ACOUSTIC MEASUREMENTS OF VOCALIC NASALITY IN MANDARIN CHINESE

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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). The research reported here used acoustical analog recording and digital analysis techniques to quantify assimilation nasality patterns in Mandarin Chinese as a function of vowel height, place of articulation of the following nasal consonant, and tonal characteristics of the vowel.

2. PROCEDURES

2.1. Subjects/Speech Sample

Subjects were 8 young adult native speakers of Mandarin Chinese, with normal hearing, voice qualities and articulation patterns. They read aloud Chinese words in which the vowels /i, e, o, a, u/ were embedded in the contexts CVN and NVN, where V= one of the target vowels, C= a non-nasal obstruent and N= /m/, /n/, or /ŋ/.

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 Kay Elemetrics Nasometer 6200. The Nasometer microphone signals were recorded simultaneously on separate channels of an FM tape recorder, low-pass filtered at 4.8 kHz and digitized at 10 kHz via CSpeech (Milenkovic 1990). The vowel portion of the oral and nasal component 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 three dependent measures: 1) degree of nasal resonance, using 0.5, or 50% nasalance as an arbitrary threshold, 2) percentage (%) of the vowel with nasalance values above 0.5, and 3) absolute duration (ms) of the vowel with nasalance above 0.5.

3. RESULTS

3.1. CVN data

Fig. 1 illustrates a common nasalization pattern for CVN signals. In the first portion of the vowel, the nasalance level remains below the threshold value of 0.5; in the last portion of the vowel, opening of the velopharyngeal port in anticipation of the following nasal consonant leads to an increase in the nasalance level.

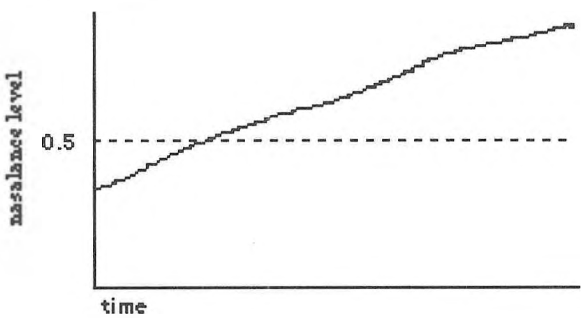

Fig. 1: Common pattern of nasalization in CVN signals.

In a number of cases, however, the nasalance level exhibits a value above the threshold of 0.5 for the entire duration of the vowel, i.e., from the very beginning of the vowel, as represented in Fig. 2.

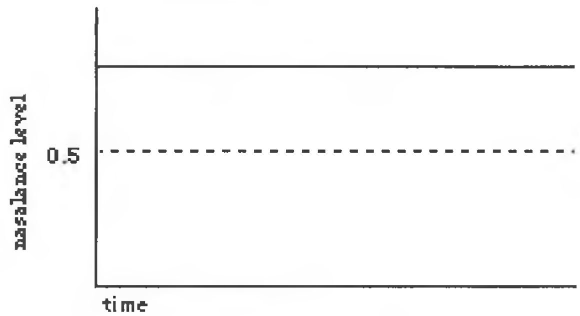

Fig. 2: Nasalization of the entire vowel.

Fig. 3 shows that the percentage of tokens with a nasalance level above 0.5 for the entire duration of the vowel is higher for the high vowels than for the mid vowels; there were no cases in which low vowels exhibited a nasalance level above 0.5 for the entire duration of the vowel. On the other hand, for 2% of the low vowels, the nasalance level remained below the 0.5 threshold for the entire duration of the vowel. Such a pattern was not observed for the high or the mid vowels.

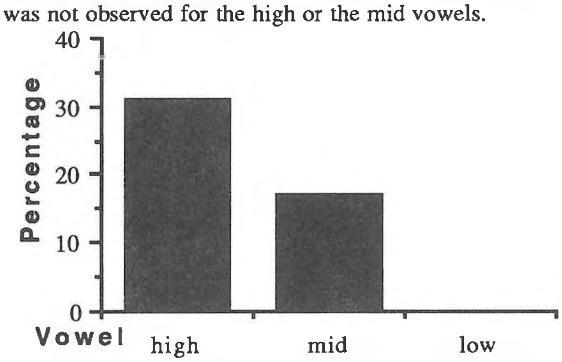

Fig. 3: Percentage of vowels nasalized for their entire duration.

Among tokens characterized by the nasalization pattern represented in Fig. 1, the high vowels exhibit more influence of the nasal consonant than the other vowels.

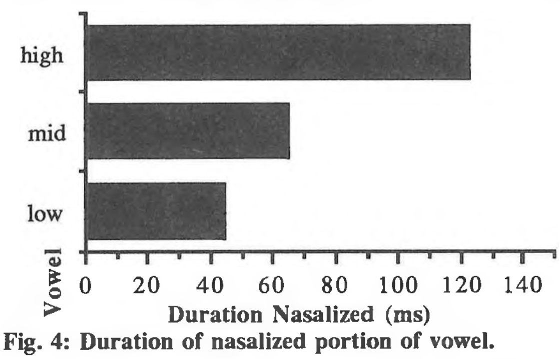

Fig. 4: Duration of nasalized portion of vowel.

This is true if we consider the absolute duration of the portion of the vowel with a nasalance level above 0.5 (Fig. 4). A one-way ANOVA showed that vowel height had a significant effect on the duration of the nasalized portion the vowel ($F(2,384)=129.172$, $p<0.0001$). A Sheffé test revealed that nasalization of the high vowels, with a mean duration of 123 ms, was significantly longer than for mid and low vowels, and that nasalization of the mid vowels (mean duration of 65 ms) was significantly longer than for the low vowels (44 ms; $p<0.01$).

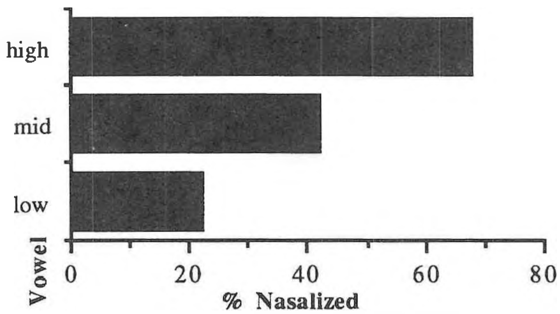

Fig. 5: Percentage of vowel nasalized (CVN).

The same is true if we consider the proportion of the vowel nasalized instead of its absolute duration (Fig.5; $F(2,384)=279.652$, $p<0.0001$). The differences among the three vowel categories--68% for the high vowels, 42% for the mid vowels, and 22% for the low vowels--are also significant (Scheffé, $p<0.01$).

On the other hand, no significant differences were observed in the duration of anticipatory nasalization in terms of the place of articulation of the following nasal consonant, or of the tonal characteristics of the vowel.

3.2. NVN data

Fig. 6 illustrates the pattern of nasalization characteristic of NVN signals. The nasalance level is above 0.5 in the initial portion of the vowel, as the result of carryover nasalization from the preceding consonant, and in the last portion of the vowel as the result of nasalization in anticipation of the following consonant. It is not uncommon, however, for the central portion of the vowel to remain at or above the 0.5 nasalance level (Fig. 2).

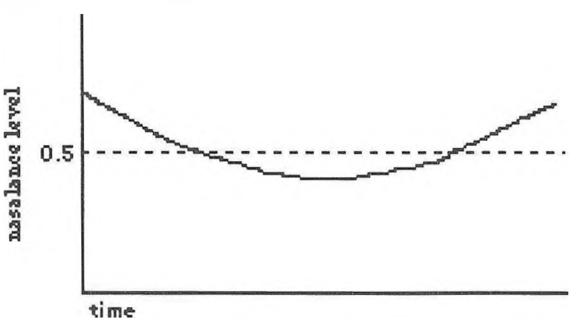

Fig. 6: Common pattern of nasalization in NVN signals.

In the case of high vowels, 98% of the tokens followed the pattern of nasalization represented in Fig. 2 (with a mean nasalance of 0.77), and 2% followed the pattern of nasalization represented in Fig.6. For the mid vowels, 13% exhibited a nasalance level above the 0.5 threshold (mean nasalance of 0.64), 77% followed the pattern of nasalisation represented in Fig. 6, and 10% were characterized by a level of nasalance below the 0.5 threshold (mean nasalance of 0.32). As for the low vowels, a mere 1% exhibited a nasalance level above the 0.5 threshold (mean nasalance of 0.58), 92% followed the pattern of nasalisation represented in Fig. 6, and 7% were characterized by a level of nasalance below the 0.5 threshhold (mean nasalance of 0.34).

As in the case of the CVN signals, these results suggest that the level of vocalic nasalance is positively correlated with the height of the vowel. On the other hand, no relationship was observed between degree of nasalance and consonantal place of articulation or tonal characteristics of the vowel.

4. SUMMARY/DISCUSSION

The results of this study indicate that, in Mandarin Chinese, the degree of vowel nasalization in a nasal consonant context varies with the height of the vowel: High vowels exhibit more assimilation nasality than mid and low vowels. These results are in keeping with those of Rochet and Rochet (1991) for Canadian English and Standard French. The apparent contradiction between these findings and those of Clumeck (1976) may be related to his use of the term "nasalized" to describe articulatory gestures of the velum, and to the fact that the biomechanical behavior of the velopharynx cannot be assumed to be monotonically related either to the perception of nasal resonance or to the acoustical consequences of nasal coupling during speech production. The acoustic attributes of nasal resonance are ultimately a function of the relative acoustic impedances of the oral and nasal cavities, as well as of the formant frequency values of the vowel in question. Curtis (1968) has shown that the spectral envelopes of /i/ and /u/ are more markedly affected by small degrees of nasal coupling than vowels with a more open tract configuration. This is consistent 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 (House and Stevens 1956).

5. CONCLUSIONS

5.1. The higher levels and longer durations of assimilation nasality observed for the high vowels in Mandarin Chinese--as well as in both French and English--appear to be related to the acoustic impedance of the vocal tract for the production of these vowels. There is no obvious articulatory or physiological reason for the earlier lowering of the velum observed by Clumeck (1976) for low vowels in the CVN context. It may simply be that such lowering can take place because it does not have an undesirable acoustic effect, and does not lead to excessive detectable nasalization of these vowels. Later lowering of the velum for high vowels, however, may ensure that their spectral envelopes are not too markedly affected by extraneous nasal resonance.

5.2. In order to help understand and reconcile the apparent discrepancies among studies of assimilation nasality based on various methods of observation, further research is recommended by means of simultaneous multidimensional sampling methods that could consider biomechanical, perceptual and acoustical parameters of vowel production in a large number of languages.

6. REFERENCES

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