COARTICULATION AND THE PERCEPTION OF NASALITY

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ABSTRACT

Nasality judgments of oral and nasal vowels in nasal, oral, and null contexts were elicited from American English listeners. While nasal vowels were most often perceived as nasal, listeners performed best on vowels in isolation and worst on vowels in a nasal context. The consequences of these results for current approaches to coarticulatory compensation are discussed.

1. INTRODUCTION

A growing body of data indicates that vowel perception is influenced by phonetic context such that listeners adjust for the coarticulatory effects of adjacent consonants. For example, Kawasaki [2] showed that perceived vowel nasality is enhanced as flanking nasal consonants are attenuated; the same vowels in a clearly audible nasal context are more likely to be perceived as oral. One possible interpretation of these results is that, when presented with a nasal vowel in a nasal consonant context, listeners do not integrate the nasal resonance with the vowel itself, but instead hear it as part of the nasal consonant [1].

However, the results of Krakow et al. [3] have been interpreted as suggesting that listeners are able to associate the nasal resonance in a vowel in a nasalizing context with nasal coupling. We found that, for American English listeners, oral and nasal vowels produced with the same oral tract shape were perceived as having the same height given an appropriate coarticulatory context (i.e., CVC vs. CṼNC, where C is an oral consonant and N is a nasal consonant). But when the oral and nasal vowels were embedded in an oral context, the nasal vowels were perceived as shifted in height (CVC vs. CṼC). We suggested that, lacking a context for nasality, listeners interpreted the low-frequency nasal resonance of the nasal vowels in CṼC syllables as reflecting a shift in tongue/jaw height. In contrast, the presence of a nasal consonant in CṼNC syllables enabled listeners to correctly attribute the low-frequency nasal resonance in the nasal vowel to nasal coupling.

The results of Kawasaki [2] and Krakow et al. [3] therefore allow for conflicting interpretations. But the potential conflict cannot be resolved with these two studies alone as there are several methodological differences which may have influenced the findings. First, Kawasaki compared nasal vowels in appropriate coarticulatory contexts (NṼN) and isolation (Ṽ), while we compared nasal vowels in appropriate (CṼNC) and inappropriate (CṼC) consonantal contexts. It is unlikely that the perception of vowels in an inappropriate consonantal context is analogous to the perception of vowels in no context. Second, Kawasaki examined nasality judgments while we examined vowel height judgments. It is possible that, although listeners in our study were able to correctly attribute the effects of nasal coupling on the vowel spectrum to nasality (in CṼNC contexts), they would not have labeled these vowels as "nasal". Third, Kawasaki used edited natural speech while we used synthetic speech.

These differences leave many questions regarding the effects of coarticulatory contexts on perceived vowel nasality unresolved and provide the basis for the present study, which compared listeners' judgments of edited naturally produced tokens of nasal and oral vowels in C_C, N_N, and #_# (null) contexts. Using data obtained from vowel nasality judgments (elicited in a paired comparison test) and vowel identity judgments (matching test), we address the following questions: (1) Can listeners determine whether a vowel in a nasal context is nasalized? Kawasaki's results indicate that listeners will identify the vowel in NṼN as oral, while our interpretation of Krakow et al. suggests that listeners might perceive the vowel as nasal. (2) Are listeners more accurate at determining the nasality of a vowel in isolation than in (an appropriate or inappropriate) context? Previous work by Stevens et al. [4] suggests that within-category information regarding vowel quality is more evident in isolated vowels than in vowels in context. Here we ask whether the same is true of vowel nasality. (3) Are listeners more accurate when judging oral vowels as oral than when judging nasal vowels as nasal? Is nasality per se problematic, irrespective of the context?

2. METHODOLOGY

We recorded a male native speaker of American English producing multiple tokens of bed and men. Two tokens of each were selected so as to yield two bed-men pairings whose members were matched as closely as possible for duration and intensity. Waveform editing techniques were used to create the following 6 syllable types: CVC ([bɛd]), NṼN ([mɛ̃n]), isolated oral V ([ɛ] from [bɛd]), isolated nasal vowel ([ɛ̃] from [mɛ̃n]), cross-spliced CṼC ([bɛ̃d] with consonants from bed and vowel from men), and cross-spliced NVN ([mɛn] with consonants from men and vowel from bed). To control for any effects of splicing, the CVC and NṼN tokens were created by splicing across the two repetitions of each pair type.[1]

Twelve native speakers of American English were asked to respond in two test conditions. The Matching test involved an ABX format. In each trial, listeners heard two consonant-vowel-consonant syllables followed by an isolated vowel. Listeners were asked to determine whether the isolated vowel sounded more like the vowel in the first or second consonant-vowel-consonant syllable. Each AB pair was either CVC-CṼC or NVN-NṼN and X was either V or Ṽ, yielding four ABX condition types.

A Paired Comparison test was presented after the Matching test. This test involved all possible pairings (AB) of the 6 types of syllables, for a total of 21 condition types. Listeners were asked to determine whether the first or second member of each pair sounded "more nasal" or whether they sounded "equally nasal". For both tests, there were 8 randomized repetitions of each condition, with the order of A and B in each condition counter-balanced.[2]

3. RESULTS

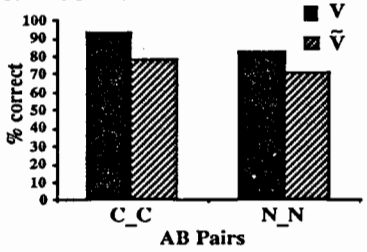

Figure 1. Matching test results. Each column represents responses to one of the ABX conditions (where A and B differ in vowel nasality). A or B (the correct match to X) is represented along the abscissa. and X is represented by column type (solid or hatched).

Figure 1 shows the percent correct responses to the Matching test. Listeners were generally quite accurate at matching vowels in (appropriate or inappropriate) context to vowels in isolation on the basis of nasality. Nonetheless, listeners were more accurate at matching oral vowels than nasal vowels, and more accurate at matching isolated vowels to vowels in an oral context than to vowels in a nasal context. Listeners did least well matching NṼN and Ṽ, making the most common error a match between NVN and Ṽ. Listeners incorrectly matched NVN to Ṽ over 30% of the time; they incorrectly matched NṼN to V less than 20% of the time.

Figures 2-4, which we shall address in turn, show the results of the Paired Comparison test. Figure 2 focuses on the effect of inappropriate consonantal versus null contexts on perceived vowel

nasality. For all types of pairings, the nasality of a nasal vowel was more often correctly judged when in isolation (Ṽ) than when in a NṼN context (Fig. 2a) or in a CṼC context (with one exception; Fig. 2b). Comparison of the perceived nasality of nasal vowels in consonantal contexts shows greater accuracy for vowels in inappropriate CṼC contexts than appropriate NṼN contexts (Fig. 2c). Apparently, an inappropriate consonantal context (CṼC) makes nasality more evident than an appropriate one (NṼN), but a null context (Ṽ) makes nasality most evident.

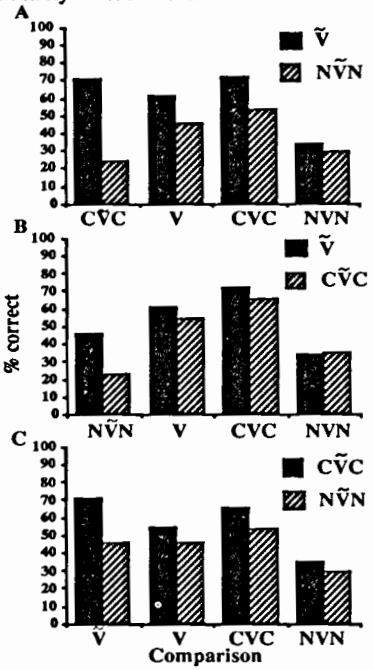

Figure 2. Paired comparison test results showing the effect of context. Each column represents correct responses to the AB comparison indicated. (Some conditions are repeated for reference.)

Figure 3 addresses the question of whether vowel nasality is more difficult to assess on nasal vowels than on oral vowels for American English listeners, independent of context. With one exception, listeners were less accurate at judging two nasal vowels as similar than they were at making the same judgment of two oral vowels.

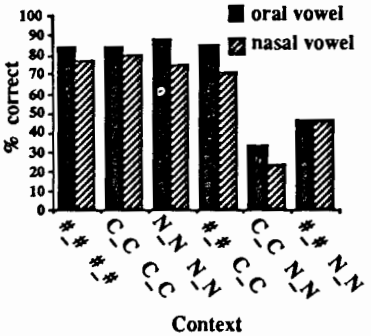

Figure 3. Results of paired comparisons between the contexts shown for two oral or two nasal vowels.

The exceptions to the two generalizations above both involved the N_N context, leading us to ask whether the N_N context is problematic irrespective of vowel nasality. Figure 4 shows listeners' responses to pairs involving one oral and one nasal member. The data represent the percentage of "more nasal" responses to each pair member. Nasal pair members were judged "more nasal" more often than oral ones when the oral vowels were in isolation (Fig. 4a) or in an oral context (Fig. 4b). But, in a nasal context, the *oral* member was more often judged as the more nasal member (Fig. 4c).

4. DISCUSSION

Overall, the results suggest that perception of vowel nasality is influenced by the coarticulatory context in which the vowel occurs. In two types of tests designed to elicit nasality assessments, American English listeners were less accurate at judging a vowel as nasal in appropriate (N_N) than in inappropriate (C_C, #_#) contexts. However, the data exhibit certain patterns not predicted by current approaches to coarticulatory compensation. One such pattern is that listeners were generally more accurate at judging oral vowels as oral than judging nasal vowels as nasal, irrespective of coarticulatory context. This finding may be linked to the non-distinctive status of vowel nasality in English, and points to the importance of extending this research to languages with distinctive vowel nasalization. A second pattern is that the distinction between "appropriate" and "inappropriate" coartic-

ulatory contexts is insufficient to explain listeners' judgments. That is, listeners perform less accurately on C_C than #_# conditions, both of which are inappropriate contexts for vowel nasalization in English.

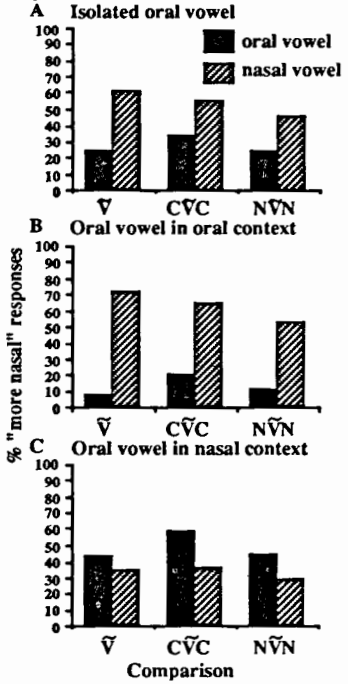

Figure 4. Results of paired comparisons between oral and nasal vowels. The oral member of each pair is represented in each panel (a-c); the nasal member of each pair is represented in the abscissa.

Furthermore, the present data fail to support a strong interpretation of the results of either Kawasaki or Krakow et al. Listener judgments of nasal vowels in appropriate nasal contexts (NṼN) were not as consistently oral or nasal as the former or latter, respectively, seem to predict. While the data suggest that listeners may factor out some of the nasality given an appropriate coarticulatory context, they are still more likely to judge these vowels as nasal than oral. In general, American English listeners demonstrate a lack of certainty as to the nasality of vowels in nasal contexts, an uncertainty which holds for both appropriate (NṼN) and inappropriate (NVN) coarticulatory nasal contexts. (It is unclear from these data whether the unexpectedly large number of "more nasal" responses to NVN stimuli reflect the phenomenon of hyponasality or whether these stimuli simply sounded odd to listeners, with "odd" being encoded as a "more nasal" response.) Listeners appear to be tacitly aware that a nasalizing context alters a phonemically oral vowel. And, in most cases, they will report a nasality difference between a contextually appropriate nasal vowel and a corresponding contextually appropriate oral vowel.

5. REFERENCES

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[1] To control for duration differences (the oral vowels in C_C contexts being roughly 50 ms longer than the nasal vowels in N_N contexts), vowel length was manipulated in the isolated vowels and cross-spliced syllables, creating in addition to the normal-length versions, long versions of the nasal vowels and short versions of the oral vowels.

[2] For all test pairs, vowel durations were matched, with the selected duration corresponding to that of the vowel in an appropriate context; in the few pairs where neither pair member was in an appropriate context for English, the duration was that which would normally occur in that context (i.e., longer durations in C_C contexts and shorter durations in N_N contexts).