ACOUSTICAL ANALYSIS OF NASAL RESONANCE PATTERNS IN SPEECH

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1. Background and Introduction

Under normal speaking circumstances, a nasal quality is associated with the production of nasal consonants in spoken English, and with a nasal consonant or vowel in spoken French. In addition, the influence of a nasal consonant tends to "spill over" to vowels that precede or succeed it, a phenomenon known as anticipatory or carry-over assimilation nasality, respectively. A certain amount of assimilation nasality is normal in languages where nasal consonants are a part of the speech sound repertoire. There are limits to what is perceived as normal, however, within and across languages. English and French, for example, differ with respect to phonemic and assimilation nasalization characteristics; therefore, inappropriate nasalization can distort the intelligibility of French spoken by anglophones, and vice versa. Within a language, less than the expected amount of nasality or assimilated nasality during speech is referred to as "hyponasal" resonance, and more than the expected amount as "hypernasal" resonance. Disorders of resonance, particularly hypernasality, degrade speech intelligibility in any language.

Historically, the acoustical characteristics of normal or deviant nasal resonance have been difficult to document or quantify instrumentally. Speech scientists, linguists, teachers of French or English, and speech-language pathologists have had to rely primarily on listeners' identification (i.e., auditory perceptions) of normal, hypo- or hypernasal resonance in the study of nasality patterns across languages and in speakers whose resonance is distorted. Although this subjective method does have social validity, it is not always reliable across repeated measures and not easy to incorporate systematically into speech research or second-language teaching protocols. Therefore, interested investigators continue to seek instrumental methods to document and quantify normal and deviant nasal resonance patterns reliably in connected speech, to complement the subjective, qualitative assessment of resonance balance within and across spoken languages.

This paper describes a dual-channel, analog/digital analysis system that we have applied to the study of oral/nasal resonance patterns in Canadian English and European French, for normative data against which to compare speakers of either language who have deviant nasal resonance, and as a basis from which to teach persons learning to speak English or French as a second language.

2. Instrumental Array

The oral and nasal acoustical components associated with subjects' productions of test utterances are transduced by means of two uni-directional microphones positioned in front of the mouth and nose and separated by a metal plate (Kay Elemetrics Nasometer 6200) and recorded on separate channels of an FM tape recorder (Hewlett-Packard 3964A). The oral and nasal signals for a given token on the FM recorder are low-pass filtered (@ 4800 Hz via matched Frequency Devices 901 filters) and digitized at 10 kHz via CSpeech waveform analysis software (Milenkovic, 1990) supported by an IBM-AT. The vowel portions of the oral and nasal components of each digitized signal are isolated and stored as CSpeech files. These files are converted to rms values by means of software customized for operation in MS-DOS, and the degree of nasalance is established by comparing rms amplitudes of corresponding oral and nasal data across the duration of a vowel in 5 ms steps, according to the formula:

$$\% \text{ nasalance} = [(\text{nasal rms}/\text{nasal} + \text{oral rms}) \times 100].$$

Figure 1 schematizes the oral/nasal data acquisition, analog-to-digital conversion and comparative analysis sequence.

3. Representative Data

Thirty normal adults, 15 speakers of Canadian English and 15 of Standard French have been recorded using this system (Rochet & Rochet, 1991). The data base consists of English vowels /i, I, E, a, u/ and French vowels /i, E, a, u, y/ embedded in the contexts CVC, NVC, CVN and NVN, where V= one of the target vowels, C= a non-nasal obstruent, and N= /n/ or /m/. Each word is produced as the terminal item in a carrier phrase, e.g., "A half keen," or "Neuf quines," and ten repetitions of every token are obtained from each subject. Figure 2 illustrates raw data for the non-nasal (CVC) utterance, "A half keet," produced by a female speaker and digitized in CSpeech. Figure 3 illustrates an edited version of that utterance in which just the syllable "keet" has been isolated; further editing isolates the vowel nucleus for rms conversion and temporal analysis. Figure 4 shows the syllable "neet," a carry-over (NVC) nasality context. Figure 5, "keen," illustrates an anticipatory (CVN) nasality context, and in Figure 6, "neen," the vowel is surrounded by nasal consonants in the NVN context. Figures 7 and 8 are examples of the final product of data analysis in which assimilation nasality patterns for the English and French speakers are compared graphically with respect to the proportions of vowels common to both languages that are nasalized (i.e., nasalance >0.5) following the nasal consonant in the NVC context (Figure 7), and in anticipation of the nasal consonant in the CVN context (Figure 8).

Such data not only illustrate the differences in assimilation nasality patterns within each language as a function of vowel height but also allow assimilation nasality patterns between languages to be compared for differences that are salient to second language teaching, perception and production.

4. References

Milenkovic, P. (1990). Department of Electrical and Computer Engineering, University of Wisconsin, Madison, WI 53705 U.S.A.

Rochet, A.P. and Rochet, B.L. (1991). The effect of vowel height on patterns of assimilation nasality in French and English: Quantification and interpretation. Proceedings of the XIIth International Congress of Phonetic Sciences, Aix-en-Provence, France.

Figure 1

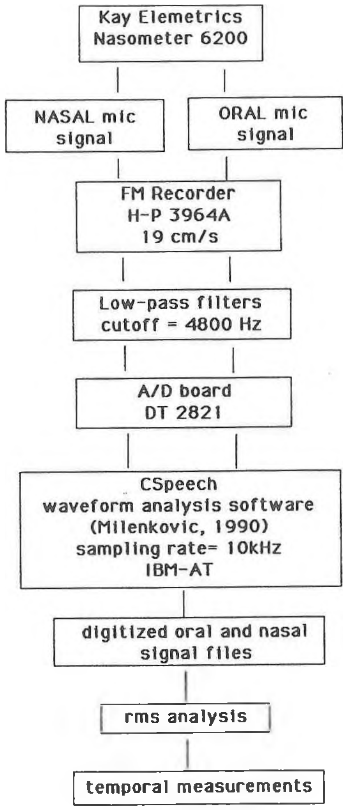


Figure 2

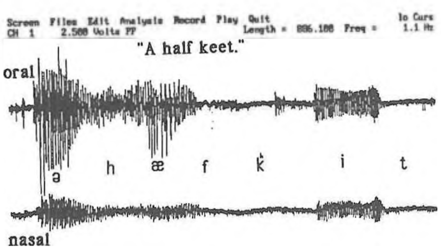


Figure 3

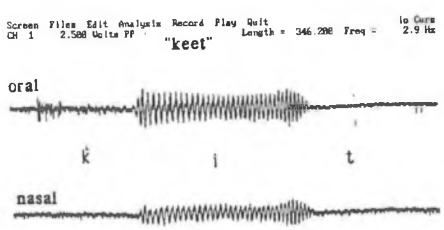
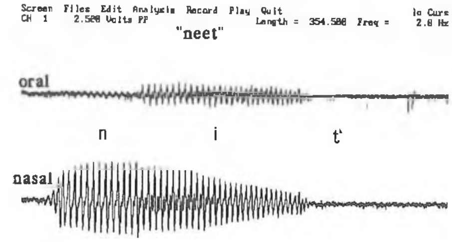


Figure 4



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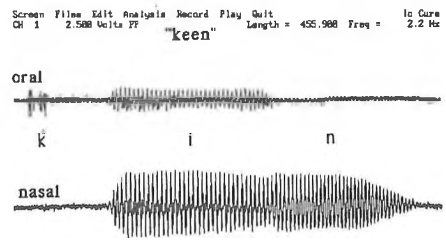

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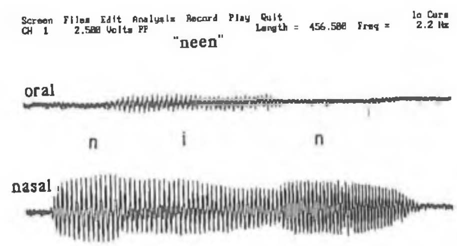

Figure 7

/NVC/ FRENCH & ENGLISH
PERCENTAGE OF VOWEL NASALIZED

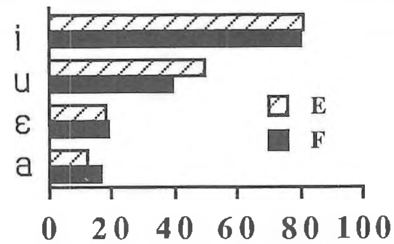

Figure 8

/CVN/ FRENCH & ENGLISH
PERCENTAGE OF VOWEL NASALIZED