INTERSPEECH 2021
30 August – 3 September, 2021, Brno, Czechia

Characterizing Voiced and Voiceless Nasals in Mizo

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Abstract

Mizo has voicing contrasts in nasals. This study investigates the acoustic properties of Mizo voiced and voiceless nasals using nasometric measurements. The dual channel data obtained for Mizo nasals is separated into oral and nasal channels and nasalance is calculated at every 10% of the duration of the nasals. Apart from that, the amount of voicing and duration of the nasals are also measured. The results show that nasalance is affected by the place of articulation of the nasals. Additionally, the voiceless nasals are found to be significantly longer than the voiced nasals.

Index Terms: Mizo, voiceless nasals, Nasometer, nasalance

1. Introduction

This study analyzes the nasals of the Mizo language (ISO 639-3 code: lus), that contrasts in voicing. Mizo is part of the Tibeto-Burman language family under the Kuki-Chin subgroup, primarily spoken in the province of Mizoram in the northeast of India by a population of 830, 846 speakers [1, 2]. The voicing contrasts in Mizo nasals are found in three places of articulation (POA), namely, bilabial (/m, m̥/), alveolar (/n, n̥/) and velar (/ŋ, ŋ̊/) [3, 4, 5]. The voiceless nasals in Mizo are also reported as voiced aspirated nasals [6, 7].

Voicing contrast in nasals is a comparatively rare phenomenon in the world's languages [8]. Apart from that, recording and analysis of acoustic signals associated with nasals contrasting in voicing is a complex and time and cost intensive process. The studies reported in the literature on voiceless nasals have used nasometric measurements, aerodynamic measurements, and electroglottographic measurements, with small number of participants due to limited access to the speakers of languages that have voicing contrasts [9, 10, 11, 12, 13]. Hence, the current study contributes to the small body of acoustic data on languages with voicing contrasts in nasals.

Burmese is one of the most studied languages as far as acoustics of voiceless nasals are concerned. In one of the earliest acoustic analysis of the voiceless nasals in Burmese, it was showed that there are two portions in the Burmese voiceless nasals. The first portion is noisy, which is the nasal friction regarded as the voiceless part since no striations are observed. The latter portion is the voiced part characterized by clear striations [9].

In a more comprehensive study of voiceless nasals in Burmese, Mizo and Angami, it was ascertained that languages with voiceless nasals are of two different types [11]. The study claimed that the two types are voiceless unaspirated nasals and voiceless aspirated nasals. While the voiceless nasals of Mizo and Burmese belong to the first type; the voiceless nasals of Angami, another Tibeto-Burman language spoken in the northeast of India, belong to the second type [11].

The existence of the two types of voiceless nasals is corroborated by a recent study, which considered them as preaspirated nasals, such as, Mizo and Burmese and voiceless aspirated nasals such as Angami, Kham Tibetan and Xumi [13]. The same study also reports that the second type of voiceless nasals are more common. The preaspirated nasals begins with a voiceless period characterized by nasal and oral airflow that terminates with a voiced nasal portion characterized by only nasal airflow. The aspirated voiceless nasals have continuous nasal airflow which even continues onto the following vowels. Towards the end, these nasals are partially voiced and are characterized by simultaneous nasal and oral airflow [13].

In terms of duration, the voiceless nasals are systematically longer than the voiced nasals in Burmese, Dzongkha, Xumi and Angami [9, 12, 14]. No such systematic durational differences are reported for Kham Tibetan [13]. It is reported that the voiceless portion has longer duration than the voiced portion in the voiceless nasals of Burmese and Dzongkha [11, 12]. The duration of the voiced portion occupies 18% and 22.5% of the total duration of the voiceless nasals in Dzongkha and Burmese respectively. In terms of voicing, 16% and 33% of voicing is noticed in the voiceless nasals of Xumi and Burmese, respectively [13]. In case of voiceless Angami nasals produced in isolation, 36% of voicing is reported [14].

In a study on Angami nasals using the Nasometer, nasalance scores were obtained at every 10% of the duration of voiced and voiceless nasals in the language [14]. It was shown that the nasalance score in the isolation context of Angami nasals has shown high nasality for about 80% - 90% of the total duration of the voiced nasals, while the voiceless nasals has retained high nasality until about 20% of the total duration of the nasals [14]. The same study also reported that bilabial nasals have the lowest nasality score in both voiced and voiceless nasals while palatal nasals has the highest nasalance.

As far as previous acoustic studies on Mizo voiceless nasals are concerned, several limitations are observed. It is observed from the literature that the Mizo data used for the analyses was not comprehensive enough since it is mentioned that Hmar, another language belonging to the Kuki-Chin subgroup was considered [11]. Apart from that, Mizo is a tone language and the reported studies did not control for tones in analyzing nasals in the language [7, 3, 4]. Hence, the present study aims at providing the characteristics of nasals in Mizo by obtaining the data from the native speakers in controlled phonetic environments. Additionally, the present study uses the Nasometer to obtain stereo data from both oral and nasal channels, while the Mizo voiceless nasals are produced by the native speakers. The nasometric studies reported in the literature primarily provide only nasalance scores, while in this study, we conduct acoustic analysis of the nasal and oral signals obtained from the Nasometer.

http://dx.doi.org/10.21437/Interspeech.2021-2104

This analysis is novel as we are not aware of any other study, except one [14], that conducted separate acoustic analysis on the nasal and oral channel data obtained with the Nasometer.

The organization of the rest of the paper is as follows: Section 2 describes the methods used in the study. The results of the study are provided in Section 3. Lastly, Section 4 discusses and concludes the paper.

2. Methodology

2.1. Dataset

The data list is comprised of nonwords in CVV syllables with all the Mizo nasals, /m, n, ŋ, m̥, n̥, ŋ̊/ in the onset and the five Mizo vowels /a, i, e, u, o/ in the nucleus. This results in 15 minimal sets and hence, there are 30 unique nonwords in total. These 30 nonwords were recorded 5 times by each participant resulting in 450 unique tokens. The lexical Mizo words with high tone were provided to the participants and were instructed to replicate the high tone while producing the CVV nonwords.

2.2. Participants

There were 3 female Mizo native speakers who participated in this study. They were born and brought up in Mizoram and could speak Mizo and English. During the time of the speech recordings, all of them were engaged in higher education in Guwahati. The average age of the participants is 29. None of them have reported any speech or hearing complications.

2.3. Recording procedure

The nasometer recordings was carried out in a sound attenuated booth in the Phonetics and Phonology Laboratory in IIT Guwahati. A KayPENTAX Nasometer II Model 6450 was used for reording the nasal and oral channel signals. Prior to each recording, the calibration of the headset was done with a value range of 0.9. In a Nasometer, the upper microphone captures the nasal energy and the oral energy is obtained from the lower microphone. The participants were asked to produce the list of data provided in a sheet of paper and the speech was recorded simultaneously using the built-in Nasometer II software.

2.4. Acoustic and statistical analysis

The recorded speech were segmented and annotated carefully by examining the waveforms and the spectrograms of the words from the nasal and the oral channels in Praat (version 6.1.08) [15]. The voiced nasals were marked between the interval of the onset of the nasal closure and the release of the nasal. The voiceless nasals were marked into two regions, the first region is the voiceless parts of the phonemes where there is only nasal signal and the second region is a voiced part of the phonemes which occur at the later region of the phonemes where there are both oral and nasal energy. The nasalance values were calculated using a Praat script by using the equation in (1)

$$Nasalance = \left(\frac{N}{O+N}\right) \times 100 \tag{1}$$

In equation 1, N represents the amplitude of the nasal signal whereas O refers to the amplitude of the oral signal. The measurement of the nasalance score is done at every 10% of the total duration of each segments. Apart from nasalance, the amount of voicing in each nasal is also calculated for this study by measuring the number of voiceless frames. The proportion of voiceless frames was calculated using the Voice Report function in Praat. Additionally, the duration of the nasals are also calculated to see if they differ by voicing. These values were exported to a spreadsheet and were used for descriptive and statistical analyses in R [16]. For visual examination, the waveforms of the Mizo nasals were obtained from Praat. The averaged time normalized nasalance values were plotted in R using the *ggplot2* package [17]. The core functions of R were used for descriptive statistic. Linear Mixed Effects (LME) models were used for exploratory statistics using the *lme4* package in R [18]. To see the significance of the fixed effects, Type II Wald chisquare tests were done using the Anova function in R by using the *car* package [19]. Lastly, Bonferroni post-hoc tests were conducted using *emmeans* package in R to see the contrasts between the levels in the fixed factors [20].

3. Results

3.1. Waveforms of Mizo nasals

The waveforms of the voiced and voiceless nasals in three places of articulation obtained from Nasometer are provided in Figure 1. In the figure, the nasal and the oral channels are shown separately. In terms of the voiced nasals, the waveforms obtained from the nasal channels show that nasals have high amplitude from the initiation of the nasals, which, gradually lowers at the beginning of the following vowels. The presence of nasal amplitude in the following vowel suggests that the vowels are nasalized in Mizo, when preceded by a voiced nasal. The oral channels of the voiced nasals do not show much oral energy, resulting in high nasalance. The pattern of the waveforms mentioned in voiced nasals are similar for all the three voiced nasals regardless of the place of articulation.

In case of the voiceless nasals, the nasal channels show continuous nasal energy throughout the production. However, most of the nasal waveform is characterized by aperiodic waves. Only the final portion of the nasal shows periodicity confirming voicing of the voiceless nasals in the vowel boundary. As in the voiced nasals, in voiceless nasals too, nasality continues into the following vowels. Unlike in Angami, as seen in Figure 2, there is no oral energy in the voiceless nasals in Mizo. It is observed from the waveforms of Mizo nasals that there is barely any oral energy during the production of the nasals in both the voiced and the voiceless nasals. Therefore, aperiodic waveform is absent which suggested that there is no aspiration involved. Additionally, it is observed that the voiceless nasals comprised of a longer voiceless region followed by a short voiced region.

3.2. Nasalance

The time normalized values of nasalance scores of each segment for Mizo voiceless and voiced nasals in CVV syllables are plotted with the standard error (represented by ribbon) in Figure 3 and Figure 4 respectively. In Figure 3, the nasalance is observed from the beginning until about 22% of the total duration which is regarded as the voiceless region of the nasals. This is followed by a low nasalance with an abrupt reduction of nasal energy for a short period of time resulting in the presence of oral energy and therefore, this region is voiced. At the beginning of the vowel, nasalance values show a systematic pattern adhering to the place of articulation of the nasals. The velar nasal has the

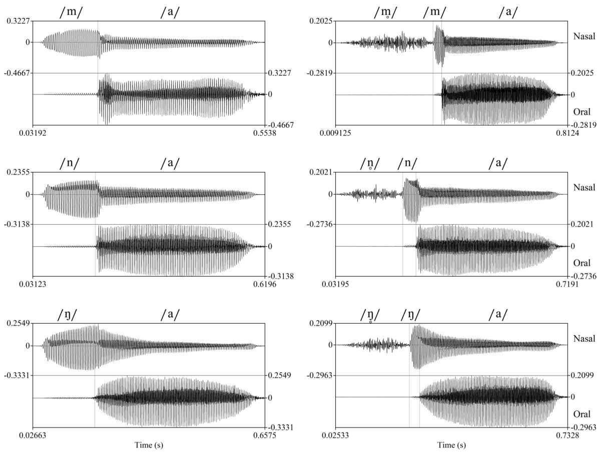

Figure 1: *The waveforms of Mizo nasals with dual channels.*

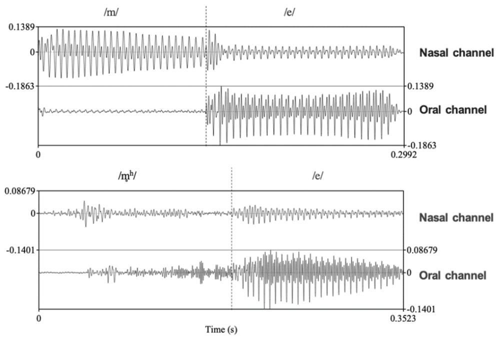

Figure 2: *Nasals waveform in Angami obtained from [14].The first panel shows /me/ and the second panel shows /m̥^{h}e/.*

highest nasalance followed by the alveolar, and then by the bilabial nasal. The nasalance in this region may serve as perceptual cues for the Mizo speakers to distinguish among the POA of the Mizo voiceless nasals. In case of voiced nasals too, the initial portions of the vowel following the nasals show POA specific nasalance values, as seen in Figure 4. Unlike in the voiceless nasals (Figure 3), the voiced nasals have shown the POA differences right from the initiation of the nasal until the initial parts of the vowel.

However, the pattern of nasalance in the voiced region of the voiceless and the voiced nasals are similar. There is a gradual lowering of the nasalance for more than half of the duration of the region followed by a rapid lowering of the nasalance. The vowel region in the voiceless and the voiced nasals has much lower nasalance as oral energy increases in this region. The nasalance scores for each segment in voiced and voiceless nasals are provided in Table 1. From the table, we see that the nasalance score in the voiceless region of the voiceless nasals in Mizo is the highest. The nasalance scores in the voiced regions of both types of nasals are comparable. Similarly, nasalance scores in the vowel regions of both types of nasals are comparable.

3.3. Voicing

The amount of voicing in the Mizo nasals are provided in Table 2. The table shows that unsurprisingly, the voiced nasals in

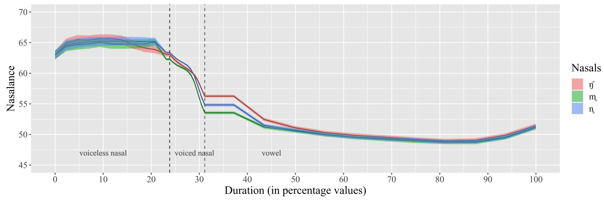

Figure 3: *Nasalance of Mizo voiceless nasals in CVV syllable.*

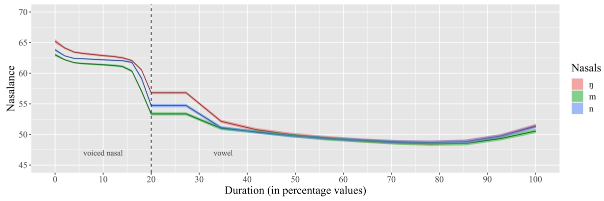

Figure 4: *Nasalance of Mizo voiced nasals in CVV syllable.*

Mizo has higher amount of voicing in comparison to their voiceless counterparts. It is also noticed that the highest amount of voicing is associated with the bilabial nasals in both voiced and voiceless nasals. Velar nasal has the lowest amount of voicing. To see the differences in the amount of voicing across the nasals, three LME models were built where the percentage of voicing was the dependent variable, segment was the fixed effect; speaker, iteration, word and the following segments were considered random effects. The backward reduction of the random variables of all the three models provided the final model with segment as the fixed effect and speaker as the random effect. The models were subjected to a Type II Wald-χ^2 analysis of deviance test. The result showed significant effect of segment and hence, to see the segment-wise differences, the final models were subjected to pairwise variability tests using the emmeans function with Bonferroni post-hoc tests. The results of the pairwise comparisons are provided in Table 3. The results indicate that the voiced and voiceless nasals are significantly different in terms of the amount of voicing. Apart from this, the amount of voicing in the voiceless and the voiced region of the nasals are given in Table 4. The table shows that there is complete voicing in the voiced region of the voiceless nasal and the amount of voicing is even higher than the voiced counterpart. The voiceless region in the voiceless nasals have some amount of voicing which, differs in terms of the POA as seen in Table 2.

3.4. Duration

The duration of the Mizo nasals is provided in Table 5. The table shows that the voiceless nasals are almost two times longer

Table 1: *Nasalance scores of Mizo segments.*

Nasals	Voiceless	Voiced	Vowel
/m̥/	64.40 (0.69)	59.20 (0.19)	50.10 (0.30)
/n̥/	64.76 (0.67)	60.26 (0.18)	50.33 (0.30)
/ŋ̊/	64.67 (0.67)	60.31 (0.27)	50.74 (0.31)
/m/		60.41 (0.18)	49.86 (0.30)
/n/		61.43 (0.16)	50.17 (0.27)
/ŋ/		62.42 (0.20)	50.52 (0.31)

Table 2: *Mean amount of voicing (in percentage) and standard errors in Mizo nasals.*

Nasals	Voicing in %
/m/	99.68 (0.18)
/n/	99.35 (0.29)
/ŋ/	99.02 (0.32)
/m̥/	51.64 (1.62)
/n̥/	48.60 (12.83)
/ŋ̥/	47.38 (1.66)

Table 3: *Pairwise comparison of the amount of voicing in Mizo nasals (df=452).*

Nasal contrast	estimate	SE	t-ratio	p-value
/m̥/-/m/	-48.04	1.48	-32.46	<.0001
/n̥/-/n/	-50.86	1.48	-34.50	<.0001
/ŋ̥/-/ŋ/	-51.48	1.48	-34.67	<.0001

Table 4: *The percentage and standard error of the amount of voicing in the voiceless and voiced regions of Mizo nasals.*

Nasals	Voiceless	Voiced
/m̥/	34.87 (2.26)	100 (0)
/n̥/	33.27 (1.9)	100 (0)
/ŋ̥/	30.07 (1.89)	100 (0)
/m/		99.68 (0.18)
/n/		99.35 (0.29)
/ŋ/		99.02 (0.32)

Table 5: *Means and standard errors of duration in Mizo nasals.*

Nasals	Duration (in ms)
/m/	103.57 (2.88)
/n/	118.66 (3.69)
/ŋ/	121.99 (5.70)
/m̥/	190.39 (5.78)
/n̥/	201.97 (5.18)
/ŋ̥/	195.30 (5.93)

Table 6: *Pairwise comparison of duration in Mizo nasals (df=448).*

Nasal contrasts	Estimate	SE	t-ratio	p-value
/m/−/m̥/	-86.81	5.68	-15.28	<.0001
/n/−/n̥/	-76.76	5.68	-13.512	<.0001
/ŋ/−/ŋ̥/	-73.24	5.68	-12.891	<.0001

Table 7: *The mean and standard error of duration in the voiceless and voiced region of Mizo nasals.*

Nasals	Voiceless	Voiced
/m̥/	143.28 (5.45)	47.11 (1.78)
/n̥/	156.21 (4.81)	45.50 (1.82)
/ŋ̥/	146.79 (4.89)	48.64 (2.46)
/m/		103.57 (2.88)
/n/		118.66 (3.69)
/ŋ/		121.99 (3.70)

than their voiced counterparts. To examine the effect of duration in different nasals, three LME models were constructed where duration is the dependent variable, the fixed and random effects were similar to the models of the amount of voicing in the previous section. These three models were then subjected to a backward reduction of effects resulting in a reduced model where duration is the dependent variable, segment is the fixed effect and, speaker and the following segments were the random effects. The reduced model for duration is subjected to a Type II Wald χ^2 analysis of deviance test. The results from all three models show significant effects of segment on duration. To see the segment-wise effects on duration differences across the nasals, the final models were subjected to a pair-wise variability test using the emmeans function with Bonferroni post-hoc tests. The test results are given in Table 6 which show that all the voiceless nasals and their voiced corresponding nasals are significantly different from each other in terms of duration.

The duration of the voiceless region and the voiced region of the Mizo nasals are taken into account and are provided in Table 7. It is seen that the duration of the voiced nasals are shorter than the voiceless regions of the voiceless nasals. In case of voiceless nasals, 32% of the total duration is voiced.

4. Conclusions

The present study provides a nasometric analysis of the voiced and voiceless nasals in Mizo. It confirms that the voiceless nasals in Mizo are unaspirated nasals, unlike reported in the previous study, the voiceless parts of Mizo nasals are not accompanied by oral airflow [13] and hence no aspiration is found. The results also showed that Mizo voiceless nasals consist of a long voiceless portion characterized by high nasalance. The voiceless portion is followed by a short voiced portion where the nasalance becomes lower. However, in the voiced portion, and in the following vowel portions, the nasalance shows POA specific variations. Hence, we assume that these portions may be responsible for providing POA cues to the Mizo speakers. Similar observations are also made in the previous studies [21]. We observed that the velar nasals have the highest nasalance while bilabial nasals have the lowest. This may be correlated to the energy loss due to the length of oral cavity in the production of nasals of various POA. As bilabial nasals have longer oral cavity, the loss of energy to the oral side branch will result in lower nasal amplitude. The reverse will be true for velar nasals that have next to no loss of energy to the side branch. The voiceless nasals are significantly longer than the voiced nasals in Mizo. This may be attributed to the complex articulation of the voiceless nasals involving both voiceless and voiced articulatory configurations.

5. Acknowledgements

The Nasometer used in this study belongs to the Pathological Speech Processing Laboratory of North East Centre for Biological Sciences and Healthcare Engineering (NECBH), IIT Guwahati funded by the Department of Biotechnology, Government of India, project no. BT/COE/34/SP28408/2018.

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