

Effect of Contextual Vowel Height on Nasals in Ambon

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Abstract: This study analyses the effect of contextual vowel height on word-initial and word-final nasals in Ambon. Additionally, a few instances of word-final nasal deletion are discussed. Although deletion of oral stops has been mentioned in the existing literature, there is no clear discussion on nasal stops. In this paper, we compare the duration and intensity of the nasals in word-final and word-initial positions and how the contextual vowel height affects these features. Furthermore, we investigate if the instances of nasal deletion are affected by the nasalization of the preceding vowel. The results show that there is an effect of the height of the contextual vowel on the realization of the nasal, in terms of both intensity and duration. We also see that the vowels before the deleted nasals are more nasalized, but we cannot make any inference as we do not have enough tokens of words with nasal deletion for generalizing the findings.

1. Introduction

Ambon or Ambonese Malay is a creole spoken primarily in the Ambon island, which is a part of the Maluku islands of Indonesia. There are several phonological processes that distinguish Ambon Malay from standard Malay. Such processes include the loss of /ə/, deletion of word-final oral stops, velarization of final nasals and neutralization of /u/ with /o/ (Grimes, 1991; Minde, 1997; Collins, 1992). These phonological processes are restricted to native Ambon words and are not seen in borrowed words (Grimes, 1991; Minde, 1990). Also, the only consonants that appear in the word-final position in native Ambon words are /ŋ, s, l, r/, but borrowed words may have /p, t, m, n, h/ in word-final position. The nasal phoneme has also been described as an archiphoneme ‘N’, which assimilates to the place of articulation of the following stop (Minde, 1990). However, acoustic characteristics of the nasals and nasalization of the vowels have not been the focus of any existing literature. The goal of this study is to analyze acoustic characteristics such as duration and intensity of the nasals and how they can be affected by the contextual vowel height.

Although not discussed in any existing literature, we have observed in our data that the word final nasal is occasionally deleted in natural speech. A similar alteration of the nasal segment is also seen in some varieties of Spanish where the final nasal is velarized to /ŋ/ (Lipski, 1986). A study on dialectal variation in Spanish states that velarization of /N/ is in fact an intermediate process before the nasal gets completely deleted (Mondéjar, 1989). A factor that has been associated with the deletion of the nasal segment is nasalization of the vowel in the preceding context, that is, nasals can be deleted after a nasalized vowel (Lipski, 1986). Nasalization is not phonemic

in Ambon, but phonetic nasalization of vowels before a nasal consonant has been reported by Minde (1990, p 80). Based on these studies, we hypothesize that the degree of nasalization of the preceding vowel affects the deletion of the word final nasal. That is, the vowel before a deleted nasal has a higher degree of nasalization than the one where the nasal surfaces.

1.1. Overview of the Language

Ambon is spoken by a native population of about 200,000 people residing on the island of Ambon (Paauw, 2008). Although widely used as a vernacular in the Maluku islands of Indonesia, it is considered an inferior variety of standard Indonesian (Grimes, 1991). It is a very common second language in the island of Maluku and thus is the lingua franca for the various dialects spoken in that region (Grimes, 1991). The vocabulary of Ambonese Malay is the result of a mix of different languages that came into contact mainly for trade. The trade had been dominated by the Portuguese, who were the first Europeans to arrive in the 15th century and then by the Dutch (Paauw, 2008). However, there is evidence that the Chinese, Indians and Romans might have been involved in the trade as early as the second half of the first millennium B.C., speculated from their literary sources (Fraassen, 1981). Persians and Arabs were also among the foreign merchants that were involved in the trade. The influence of all these languages can be seen in the various aspects of the language like the vocabulary and phonology.

The general phoneme inventory of the Malay creoles includes 5 vowels and 21 consonants. Figure 1 shows the consonant inventory, and figure 2 shows the vowel inventory of Malay as described in Paauw (2008). The consonants and vowels shown in parentheses are the ones that are found only in some dialects.

	Labial	Alveolar	Palatal	Velar	Glottal
Voiceless stops	p	t	c	k	(ʔ)
Voiced stops	b	d	ɟ	g	
Fricatives	f	s			h
Nasals	m	n	ɲ	ŋ	
Lateral		l			
Trill		r			
Glides	(w)		j	w	

Figure 1: The basic consonant chart of Malay varieties, from Paauw, 2008

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i		u
e	(ə)	o
	a	

Figure 2: The basic vowel chart of Malay varieties, from Paauw, 2008

1.2. Measuring nasalization

Acoustic characteristics of nasals are very different from oral sounds because articulation of nasal consonants and nasalized vowels involve not just the oral cavity but also the nasal cavity. However, the coupling of the oral and nasal cavity is different for nasal consonants and nasalized vowels. In nasal consonants, the oral cavity is completely closed and air escapes only through the nasal cavity; whereas, air escapes through both the oral and nasal cavities in nasalized vowels. Therefore, the acoustic cues associated with nasal consonants and nasalized or nasal vowels differ substantially. The resonance of the nasal cavity when combined with the oral resonances primarily affects the lower end of the spectrum. The nasal resonance frequencies add nasal poles and zeros to the spectrum, perturbing the oral resonance frequencies. Nasal poles are the peaks of the resonance frequencies seen in the spectrum and zeros (also known as anti-resonance) are the valleys. These nasal features interact with the oral features to give us the final acoustic output. Some of the robust properties seen in nasal spectrum and spectrograms are a low first formant, an overall low amplitude and a wider bandwidth (Johnson, 2004). This occurs because the nasal and the oral cavity provide more surface area for the sound waves to get absorbed, resulting in severe damping of the formant amplitudes. Damping of the formant frequencies reduces their amplitude and increases the bandwidth. This is illustrated in Figure 3, where the effect of damping is seen in the frequency bands B and C. Damping increases the bandwidth (BW) and decreases the amplitude of the bands.

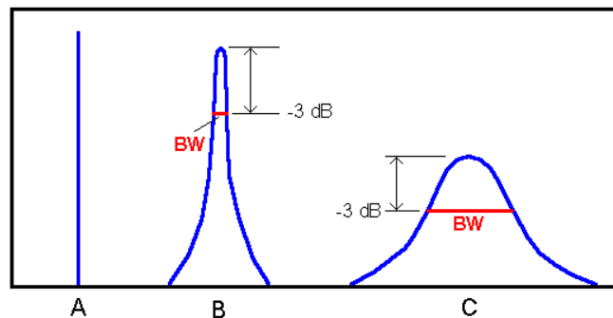


Figure 3: Effect of damping on frequency bands (x-axis = frequency, y-axis = amplitude)

However, measuring the degree of nasalization is much more complicated than that. Despite extensive research, no single criterion has been found that can successfully give us the degree of nasalization in a vowel across speakers and languages (Beddor, 2009, Footnote 3). Most studies that deal with degree of nasalization base their results on a large dataset to increase its reliability. Because of both the coupling of the oral with the nasal cavity and the tongue position, many factors

perturb the acoustic output spectrum. This makes nasalization one of the more complex phenomena to investigate (Johnson, 2004). Apart from formant characteristics, studies on temporal measures of nasalization have found that increase in vowel duration favors perception of nasality in vowels (Lintz and Sherman, 1961; Cagliari, 1977). Nasalized vowels are also found to be of lesser amplitude than their oral counterparts (Bjuggren and Fant, 1964). In the frequency domain, it has been shown that for non-low vowels the first formant frequency (F_1) is generally increased by nasalization because the nasal formant appears above the F_1 and spreads the energy distribution higher (Fujimura and Lindquist, 1971). For low vowels on the other hand, which already have a high F_1 , the nasal formant appears below where the usual F_1 would be without nasalization. The low nasal formant lowers the energy distribution and makes the F_1 shift lower. This is seen as being particularly heavy in terms of nasalization (Kluender et al., 1990). Therefore, we can say that with heavy nasalization, the F_1 of low nasal vowels like /ã/ is lower than with the non-nasal counterpart. Another feature of nasalization is the appearance of the anti-formant or the nasal zero. This is usually the deep valley seen in the FFT (Fast Fourier Transform) or the LPC (Linear Predictive Coding) spectrum, and seen as very low amplitude white space in the spectrogram. It appears when the coupling of the nasal and oral tract cancels out some resonances. However, the anti-formant can be affected by a number of factors including voice quality, place of articulation, and the degree of nasalization, rendering anti-formants unreliable as cues for nasalization.

Existing literature shows several other cues that can be associated with nasalization, although not always applicable cross-linguistically. The difference between amplitudes of the first formant (A_1) and the anti-formant (P_0) was used for English and French (Chen, 1997). The amplitude of F_1 minus the amplitude of the first harmonic (H_1) was also found to be relevant for nasalization in English (Huffman, 1990). Another study found the difference between the amplitude of the first nasal formant (N_1) and the second nasal formant (N_2) to be relevant for perception of nasalization in French (Maeda, 1993). Some of the other secondary cues are the spectral tilt measured by the difference between the amplitude of the 3rd formant (A_3) and the nasal formant (P_0), prominence of the anti-formant (P_0), bandwidth, and vowel duration (Styler, 2015). Figure 4 shows an example spectrogram and FFT spectrum of nasalized vowels. In this study, we use $A_3 - P_0$ as a measure of spectral tilt.

However, more recent research has shown that the reliability of these measures can vary across languages, depending upon whether they have coarticulatory nasalization like English or contrastive nasalization like French (Styler, 2015). Styler finds that in French, the spectral tilt measured by the difference between amplitude of the 3rd formant (A_3) and the anti-formant (P_0) gives the best measure. On the other hand, $A_1 - P_0$ gives the best results for English.

Figure 4 below shows us the difference between the spectrogram of a nasal vowel and its oral counterpart.

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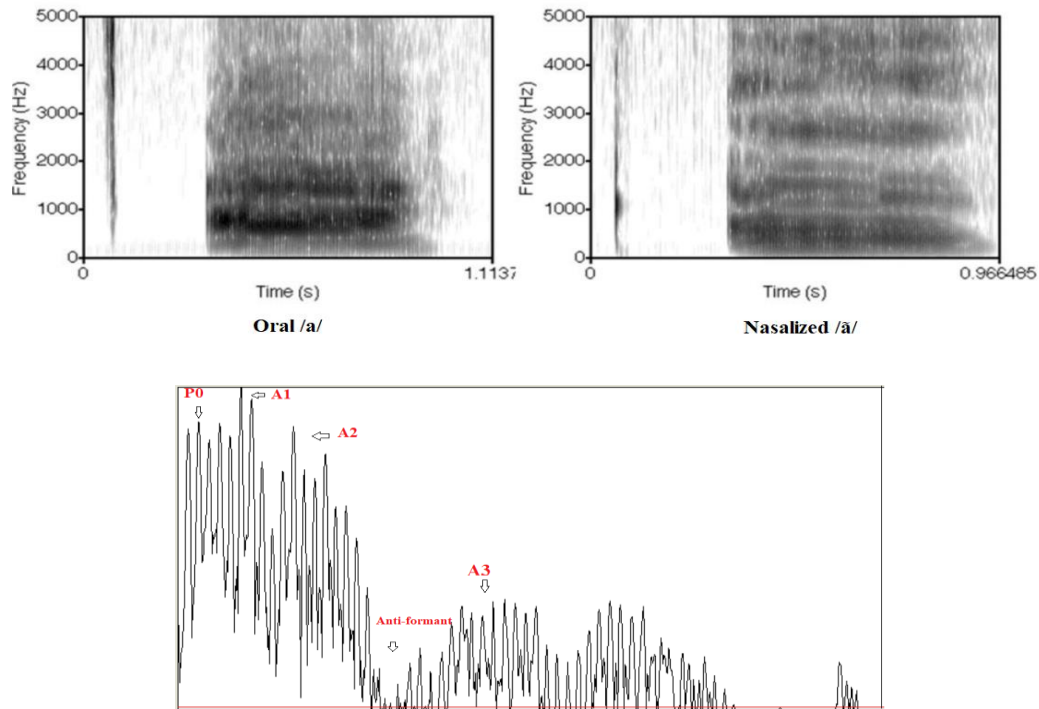


Figure 4: Spectrogram of an oral vs. nasal vowel (top) and FFT spectrum of a nasal vowel (bottom). (Image retrieved from <https://slideplayer.com/slide/9136977/>)

For the current study, we choose to investigate nasalization using spectral tilt, A_1 - P_0 , and the location of the first formant.

2. Method

2.1. Speaker

The data used for this study was recorded from a female native speaker in her thirties.

2.2. Stimuli

The speaker was provided with a wordlist of 52 words. Mostly disyllabic words were used in the list, except for 2 trisyllabic words when disyllabic words with the required pattern were not available. The stress on these words is always on the first syllable of the disyllabic words and penultimate syllable on the other words. The words were divided into the following 3 sets:

- 1) σ .CVN# : The final syllable ends in a nasal sound.
- 2) #NVC. σ : The initial syllable starts with a nasal sound
- 3) σ .CVC# : Control group for nasalized vowels, where the final syllable ends in a non-nasal stop.

Although Ambon has 4 nasals, /n, m, ŋ, ɲ/, the distribution is limited by their position in the syllable. For instance, /n, m, ŋ/ appear in both onset and codas, but /ɲ/ is restricted to only onset

position. Therefore, we do not include /ɲ/ in our analysis. 30 tokens of both word final nasals were recorded (3 nasals * 5 vowels * 2 examples each = 30 tokens). Although the neutralization of /u/ with /o/ has been stated in previous literature (Grimes,1991; Minde,1997; Collins,1992), for this study only the surface representation is considered and therefore /u/ and /o/ are treated as two separate vowels. Our word list had no examples of word-initial nasal followed by /e/. This is because the consultant was not familiar with words with the N+/e/ combination. Therefore, we had 24 tokens of word initial nasals (3 nasals * 4 vowels * 2 examples each = 24 tokens). We had also omitted 5 tokens from both sentence and word list condition for the analysis as our consultant later stated dialectal variations in those words. This made it a list of 43 words, including nasals in both word final and word initial positions.

Word final nasal deletion was observed in only three out of 43 words with a final nasal. The instances of nasal deletion were also the ones where the nasal was preceded by the /a/ vowel. Therefore, in this study, we analyze nasalization only in the /a/ vowel.

2.3. Procedure

The words were presented in a random order along with their English translation. To mask the objective of the task, three random words were included in the beginning and the end of the list. Three repetitions of the word list were recorded. In addition to reading the word list, the speaker was also asked to create a sentence using each word provided in the list. Each sentence was repeated twice. This enabled us to get a more naturalistic production, while preventing the speaker from focusing on the target word. The recording was carried out in a sound attenuated booth with a condenser microphone, at a sampling frequency of 44,100 Hz.

2.4. Analysis

The analysis of the sound files was done using the software PRAAT (Boersma & Weenik, 2018). The phonemes were annotated manually and then a script was run to get the duration, amplitude and F1 measures of the segments. In word-initial position, the onset of the nasal was measured from the onset of the first formant to the beginning of the following vowel. In word-final position, the onset of the nasal was marked at the closure of the preceding vowel, and a drastic drop in amplitude was observed. The offset is marked at the end of the F2. RMS (root mean square) amplitude was taken as a measure of intensity of the nasals.

To measure the degree of nasality, the amplitude of the first formant (A_1), amplitude of the 3rd formant (A_3), and amplitude of the nasal formant (P_0) were extracted from the FFT spectrum of 30 ms window size.

3. Results

The optional deletion of the word final nasal was observed in a few instances in the data set and the deletion is seen only in the sentence condition and in one of the two repetitions. In the word list condition, the nasals were consistently realized in all the words. Moreover, all the three instances of deletion were only found in the context of a preceding low vowel /a/. An example of

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the same word read from the word list vs. spontaneous speech is shown in Figure 5. The spectrogram and waveform in the top panel shows the word [badan] in the word list and the bottom panel is of the same word in a sentence. In the bottom panel, the word [badan] is followed by the word [akan]. We can clearly see that [n] of [badan] is deleted and the following vowel is uttered merging the two vowels.

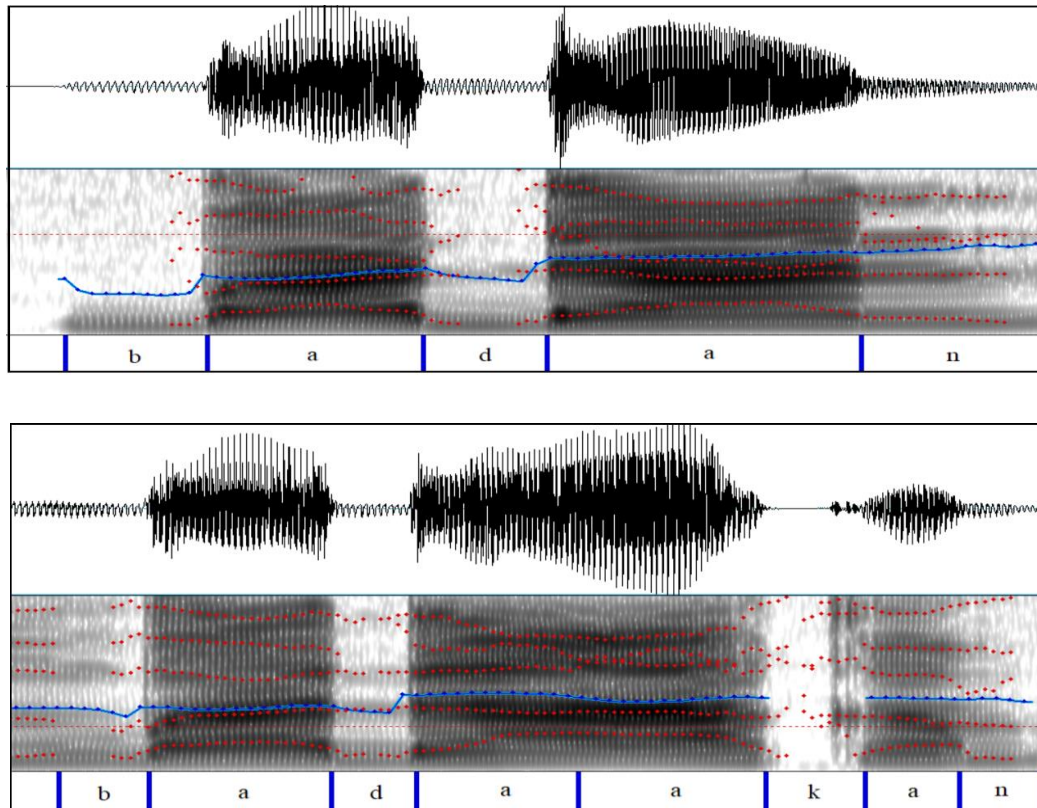


Figure 5: Spectrogram of the word [badan] with the final nasal (top) and without the final nasal (bottom)

The results are presented in 3 different sections: duration (section 3.1), intensity (section 3.2), and nasalization of the contextual vowel (section 3.3). The duration and intensity of the nasals in relation to their adjacent vowels are analyzed.

3.1. Duration

The duration measures of the nasals in the word-final position versus word-initial position show that the word-final nasals are longer than the word initial nasals in both sentence and word list condition, as can be seen in Figure 6 (left). Two separate two-tailed independent t-tests were performed for the sentence condition and the word-list condition, taking duration as the dependent variable and context (initial versus final) as the independent variable. The results of the sentence condition reveals a non-significant difference in duration between word-initial and word-final nasals [$t(34)=-1.44$, $p=0.11$]. However, the results of the word list condition showed a significant

difference in the duration of nasals between the word-initial and word-final position [$t(27)=-3.20$, $p<0.05$], that is word-final nasals are longer than word-initial nasals in the word list condition. From the plot on the right in Figure 6, we see that this difference between word-initial and word-final nasals is consistent for /m/ and /ŋ/ (represented as ‘ng’ in the plot) and corresponds to the pattern of the aggregate of the nasals (Figure 6, plot on the left). However, /n/ deviates from this pattern. A two-way ANOVA was performed only on the word list condition, with duration as the dependent variable and place of articulation and position of the nasal as the independent factors. The results show that there is no significant effect of place of articulation of the nasal [$F(2,38)=1.71$, $p=0.31$]. However, there was a significant effect of position [$F(1,38)=1.60$, $p<0.005$] with no significant effect of their interaction [$F(2,80)=4.45$, $p<0.05$].

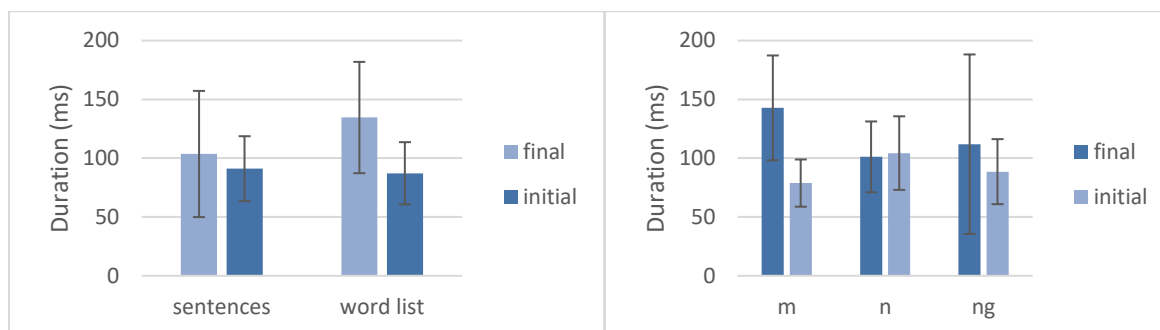


Figure 6: Average duration (ms) of nasals in word final and word initial context. The left plot shows the average measure of all the nasals combined, plot on the right shows the average duration of each nasal in both word initial and final position (error bars represent standard deviation).

Figure 7 shows the comparison of the average duration of word-initial and word-final nasals in the context of five different vowels. The average duration of all the nasals combined are plotted in the figure. We see that in the word-final position, the duration of the nasals after low and mid vowels /a/ and /e/ are shorter than with the high vowels /i/ and /u/. In the word-initial position we lack data for the /e/ as a contextual vowel. Our sample size is not large enough or evenly distributed enough to confirm the effect of vowel height on the duration of nasals in word-final and word-initial positions separately. However, from the descriptive plot in Figure 7, we do see that the duration of /a/ and /e/ generally tend to be shorter than /i/, /o/ and /u/. To find if this is statistically significant, we performed a one-tailed independent sample t-test on the duration of /a/ and /e/ as one group and on the duration of /i/, /o/ and /u/ as the other group, both word-initial and word-final nasals combined but only on the word-list condition. Even though /e/ is considered a mid vowel, we find from our recorded data that it is closer to /ε/ even though the literature states otherwise. This is why we have considered grouping /a/ and /e/ into one set which is lower than the other set that includes /i/, /o/ and /u/. The result of the t-test showed a significant difference in that the duration of nasals was significantly shorter in the context of relatively lower vowels compared to nasals in the context of higher vowels, [$t(23)=-2.84$, $p<0.005$].

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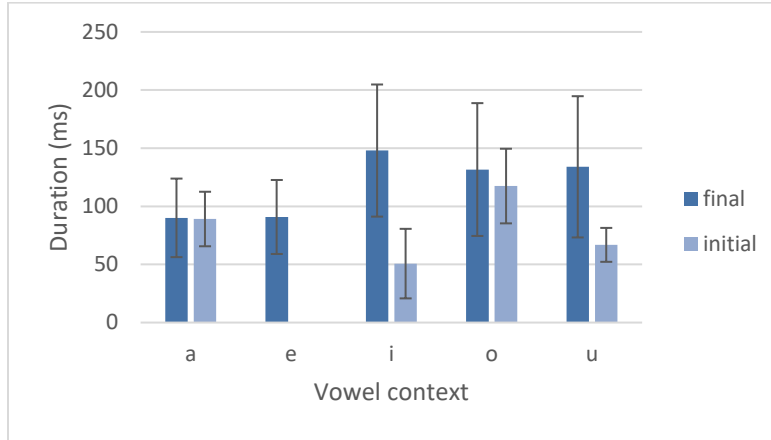


Figure 7: Average duration (ms) of nasals in word final and word initial context in the word list condition, in different vowel contexts (error bars represent standard deviation)

Figure 8 shows the average duration of the nasals in the word-final position in five different preceding vowel contexts. We see that across both sentence and word-list condition, the nasals are shorter when preceded by the vowels /a/ and /e/ than by high vowels /i/, /o/ and /u/. A one-tailed independent sample t-test was performed between nasals followed by /a/ and /e/ as one set and nasal followed by the vowels /i/, /o/ and /u/ as the other set. . The results show that the nasals followed by the lower vowels /a/ and /e/ (considered low in this set of data) are significantly shorter than the ones followed by the vowels /i/, /o/ and /u/, [$t(38)=-4.18, p<0.005$].

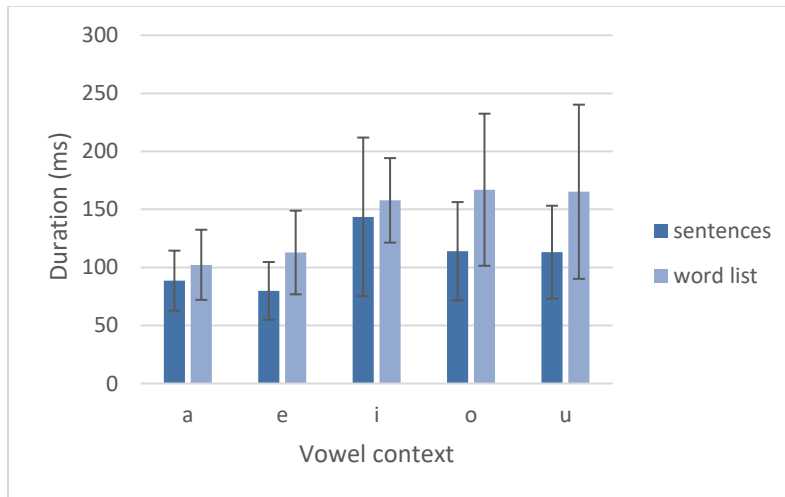


Figure 8: Average duration (ms) of nasals in word final context, in different preceding vowel context (error bars represent standard deviation)

3.2. Intensity

The results of the intensity measure, as seen in Figure 9, show that the intensity of word-final nasals is lower than in word-initial position. This difference is consistent for both sentence and word list conditions. The results of a one-tailed independent sample t-test performed on the sentence conditions with average intensity as the dependent variable and position as the independent variable showed that there is a significant difference in the intensity of the nasals in word-initial vs. word-final position in the sentence condition, [$t(51)=2.15, p<0.05$]. However, a similar t-test on the word-list shows no significant difference in the intensity of nasals between the word-final and word-initial position, [$t(65)=-1.48, p = .61$]. We also see that the difference is consistent across different places of articulation. To find if there is an effect of place of articulation or the position of the nasal on the intensity, a two-way ANOVA was performed only on the sentence condition, with intensity as the dependent variable and place of articulation and position of the nasal as the independent factors. The results show a significant main effect of place of articulation [$F(2,81)=3.22, p<0.05$] and also of position [$F(1,38)=3.95, p= 0.05$]. However, there was no significant effect of their interaction [$F(2,80)=1.28, p=0.28$]. A Tukey HSD follow-up test with place of articulation as the dependent variable showed that the difference was significant only between the velar nasal /ŋ/ and alveolar nasal /n/, that is, velar nasals have a higher intensity than alveolar nasals.

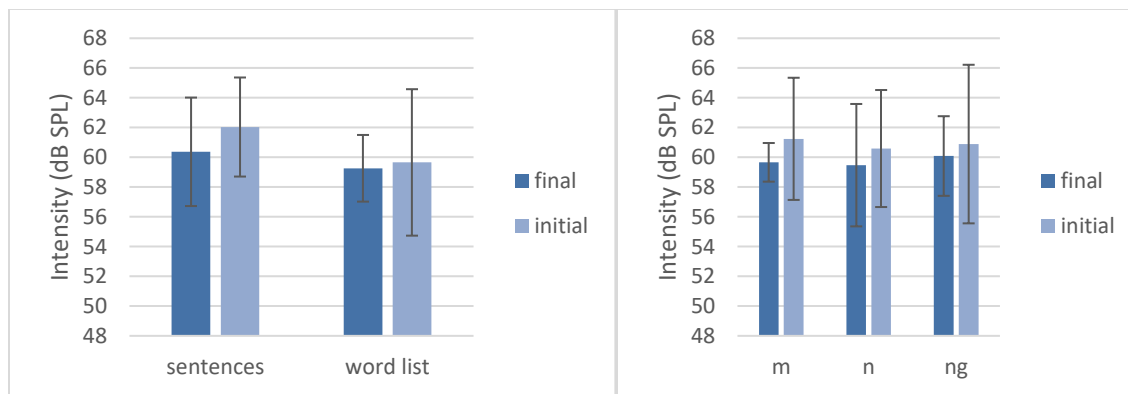


Figure 9: Average intensity (dB SPL) of nasals in word final and word initial context, in different preceding vowel context (left). The average intensity of the three places of articulation (right). The error bars represent standard deviation.

Figure 10 shows the average intensity of the nasals preceded by the five different vowels in both word-final and word-initial positions. We do not have an evenly distributed data set of nasals in word-initial position to perform a statistical significance test. However, a one-way ANOVA on the intensity of the word final nasals, with preceding vowel context as the dependent variable shows that there is no significant effect of the contextual vowel on the intensity of the nasal, [$F(4,107)=0.89, p=0.47$].

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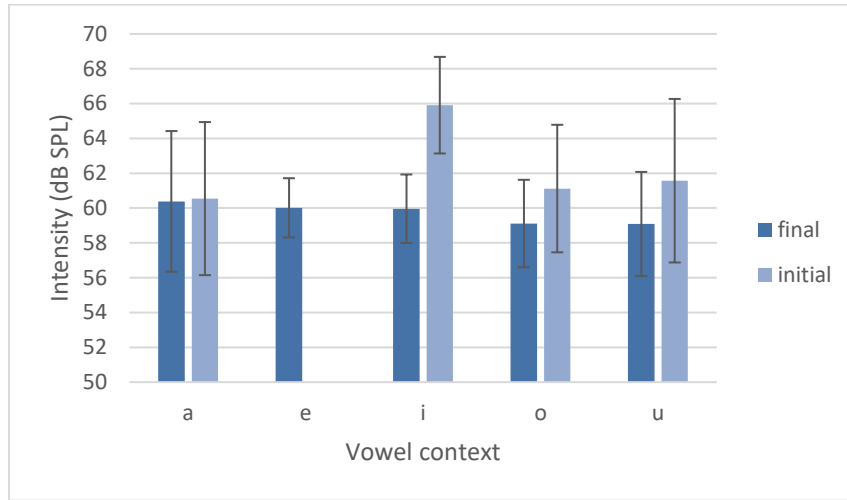


Figure 10: Average intensity (dB SPL) of nasals in word initial and final context, in 5 different vowel contexts. (error bars represent standard deviation)

The difference in the intensity of nasals in both sentence and word list conditions is plotted in Figure 11 across five different vowel contexts (initial and final positions). The error bars from the figure show that the standard deviation of the intensity measures for each vowel context is too high to find a statistically significant difference between the intensity of the nasals across different vowel contexts. This is also confirmed by a one-way ANOVA on the intensity measures of sentence condition and word list condition combined and vowel context as the independent variable [$F(4,153)=0.41, p=0.79$].

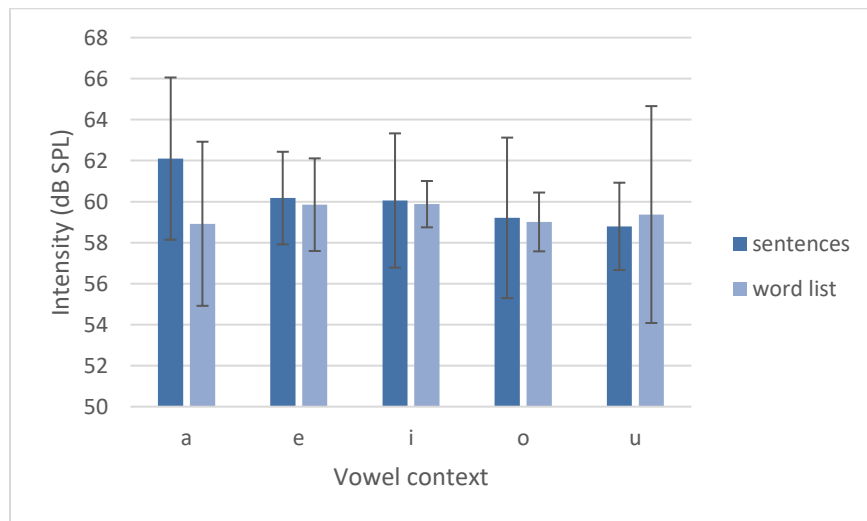


Figure 11: Average intensity (dB SPL) of nasals in word final position, in different preceding vowel context.

3.3. Nasalization of contextual vowel

Comparing the F_1 of nasalized vowels with the F_1 of their oral counterparts, as expected, we see that the average of nasalized /ã/ is lower than the oral /a/. The average of the nasalized F_1 was 903 Hz and oral F_1 was 1048 Hz.

The degree of nasalization was investigated only for the nasalized low vowel /a/, as it was the only vowel to allow deletion of the following nasal. There were three clear instances of nasal deletion after the nasalized /a/, all in the sentence condition. Also, only one of the two repetitions showed the deletion of the nasal. Table 1 shows the F_1 values of the vowels in the two utterances of the same word, one where the nasal is deleted and the other with the nasal. The F_1 measurements were taken at the mid-point of the vowels. From the table, we see that for the two words [badan] and [makan], the F_1 is lower when the nasal deletion takes place. As discussed in our literature review, this suggests that there is more nasalization of the low vowel when the following nasal is deleted. However, it is not the same with [bukan], where the F_1 is higher when the nasal is deleted.

Word	F_1 (no nasal)	F_1 (with nasal)
/badan/	990	1116
/makan/	824	1048
/bukan/	868	801

Table 1: F_1 measures of /a/ in the context of a deleted nasal and without deletion.

To measure degree of nasalization, we had selected two other measures besides F_1 based on the experimental evidence provided by studies on English and French, i.e., A_3-P_0 (Spectral tilt) and (A_1-P_0). From table 2 we see that the spectral tilt is consistently lower for the utterances without the nasal, suggesting a lesser degree of nasalization. However, there is no consistency between the A_1-P_0 measures across the two different contexts. Since we do not have sufficient data to compare these measures for ‘with’ and ‘without’ nasal instances, we do not perform any statistical tests here.

	A_3-P_0 (Spectral tilt)		A_1-P_0	
	with nasal	without nasal	with nasal	without nasal
badan	33.5	26.3	6.3	2.9
bukan	33.2	29.2	1.5	6.5
makan	30.5	28	1.7	4.7

Table 2: Comparing nasalization of /a/ in two different nasal context, in 3 different.

4. Discussion

The mean and standard deviation of the duration measures in the figure shows that nasals are longer in word-final position than in word-initial position. However, if we look at the duration of the nasals in the word-list condition and sentence condition separately, only the nasals in the word-list condition showed a significant difference in duration between word-final and word-initial position. We also found that the duration is not significantly different across the three places of articulation and that there is no significant interaction of place of articulation and position of the nasal in the word. A possible explanation might be that segment duration can be affected by different factors like intonational pattern or phrase boundary (Oller, 1972). In the word list reading, these factors remain constant. However, in the sentence condition, the different prosodic and intonational factors come to play and thus affect the duration of the speech segments. However, it is also possible that the word-final nasals are longer than word-initial nasals due to the list reading effect. We also find that the duration of the nasals is affected by the height of the contextual vowel. We considered /o/ and /e/ as low vowels since the quality of the vowel transcribed as /e/ sounded much lower and closer to /ε/. The vowels /i/, /o/ and /u/ were grouped together as one set of relatively higher vowels. The statistical significance tested on both word-final and word-initial nasals showed that the nasals were significantly shorter in the context of a low vowel than in the context of a high vowel. Nevertheless, the motivation for this is not yet understood and would require further scrutiny.

On the other hand, analysis of the intensity measures show that the difference was significant only in the sentence condition, that is, the intensity is lower in word-final nasals than in word-initial nasals. A further statistical analysis of the effect of place of articulation showed that there was an effect of place of articulation and position of the nasal, but no significant interaction effect. We found that velar nasals are of higher intensity in both word-initial and word-final conditions. The effect of the preceding vowel context on the intensity and duration of the nasals was also analyzed and the result showed no significant effect of contextual vowels in the intensity of the nasals.

The data shows us that nasals can be optionally deleted after a vowel. In our data set of spontaneous sentences, there were a total of 43 tokens with the final syllable structure of *_CVN#* (5 vowels * 3 nasals * 2 repetitions). Out of this, there were only 3 instances of complete deletion of the final nasal. We also find that the context of this phenomenon is very limited, that is, only the alveolar nasal [n] followed by the low vowel /a/ was optionally deleted. Therefore, the status of a nasal deletion rule and the conditions under which it might apply still cannot be generalized.

Since the nasal deletion in the data set was restricted to the preceding context of /a/, the effect of nasalization on only the /a/ vowel was analyzed. The F₁ of the nasalized vowel was measured in comparison with its oral counterpart.

Existing research has shown that cross-linguistically, low vowels are more nasal than high vowels (Delvaux et al., 2008, Shosted et al., 2012). Basing our results on this, we hypothesized that there might be an interaction between the nasalization of the preceding vowel context and deletion of the nasal. Two different measures were used to find the degree of nasalization within the nasal vowels to see if a higher degree of nasalization triggers the deletion of the nasal. Although we see

a difference in the degree of nasalization, this cannot be statistically proven due to the limited number of word tokens with nasal deletion in our data set. Though we cannot claim that there is a relation between the degree of nasalization and the deletion of the following nasal, we do see a possibility from the descriptive analysis.

To summarize, we find that the duration of the nasals is shorter in the context of a low vowel compared to the nasals in the context of a higher vowels in Ambon. On the other hand, the intensity can be affected by the place of articulation of the nasal, that is, velar nasals are of higher intensity than alveolar nasals. However, the degree of nasalization of the low vowel /a/ seems to affect the deletion of its following nasal, but is not yet statistically proven.

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