TRACING NASALITY WITH THE HELP OF THE SPECTRUM OF A NASAL SIGNAL

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ABSTRACT - This paper presents peliminary findings in the detection of nasalisation making use of the formant pattern in the spectrum of a nasal signal obtained with a contact microphone attached to the nose.

INTRODUCTION

When measuring nasality or velar lowering in speech for the purpose of descriptions of coarticulation or the analysis of pathologic speech, several methods have been used in the past, varying from measuring nasal airflow to descriptions of spectral events in the spectrogram of a speech signal (cf. amongst others Fujimura, 1962). Later on, the use of a contact microphone attached to the outer part of the nose was introduced (Stevens et al., 1975). Using such an accelerator microphone, the increase of vibration of the skin of the outer part of the nose, due to nasal airflow, can be measured. There might, however, be some interference from the oral signal, which makes it difficult to determine whether certain activity is related to nasal or oral airflow. So far, the usual way has been to analyse the nasal signal with the help of the intensity curve. Having the oral signal and the nasal signal and their intensity curves aligned, the diverging directions of the intensity curves at certain points indicate that the nasal signal is not influenced by the interference of the oral signal.

In the present paper another method will be presented, which makes use of the spectral information in the signal obtained with a contact microphone. This method aims to provide phoneticians and speech pathologists with a reasonably priced tool to measure onset and offset of nasality, related in its procedure to visual and manual spectrogram analysis of the usual oral speech signal. The method is tested with recordings of French speech, containing CV, CṼ and CVN sequences.

METHOD

Using a contact microphone and a two channel DAT-recorder the oral and the nasal signal of French speech, spoken by a male native speaker were recorded. The recorded speech contained sequentially read French words with CV, CṼ and CVN sequences. Some of the words were e.g. *beau, bon, bonne* , etc.

For the recording, the microphone was attached to one side of the upper part of the nose in front of the nasal bone, where the lateral nasal cartilage can be found (Figure 1). This position was observed to be the most suitable one to obtain a good nasal signal (Lippmann, 1981). The contact microphone is a lightweight accelerometer named *Hot Spot*

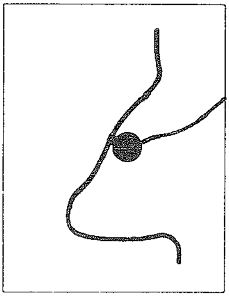

Figure 1. Placement of the contact microphone.

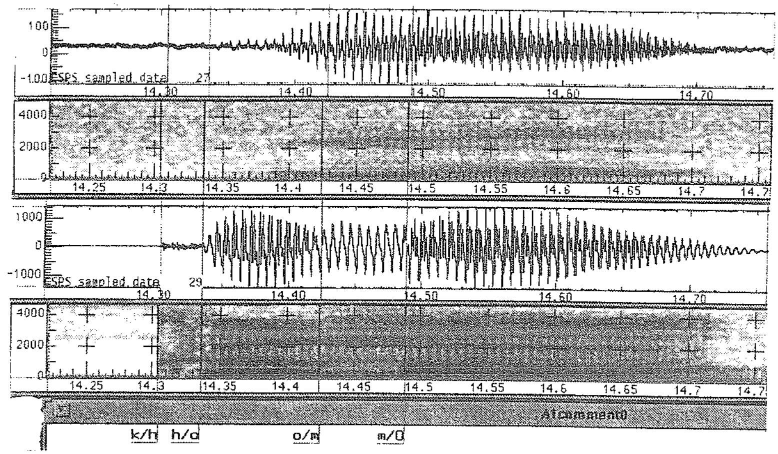

Figure 2. Oral and nasal channel representation of the waveforms and the spectrograms and the phonetic labels of the French word *comment*, in IPA-transcription [kɔmã].

made by *K & K Sound Systems*. It consists of a small metallic disc, which has a diameter of 12mm and is 0.7mm thick. It is attached to either the nose or - as originally intended - to acoustic musical instruments with an adhesive strip. The frequency response goes from 20-15000Hz. Unfortunately, the producer of the microphone did not provide us with more detailed information about the frequency response of the microphone. Lippmann (1981), however, points out that "any other accelerometer sensitive to vibrations in the frequency region 100-1500Hz could be used to detect nasalization". However, this microphone is also sensitive above the frequency region of 1500Hz. No preamplifying is needed with this microphone. Such a microphone costs about US$35.

Applying the ESPS/Waves+ environment, the signals of both channels were displayed aligned and their spectra were analysed. Labelling of the phonetic segments was done manually. In addition, the values of four formants in frames of the length of 5ms and their bandwidths were calculated for both channels of each recorded word. The formant values of the oral signal and the nasal signal were compared.

OBSERVATIONS

In Figure 2, the French word *comment* is presented in five windows. The upper window refers to the waveform of the nasal channel, recorded with the accelerator microphone. The window below shows the spectrogram of the nasal waveform. The third window from the top presents the usual oral waveform, recorded with a standard microphone. Below the oral waveform, the usual oral spectrogram can be found and in the window farthest down, the labels are marked[1].

As inthe spectrogram of the oral channel, formant structure could be observed in the spectrogram of the nasal channel in the case of the production of nasal consonants, as during the production for the nasal [m]. The same is true for the nasal vowels, as can be seen for the vowel [ã]. Furthermore, the nasality onset in a vowel preceding a nasal consonant could be seen, as is observable during the production of [ɔ].

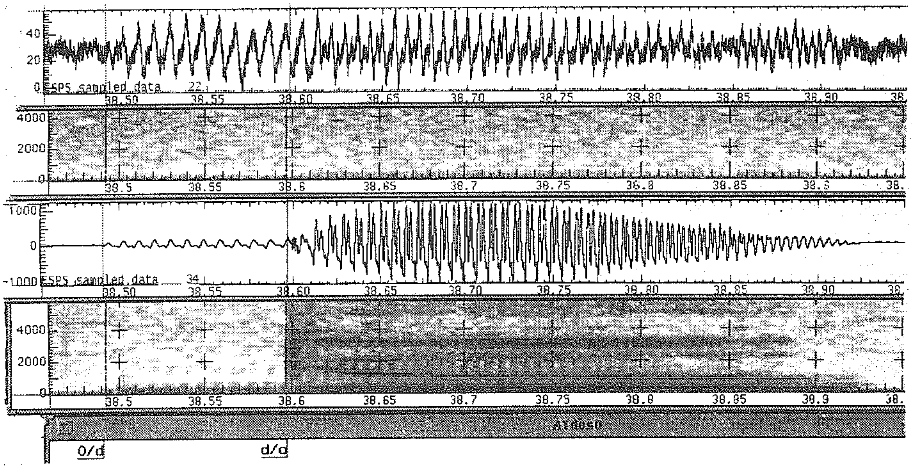

Figure 3. Oral and nasal channel representation of the waveforms and the spectrograms and the phonetic labels of the French word *dos.* , in IPA-transcription [do].

On the other hand, in the spectrogram of the nasal channel in a non-nasal environment (Figure 3), no such formant structure was observed.

In addition to Lippmann (1981), who claims that high energy around 2500 in the nasal channel is due to the "2nd or 3rd formant of certain high vowels" (p.315),one has to point out, that this is also observable in the nasal spectra of rather lower vowels (e.g. [ɔ̃] in Figure 2).

The advantage of using the spectral information of the nasal signal instead of only the waveform of the nasal signal itself, may be supported by the fact, that e.g. in Figure 3 periodicity in the waveform can be observed, which turned out to have the same frequency - with some slight deviation - as the fundamental frequency of the oral signal. Such periodicity might lead to the assumption, that there is nasal airflow present. However, this interference between the nasal and the oral signal might have been due to energy received by the microphone through external transmission and not by nasal airflow.

NATURE OF THE FORMANTS OF THE NASAL SIGNAL

When comparing the values of the formants of both channels for the nasal vowels, one realises that for all four formants the values are very similar (Figure 4). Although there seems to be some deviation for the bandwidth values, their is no unidirectional tendency for either channel in comparison to the other channel (Figure 5). For the second formant, one can even observe a lower bandwidth for the nasal channel than for the oral channel, which denotes a sharper spectral peak in the nasal signal, which correlates with higher energy.

The calculated values for the formants of the non-nasal vowels give a very different perspective (Figure 6). Apart from the values for F1, the formant values for the nasal signal are exceedingly higher than the formant values for the oral signal. The bandwidth shows quite some discrepancy between the channels for each formant (Figure 7). Here, the bandwidth values for all formants of the oral channel are much lower than for the formants of the nasal channel, which points to the fact that spectral peaks in an oral signal in a phonetically non-nasal environment are much sharper and have therefore much higher energy. The latter fact is, of course, not very surprising and is also obvious from the spectrogram of the nasal signal.

When looking at the formants in the nasal signal for the consonant [m], extracted from the word *mot*, one can see that their values are close to the formant values of the nasal channel for the nasal vowel in *bon* (Figure 8). But this might very well be the case because of the anticipatory coarticulation of the quality of the following vowel [o], which has the most similar quality to the oral vowel [ɔ] and therefore to the nasal vowel [ɔ̃].

In the case of a nasalised vowel, the nature of the formants extracted from the nasal signal seem to reflect the formants of the oral channel. This is not quite the same for the nasal consonant [m], where except for F1, the formant values for the nasal channel are higher than the respective oral formants.

CONCLUDING REMARKS

A method of measuring nasality was suggested above, by making use of the spectrogram of a signal obtained with a contact microphone attached to the nose. Clear formant structure is visible here in the case of the production of nasals, nasal vowels and at a certain period of time during the production of phonologically non-nasal vowels in the vicinity of nasals. In analogy to the traditional way of spectral analysis this low cost tool is a very handy instrument for phoneticians and speech pathologists, who have only limited lab facilities, but have access to spectral analysis tools.

The observed formant structure in nasalised or nasal vowels reflects the formant structure of the oral formants.

The findings presented above agree with Lippmann (1981), who points out, that most of the energy in the nasal signal is found below 2000Hz (F1 in Figure 5 and 7). However, visible formant structure in the spectrogram above 2000Hz (Figure 2) is a helpful indicator when tracing nasality. A spectral display up to 4000Hz is therefore suggested for the tracing of nasality.

NOTES

[1]The Epsps/Waves+ tool used for this analysis does not yet have any IPA-font available. In Figure 1, the Ipa-representation for the vowels would be as follows: lol reads as [ɔ], and lOl reads as [ã].

REFERENCES

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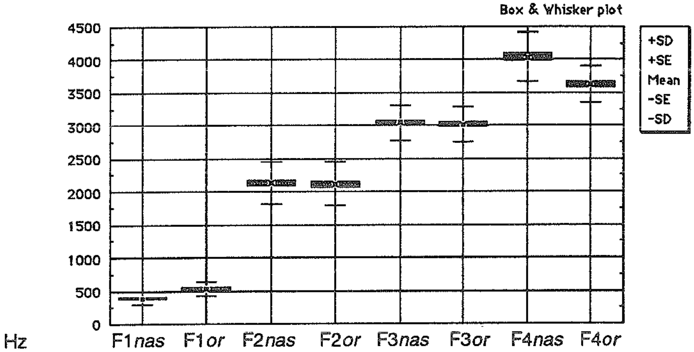

Figure 4. Boxplots of the four formants of the nasal (*nas*) and oral channel (*or*) for the vowel [ɔ̃] in the French word *bon* ([bɔ̃]).

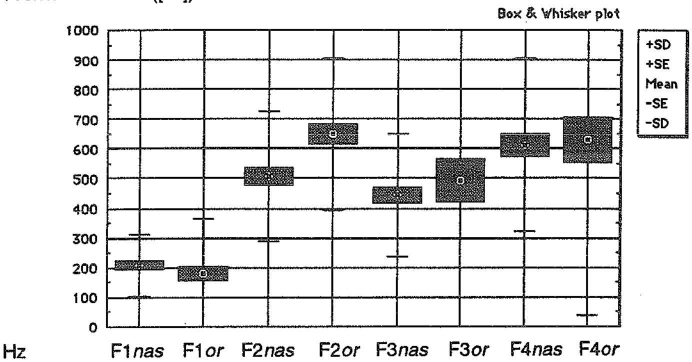

Figure 5. Boxplots of the bandwiths of the four formants of the nasal (*nas*) and oral channel (*or*) for the vowel [ɔ̃]in the French word *bon* ([bɔ̃]).

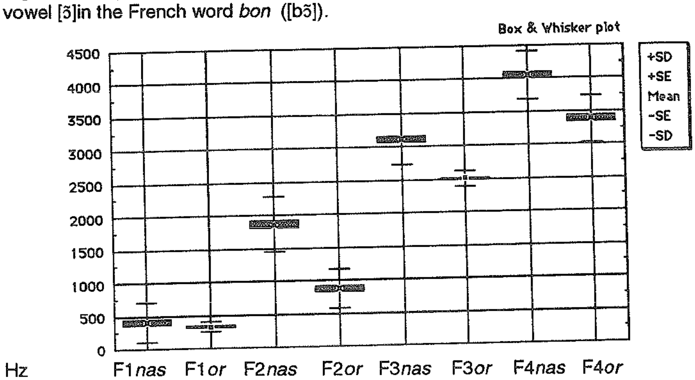

Figure 6. Boxplots of the four formants of the nasal (*nas*) and oral channel (*or*) for the vowel [o] in the French word *beau* ([bo]).

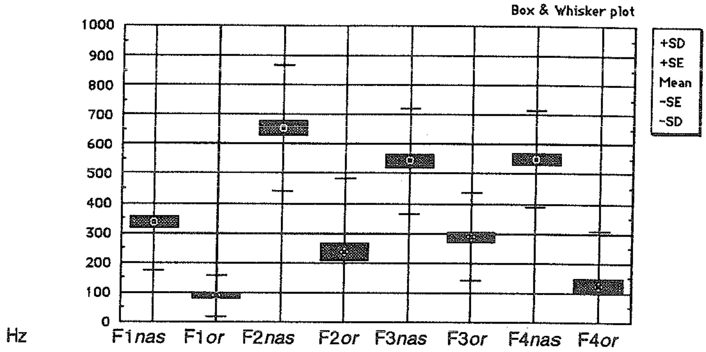

Figure 7. Boxplots of the bandwiths of the four formants of the nasal (*nas*) and oral channel (*or*) for the vowel [o] in the French word *beau* ([bo]).

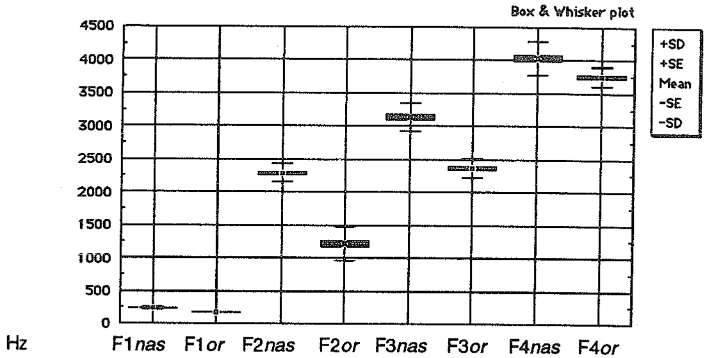

Figure 8. Boxplots of the four formants of the nasal (*nas*) and oral channel (*or*) for the consonant [m] in the French word *mot* ([mo]).