SOME ACOUSTIC OBSERVATIONS ON HALF NASALS IN SINHALESE

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ABSTRACT

Sinhalese is one of the Indic languages and is spoken in Sri Lanka. The present study is intended to explore the phonetic characteristics of half nasals in Sinhalese. From the examinations of the acoustic analysis making use of a minicomputer and a linear prediction algorithm, some phonetic properties can be clarified as follows. It appears that a half nasal consists of a nasal murmur portion, a voiced oral murmur portion, a burst and a transition portion to the following vowel. From the spectrum analysis, it can be examined that frequencies of the first formant (F1) of the nasal murmur portion are slightly higher than those of the oral murmur portion. It has been able to distinguish places of articulation by making use of spectrum features of the nasal murmur portion.

INTRODUCTION

Sinhalese is a national language of Sri Lanka, and is spoken by about 11 million people, or 75 percent of the population, living mainly in the southern and western two-thirds of the Island of Ceylon [1]. It is said that Sinhalese is an Indo-European language descended from Sanskrit, and this language was brought to the island by settlers from northern India in the 5th century B.C.[1]. There have been pointed out several problems connected with Sinhalese which arouse the interest of the linguists, e.g. Sinhalese is notable among the major Indo-Aryan languages of the past and present in having no aspirate stop phonemes nor clusters [2], literary Sinhalese is very different from spoken Sinhalese [3], etc. One of them is the phenomenon of "half nasals". In the intervocalic positions, there occur medial clusters composed of nasal plus voiced stop. There are two types of the first nasal element. One is often referred to as the single nasal and the other is referred to as the doubled nasal. The two types present a contrast, e.g., /kandə/ 'trunk' : /kanndə/ 'mountain'. In regard to voiceless stops, there are no such oppositions in the same position, only the normal type of cluster with doubled nasal occurs. In such cases, however, the doubled nasal is written with a single letter according to the convention. The length of the nasal in a cluster of single nasal plus voiced stop varies from normal to very short [2]. It has been customary in Sinhalese studies to treat the single nasal in these clusters as a special class of sounds to which was given the name "half nasal" and this is in accord with the traditional Sinhalese orthography, which uses special signs for the "half nasals" and the regular nasal letters for the "full (doubled) nasals" in the same position. From a synchronic point of view, there can be two different phonological interpretations. Some linguists regard them as independent phonemes. For example, Jones [4] treats them as separate independent phonemes. On the other hand, others regard them as consonant clusters. For example, Coates and De Silva [2] criticize Jones' view as it is an unnecessary complication of the phonemic system, increasing the number of consonant phoneme by nearly 20 percent, and treat them as consonant clusters with a single nasal, contrasting with a doubled nasal in similar clusters. However, the literature on the phonetic detail of half nasals is quite limited in quantity and quality. The present study is intended to explore the phonetic characteristics of half nasals through acoustic investigation. One of our main concerns is to confirm if the articulator is already ready for the place of articulation during the first nasal element.

ACOUSTIC ANALYSIS

Material

Lists of words were prepared, which contained four types of half nasals [mb, n̪d̪, ṇḍ, ŋg] in the intervocalic position. Each half nasal was preceded and followed by 5 vowels / i, e, a, o, u / leading to five different V_1CV_2 combination, where V_1 is the same vowel as V_2. The list includes meaningless words. Each word was written in Sinhala scripts.

Subjects

One subject (M,30) who was born in Kurunegala and brought up in Kegalla, the northeast of Colombo which is the capital of Sri Lanka, served as informant for this investigation. The subject came to Japan as foreign research student on Japanese government scholarships and were at Osaka University of Foreign Studies for six months for Japanese language training. Recording was made five months after he had arrived in Japan.

Procedure

Four lists were prepared, each containing a subset of the words including half nasals at the intervocalic position, and some of them were nonsense words. Each word was appeared four times in the recording. Therefore, 80 tokens in all (4 types of half nasals x 5 different combinations x 4 times) were analyzed. The lists were read by the informant in the soundproof room of the phonetic studio of Osaka University of Foreign Studies, Osaka, Japan. The material was taped on a TEAC A-6700 tape recorder, using a highly sensitive microphone. The distance to the microphone was set at about 30 cm. The informant was instructed to read the material at a natural tempo with a pause after every word, and with the same loudness.

Acoustic Analysis

Acoustic analyses were made at Doshita Laboratory, Department of Information Science of Kyoto University. Speech waveforms were digitized from the output of the tape recorder. A JEIC 3118 low-pass filter with 70 dB/oct for anti-aliasing (the cut-off frequency was set to 8.9 kHz) and a DATEL DAS-250 16-channel 12-bit A/D converter of 4-microsecond sampling period were used for digitization. Through the A/D converter which was connected to a FACOM U-200 minicomputer at the common bus with direct access mode, speech data samples at every 54 microsecond (18.5 kHz sampling) were stored into a cartridge-disc of 2-megabyte in real-time for about 1 minute continuously. Individual utterances were input from a digital magnetic tape to a minicomputer and the waveforms were drawn on an X-Y plotter. It was found out that each half nasal includes two types of murmur portions from the expanded waveform. From the 3500 samples of data (190 msec), waveforms including both murmur portions were sampled manually using a cursor. Each murmur portion was excised with 27 msec Hamming windows for fast Fourier transform (FFT), and linear prediction analysis was applied to obtain a smoothed spectrum. The optimal prediction order was estimated in a preliminary experiment to be 26. These spectra were analyzed and displayed on the plotter. Formants corresponding to spectral peaks were computed from the solution of higher order polynomial equation by the Muller method. We adopted the lowest three prominent peaks of murmur spectra as the first formant (F1), the second formant (F2) and the third formant (F3).

RESULTS AND DISCUSSION

From the waveforms, it was observed that a half nasal is sub-segmented into four portions; a portion of periodic repeated waveforms adjacent to the preceding vowel, a portion of quasi periodic waveforms following to the former portion, a small protrusion upon a running smooth waveforms and fluctuated waveforms after the protrusion. It is assumed that the small protrusion is a burst of the plosive. The fluctuation portion after the protrusion is assumed to be a transition portion to the next vowel. From the precise observation on earlier two portions, it was found out that the former portion has rather steady repeated waveforms in comparison with the latter portion. This implies the presence of continuous tone in this portion, and this is one of the characteristics of the nasal murmur portion. The duration of this portion is 36 ~ 141 msec. On the other hand, the intensity of the latter portion is less than that of the former portion. The latter portion has quasi repeating waveforms, though it shows the continuation of periodicity, that is to say, each waveform is quite similar but differs each other in some ways, especially in the energy. The quasi periodic waveforms of this portion show gradual decreasing energy with the aim of the burst for a plosion. This indicates that this portion is the portion of vibration of the vocal folds of voiced plosives, which precedes the release burst of the voiced plosives. The duration of this portion is 13 ~ 43 msec. In addition to these observations, fast Fourier transform (FFT) and linear prediction analysis were applied in order to obtain spectrum structures. It was noticed that the latter portion has only very low-frequency energy. The energy

Table 1. Analysis frequency values (in Hz) and standard deviations of the first formant for the former portion and for the latter portion (means and standard deviations).

	Former Portion Mean (S.D.)		Latter Portion Mean (S.D.)	
F1	290	(37)	215	(21)

Table 2. Analysis frequency values (in Hz) for the nasal murmur portion of half nasals for each place of articulation (means and standard deviations).

	Bilabial Mean	(S.D.)	Dental Mean	(S.D.)	Velar Mean	(S.D.)
F1	256	(29)	294	(43)	339	(35)
F2	1009	(139)	1338	(169)	1051	(92)
F3	2607	(225)	2787	(129)	2700	(104)
B1	112	(42)	151	(51)	175	(39)

falls off rapidly after the first formant and is very weak in the middle- and high-frequency range. The mean values and standard deviations (SDs) of the first formant of both portions are presented in Table 1. The mean F1 value of the latter portion is 215 Hz and that of the former portion is 290 Hz. The latter portion has lower F1 than the former portion. This is statistically significant ($p < 0.01$). This indicates that the latter portion has only very low frequency energy. This corresponds with the fact that the low frequency value of F1 in comparison with the adjacent segment is one of the characteristics of voiced plosives. On the other hand, it was remarked that the former portion has several resonances below 3500 Hz and anti-formant. It was assumed that the former portion is the nasal murmur portion. Therefore, a half nasal is sub-segmented into a nasal murmur portion, anoral murmur portion, a burst and a transition portion to the next vowel. These observations indicate that a half nasal is a kind of prenasalized voiced plosive.

In the next analysis, we examined if the nasal murmur portion of a half nasal has a cue for places of articulation. The mean values and standard deviations of formants and band-widths of the nasal murmur portion for each place of articulation (bilabial, dental and velar) are presented in Table 2. The properties of murmur of ordinary nasals are reported as follows (> = higher frequency than).

F1 frequency values: [ŋ] > [n] > [m]

F1 bandwidth values: [ŋ] > [n], [m]

It is assumed that the differences in F1 values are presumably related to differences in the size of the coupling section at the velo-pharyngeal passage and of the pharyngo-nasal tract [5],[6]. Although these are characteristics of ordinary nasals, it has been also reported that the murmur portion of voiceless nasals in Burmese shows the same tendency [7]. The mean values of F1 of bilabial half nasals, dental half nasals and velar half nasals are 256 Hz, 294 Hz and 339 Hz, respectively. In this analysis, retroflex half nasals are excluded, as they are considered to make the matter complicated. It can be said that there is a tendency for F1 of bilabial half nasals to be slightly lower than those of dental and velar half nasals. [m] < [n̪], [n̪] < [ŋ] are statistically significant ($p < 0.01$).

The mean value of F2 of dental half nasals is 1338 Hz. Those of bilabial half nasals, velar half nasals are 1010 Hz and 1054 Hz. There is a tendency for F2 of dental nasals to be slightly higher than those of bilabial and velar half nasals. Both [n̪] > [m] and [n̪] > [ŋ] are statistically significant ($p < 0.01$). In the framework of Jakobson, Fant and Halle [8], distinctive features were also defined by acoustic aspects. Dental nasals have an "acute" feature and, when the second formant "is closer to the third and higher formants, it is acute." Velar nasals have a "compact" feature and when the first formant "is higher (i.e. closer to the third and higher formants), the phoneme is more compact". Therefore, we tried to distinguish dental half nasals by means of the higher frequencies of the second formant, and separate velar half nasals from bilabial half nasals by means of the higher frequencies of the first formant.

Table 3 represents classification matrix of the group classification and the percent of correct classifications of discrimination analysis. The left column represents source, and the uppermost row represents judged groups after analysis. The percent of correct classifications in total are 73 %. This shows tolerably high performance. In order to obtain better resolution, all of the first, the second, the third formants and bandwidth of the first formant were used as variables for the step-wise discrimination analysis. Results are presented in Table 4. The percent of correct classifications in total are 93 %. It can be said that each

Table 3. Classification matrix (Variables: F1,F2,F3,B1)

	[mb]	[n̪d̪]	[ŋg]	
[mb]	19	0	1	95 %
[n̪d̪]	0	19	1	95 %
[ŋg]	1	1	18	90 %
TOTAL	20	20	20	93 %

group of the place of articulation is effectively discriminated. These results indicate that the nasal murmur portion of the half nasal includes necessary information to distinguish place of articulation. This confirms the view that the articulator is already ready for the place of articulation during the murmur portion of the first nasal element.

SUMMARY AND CONCLUSIONS

So far as our informant is concerned, the properties of half nasals in Sinhalese have been clarified as follows. A half nasal is sub-segmented into a nasal murmur portion, a voiced oral murmur portion, a burst and a transition portion to the next vowel. The plosive element keeps voicing before release of the consonantal constriction. These results indicate that a half nasal is a kind of prenasalized voiced plosives. Bilabial half nasals, dental nasals and velar half nasals could be distinguished by means of a step-wise discriminant analysis utilizing the value of F1, F2, F3 and B1 of the nasal murmur portion, and this confirms the view that articulator is ready for the place of articulation during the first nasal element.

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REFERENCES

[1] K. Katzner,<<The Languages of the World>>, Routledge & Kegan Paul, revised edition 1986.

[2] W. A. Coates, M. W. S. De Silva, "The Segmental Phonemes of Sinhalese", University of Ceylon Review 18, 163-175. 1960.

[3] M. W. S. De Silva, "Sinhalese", in T. A. Sebeok (ed.)<<Current Trends in Linguistics>>,Mouton, 1969.

[4] D. Jones,<<The Phoneme: Its Nature and Use>>, W. Heffer & Sons, 1950.

[5] O. Fujimura, "Analysis of Nasal Consonants", <<J. Acoust. Soc. Am>> 34, 1865-1875, 1962.

[6] D. Recasens, "Place Cues for Nasal Consonants with Special Reference to Catalan", <<J. Acoust. Soc. Am.>> 73, 1346-1353, 1983.

[7] M. Dantsuji, "An Acoustic Study on the Distinction of Place of Articulation for Voiceless Nasals in Burmese", <<Folia Linguistica>> 21(forthcoming).

[8] R. Jakobson, G. Fant, M. Halle, "Preliminaries to Speech Analysis", <<Technical Report>>13, Acoustic Laboratory MIT, 1952.