized for high vowels than for mid and low vowels in CE [$p < .0001$]. The differences observed for anticipatory nasalization among the high, mid and low vowels in SAE are not significant.

3.4 NVN context

Figure 8 illustrates the degree of nasalance above 50% in this context in which the vowel is influenced by nasal consonants at both ends. The high vowels exhibit significantly higher levels of nasalance than the mid or low vowels in both dialects, although this difference is more robust for the CE sample [$p < .0001$ for CE; $p < .05$ for SAE]. The difference in degree of nasalance between the mid and low vowels is not significant in either dialect.

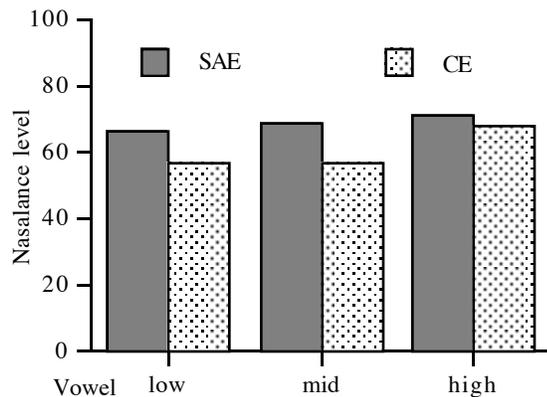


Figure 8. Nasalance level in NVN context

With respect to the percentage of the vowel nasalized in the NVN context, two patterns were observed, which are schematized in Figure 9. In pattern 1, only the portions of the vowel adjacent to the initial and the final nasal consonant were characterized by a nasalance level higher than 50%. In pattern 2, the entire vowel was characterized by nasalance above 50%.

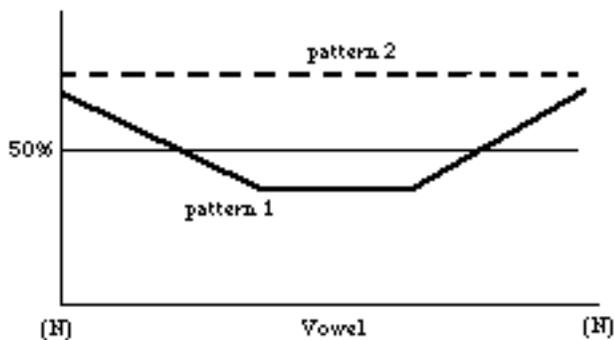


Figure 9. NVN hypothetical nasalization patterns.

In SAE, 87% of the NVN tokens followed pattern 2; that is, their vowels were nasalized throughout. Only 13% followed pattern 1, and of these 71% were low and 29% were high. In CE, 68% of the tokens were nasalized throughout. Thirty-two percent followed pattern 1, and of these, 38% were low, 39% mid, and 23% high.

4. DISCUSSION

4.1. CVC context

Figure 1 illustrates that most of the vowels in the CVC context never exceeded the arbitrary nasalance level of 50% in either dialect. This outcome is consistent with expectations for this non-nasal context and agrees with the results of earlier research on this phenomenon, using similar techniques and instrumentation [6]. The very small number of cases in which vowel nasalance exceeded 50% in this context suggests that this threshold is a reasonable one for experimental studies of this type.

4.2. NVC context

In this context, the large majority of vowels in both dialects exhibited carry-over nasalization that tapered off across the duration of the vowel (Figure 3, pattern 1). The high vowels, however, were inclined to exhibit carry-over nasalization for their entire duration and accounted for almost all the cases in which pattern 2 occurred in the NVC context. The high vowels also stand out in both dialects with respect to the degree of nasalance they exhibited (Figure 2) and the percentage of their duration nasalized (Figure 4). Although these differences between the high vowels and the mid and low vowels are significant in both dialects, the high vowels' prominence is more noticeable for CE, especially with respect to the percentage of the vowel nasalized (Figure 4).

4.3. CVN context

In this context, the influence of the nasal consonant caused the majority of vowels in both dialects to exhibit levels of anticipatory nasalization above 50% across their entire duration (Figure 6, pattern 2). Only a minority of vowels exhibited pattern 1, in which anticipatory nasalization increased across the duration of the vowel. The tendency for the high vowels to exhibit higher levels of nasalance than the low and mid vowels (Figure 5) and to be nasalized across a larger percentage of their duration (Figure 7) was significant only in the CE sample. The high vowels of the SAE sample certainly exhibited anticipatory nasalization for most of their duration, but the tendency for *all* the vowels to be saturated with anticipatory assimilation nasality was so extensive in SAE that it masked any differences among high, mid and low vowels.

4.4. Carry-over (NVC) versus Anticipatory (CVN) nasalization patterns

Figures 4 and 7 compare the percentage of the vowel nasalized in both dialects for the NVC and CVN contexts, respectively. In both dialects, anticipatory assimilation nasality is more extensive than carry-over assimilation nasality. It also appears that assimilation nasality is generally more pervasive in SAE than in CE, regardless of the vowel, with the notable exception of high vowels in NVC tokens, where CE exhibits much higher nasalization than SAE.

4.5 NVN context

In this context, most of the vowels in the samples for both dialects were nasalized throughout (Figure 9, pattern 2). This was especially noticeable in SAE (87% of tokens) compared to CE (63% of tokens). This likely reflects the SAE dialect's tendency toward generous assimilation nasality patterns, especially in anticipation of a nasal consonant. The

alternative nasalization pattern in this context (Figure 9, pattern 1) exhibits nasalance that is above threshold at each end of the vowel and dips below threshold during the vowel's mid-portion. In both dialects, the majority of tokens in which this pattern was observed included low and mid vowels. The high vowels were least likely to exhibit this pattern.

4.6 Nasalance patterns and vowel height

The high vowels in the speech samples of these two dialects of English exhibited significantly higher nasalance levels than mid or low vowels in the NVC, CVN and NVN contexts. As well, the percentage of the vowel nasalized was always more extensive in the high vowels than in the mid or low, with the exception of the SAE sample in the CVN context, where distinctions among the vowels, regardless of height, were masked by almost pervasive anticipatory assimilation nasality. The higher levels and longer durations of assimilation nasality observed for high vowels in both dialects can be interpreted in terms of vocal tract impedance. The measurement of nasalance via the acoustical sampling method and equation used here is a function of the relative impedances of the oral and nasal cavities during vowel production. Nasalance values tend to be high when oral impedance is relatively high (as during the production of high vowels), and lower when oral impedance is relatively low (as during the production of mid and low vowels). Oral tract configurations that influence oral impedance ultimately influence the oral component of the nasalance equation and its outcome. For high vowels, then, where oral impedance is high (because of high tongue and close mandible positions), the oral energy component of the equation [nasalance = nasal rms/(nasal + oral rms)] would be reduced, and the resulting nasalance value increased (assuming no change in nasal energy) [7]. This rationale is also consistent with spectral and perceptual analyses of nasal coupling on vowels of different heights. The spectral envelopes of high vowels are markedly affected by small nasal coupling, whereas vowels with a more open tract configuration are much less affected by small degrees of coupling [2]. This observation agrees with listeners' judgements that the amount of nasal coupling necessary for the perceptual identification of nasalization is almost three times as much for low vowels as for high ones [4].

5. CONCLUSIONS

These results, coupled with those of previous studies using similar acoustical instrumentation and analyses, attest to the robustness of the relationship between the extent of nasalization and vowel height. Such results encourage further exploration of this relationship in other dialects and languages. If it is truly a passive phenomenon associated with relative acoustical impedances, it may prove to be universal in the assimilation nasality patterns of vowels in the context of nasal consonants.

In addition, such results inform the clinical practice of speech-language pathology. Diagnostic methods based on acoustical and perceptual measures must control for phonetic context in speech samples obtained from persons suspected of having resonance disorders, if clinicians are to distinguish signs of assimilation nasality reliably from hypernasal resonance and make valid diagnostic decisions.

Further study of this relationship also would be useful to reconcile these results based on acoustical analyses with those of other studies that have used biomechanical [1] or aeromechanical [8] methods to investigate the behavior of the velopharynx during vowel production in the context of nasal consonants, and with the body of experimental work on the perceptual reality of this phenomenon, which remains somewhat ambiguous [3].

Finally, these findings should be kept in mind in any attempt to resolve the apparent contradictions that have been observed in historical studies that link nasal vowel formation and evolution with vowel height [3].

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