SPONTANEOUS NASALIZATION IN THAI: A CASE OF VELOPHARYNGEAL UNDERSPECIFICATION

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ABSTRACT

Spontaneous nasalization, the emergence of nasalization in contexts lacking an historical nasal phoneme, often occurs during vowels adjacent to glottal constants, as in Thai. One explanation for this nasalization is velopharyngeal underspecification (VPU) of glottal consonants: the lack of any requirement for velar closure. If VPU is the source of spontaneous nasalization in Thai we expect to find greater nasalization during glottal consonants compared to adjacent nasalized vowels. To test this we recorded nasal airflow in six speakers of central Thai. Results showed greater nasal airflow during /h/ compared to following nasalized vowels. This finding suggests that the starting point of nasalization in Thai is the glottal consonant and that nasalization spreads to the following vowel.

Keywords: Nasalization, Thai, aerodynamics

1. INTRODUCTION

The historical process of vowel nasalization typically occurs when a previously non-nasal vowel is in temporal proximity to an etymologically nasal phoneme. Through coarticulation the vowel becomes nasalized. An example is Latin UNUS 'one' that later became French [œ̃] *un* when the nasal consonant was dropped [13]. A second origin of vowel nasalization, spontaneous nasalization, is the emergence of nasalization in contexts lacking any historical etymological nasal [1]. This process is documented in languages like British English, e.g. [hɑ̃ːvəd] 'Harvard', and Thai, e.g. [hɛ̃] "parade" and [ʔãw] "to take", and other languages including Lahu/Lisu, Bzhedukh, and Laos [1, 2, 4, 10, 11]. Spontaneous nasalization in Thai only occurs after /h/ and /ʔ/ and is more likely during low vowels [5, 11]. Recent magnetic resonance imaging (MRI) data of velopharyngeal opening (VPO) in Thai has verified previous impressionistic accounts of spontaneous nasalization during low vowels after /h/ and to a lesser extent after /ʔ/ [7, 11, 5].

One explanation for spontaneous nasalization after glottal consonants is velopharyngeal underspecification (VPU). Because the place of primary constriction is at the glottis and below the velum, there is no aerodynamic need to close the velopharyngeal port [12]. Contrast this with configurations such as the voiceless plosive /t^{h}/ where velar closure is necessary to facilitate pressure buildup at the lingual constriction for the release burst. Applied to Thai, the explanation of VPU would attribute vowel nasalization after glottal consonants to a lack of velar closure during /h/ and /ʔ/. This way, the origin of spontaneous vowel nasalization in Thai may actually follow a similar pattern as French in that coarticulation is involved. In French, VPO originated from a nearby nasal consonant like /n/ and spread to the adjacent vowel. Similarly, VPO in Thai may have originated during the glottal consonants /h/ and /ʔ/ due to VPU and then spread to the following vowel.

If spontaneous vowel nasalization in Thai originated from VPU of adjacent glottal consonants, we would expect to find greater VPO during Thai consonants /h/ and /ʔ/ compared to the following spontaneously nasalized vowels. This is because the starting point of nasalization would be the glottal consonant, while the following vowel may be nasalized through coarticulation. In the present study we analyze integrated nasal airflow (cumulative nasal airflow during a segment) and the temporal location of maximum nasal airflow in Thai glottal consonants and vowels. Nasal airflow has been found to correlate with velopharyngeal opening and this measure is often applied to study nasality [3, 6, 15, 16]. While nasal airflow is correlated with VPO, the airstream mechanism can affect this relationship. While we expect to be able to measure nasal airflow during /h/ and thus infer VPO, this will likely not be possible during /ʔ/. Because the glottis is closed during /ʔ/, there is likely to be minimal supraglottal airflow. Therefore, while VPO may be large during /ʔ/, we would not be able to infer this from nasal airflow alone. While we include /ʔ/ in the current study to demonstrate this point, we expect that we will only be able to test our predictions regarding the origin of greatest nasal airflow for syllables beginning with /h/.

2. METHODS

Six native speakers of central Thai were recruited to participate in an aerodynamic study. Four of the speakers were female and two were male; all originated from Central Thailand near the Bangkok area. Their ages ranged from 18-28 y.o.. The data presented here is part of a larger project on Thai aerodynamics and phonation. The speakers produced a set of monosyllabic words and morphemes embedded in a carrier phrase, /pʰuːt˥˩ kʰam˧ waː˥˩ "_" ʔiːk˨ kʰraŋ˦/ "Say the word '_' again". The target words varied the long vowels /aː, ɔː, ɛː, eː/ after /h/ and /ʔ/. /a, ɔ, ɛ/ are reported to nasalize after /h/ and to a lesser extent after /ʔ/, while /e/ is not reported to nasalize after either glottal consonant [5, 11]. We also include the syllables /naː/ (contextually nasalized), /tʰaː/ (non-nasal), and /daː/ (non-nasal) for comparison. Speakers produced 10-12 repetitions of each item.

Data was collected with Acq*Knowledge* data acquisition and analysis software (BIOPAC, version 3.9.1). All data was sampled at 2000 Hz using the MP100 data acquisition unit. Participants held a double-compartment mask against the mouth and nose (Glottal Enterprise, Syracuse, NY), intended to capture oral and nasal airflow independently. Two heated pneumotachs were inserted into vents on the mask. Rubber cannulae connected the pressure ports to a Biopac TSD160a pressure transducer that recorded +-12 cm H20. A BIOPAC AFT6 600 ml calibration syringe was used to calibrate the signal for both the oral and nasal mask compartments. The airflow signal was also rectified during each recording session by adjusting the signal to zero during a voiceless stop /k/. Acoustics were simultaneously collected for segmenting purposes using a C520 head-set microphone recorded at 44.1 kHz (AKG Harman, Stamford, CT).

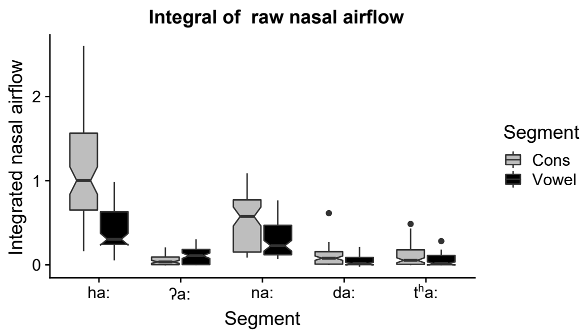
2.1. Analyses

Calibrated and rectified nasal airflow was normalized to 20 samples over time, 10 during the onset consonant and 10 during the following vowel. The integral was then taken of all samples within the consonant and the vowel separately. This yielded a single measure of cumulative nasal airflow during both the consonant and vowel for each token. For each token, the maximum of integrated nasal airflow was determined and logged as either occurring during the onset consonant or the vowel (MaxLoc).

The data were analyzed with a linear mixed effects model using the *lmerTest* package in R [8, 14]. Integrated nasal airflow was the dependent variable with fixed effects including syllable, location of maximum integrated flow (MaxLoc), and segment type (consonant or vowel). Speaker was included as a random effect. Due to the small sample size representing each gender, we did not include gender in the model.

3. RESULTS

Figure 1: Integrated nasal airflow for syllables with /a/.

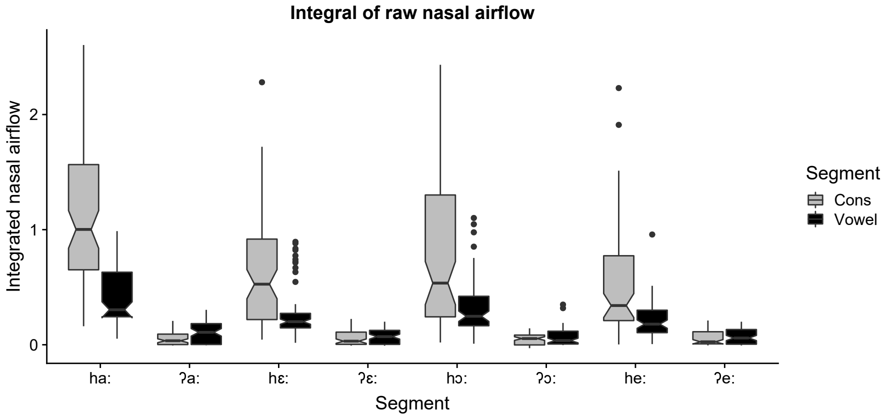


Results of a linear mixed effects model (Table 1) show significant effects between the location of maximum nasal airflow (consonant or vowel) and nasal airflow. Furthermore, whether the segment was a consonant or a vowel also effected nasal airflow. Finally, the integrated nasal airflow of /haː/ was significantly different, i.e. greater, than any other syllable.

Figure 1 shows boxplots of integrated nasal airflow for all syllables with the vowel /aː/. Two post-hoc analyses of the lme model were performed by calculating estimated marginal means with a Tukey multiplicity adjustment [9]. The first test was performed on integrated nasal airflow by Syllable contrast, while the second test was performed on integrated nasal airflow by Segment type (consonant or vowel) within the same syllables. These tests revealed many differences in integrated nasal airflow among segments. The consonant /h/ exhibited the greatest integrated nasal airflow of any other syllable during the consonant. /n/ exhibited less integrated nasal airflow than the consonant of /haː/, but similar nasal airflow to other /h/ syllables ($p>0.05$). Both /h/ and /n/ were produced with significantly more integrated nasal airflow than their following respective vowel ($p<0.05$). All other syllables are produced with similar integrated nasal airflow during the consonant and following vowel.

Figure 2 shows boxplots of integrated nasal airflow for all vowels after /h/ and /ʔ/. Again, we notice that the consonant of /haː/ was produced with

Figure 2: Integrated nasal airflow for vowels after glottal consonants



	Nasal airflow
(Intercept)	$0.90(0.07)^{***}$
Syllable:hɛː	$-0.34(0.03)^{***}$
Syllable:hɛeː	$-0.42(0.03)^{***}$
Syllable:hɔː	$-0.24(0.03)^{***}$
Syllable:ʔaː	$-0.65(0.04)^{***}$
Syllable:ʔɛː	$-0.69(0.03)^{***}$
Syllable:ʔeː	$-0.69(0.03)^{***}$
Syllable:ʔɔː	$-0.69(0.03)^{***}$
Syllable:naː	$-0.38(0.03)^{***}$
Syllable:daː	$-0.72(0.03)^{***}$
Syllable:t^haː	$-0.70(0.03)^{***}$
MaxLoc:Vowel	$-0.08(0.02)^{***}$
Segment:Vowel	$-0.20(0.01)^{***}$
AIC	515.52
BIC	597.15
Log Likelihood	-242.76
Num. obs.	1706
Num. groups: Speaker	6
Var: Speaker (Intercept)	0.02
Var: Residual	0.07

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$

Table 1: Linear mixed effects model. NasalAir $\sim$ Syllable + Segment + MaxLoc + (1|Speaker)

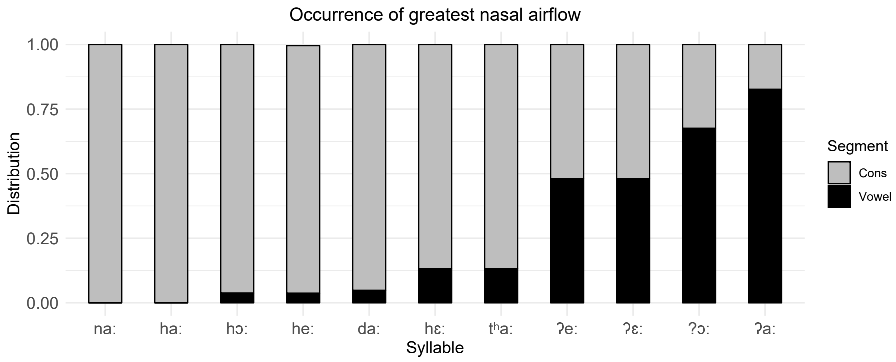
greater nasal airflow than all other consonants and vowels, including other /h/ syllables (p<0.05). Every consonant /h/ exhibited greater integrated nasal airflow than every /ʔ/. Most vowels after /h/ were also produced with greater nasal airflow than vowels after /ʔ/, except for the contrasts /hɛː/ vs /ʔaː/, /hɔː/ vs /ʔaː/ and /heː/ vs any syllable beginning with /ʔ/ (p>0.05). Furthermore, while nasal airflow was greater for every /h/ compared to the immediately following vowel, nasal airflow was similar during every /ʔ/ and its following vowel. Overall, vowels after /ʔ/ exhibited similar nasal airflow as predictably non-nasal vowels of /daː/ and /t^haː/, with the exception for the vowel of /ʔaː/ compared to /hɛː/ and /hɔː/.

The distribution of maximum nasal airflow is shown in Figure 3. For syllables /naː/ and /haː/, the maximum integrated nasal airflow occurred during the onset consonant 100% of the time. Maximum nasal airflow occurred during the consonant most of the time for syllables /hɔː/, /heː/, /daː/, and /t^haː/. The location of maximum nasal airflow was more likely to occur during the vowel for all syllables beginning with /ʔ/.

4. DISCUSSION

For all syllables beginning with /h/, including /heː/ which was not predicted to nasalize, there was greater nasal airflow during the onset consonant than any other consonants. For all other syllables, including those with /ʔ/, nasal airflow was similarly low. This result is expected because glottal stop is produced with an adducted glottis and reduced egressive airflow. However, it is surprising that nasal airflow is quite low during the low and mid-low vow-

Figure 3: Temporal location of greatest nasal airflow: consonant vs. vowel



els immediately following /ʔ/ because these contexts are reported to nasalize in previous accounts of Thai vowels [11, 5]. A post-hoc inspection of individual differences in the current study revealed that three out of six speakers exhibited nasal airflow during the vowel of /ʔaː/ that, while close to zero, was significantly greater than vowels of non-nasal conditions /daː/ and /t^haː/. We can conclude from these findings that while syllables beginning with /ʔ/ may have larger VPO than non-nasal contexts such as syllables with /d/ and /t^h/, nasal airflow during syllables beginning with /ʔ/ may be overall closer to non-nasal contexts than the more nasal /h/. Maximum integrated nasal airflow occurred during the consonant for all syllables, regardless of degree of raw nasal airflow, except for syllables with /ʔ/. For syllables with /ʔ/, maximum nasal airflow is more likely to occur during the vowel compared to the consonant.

According to the the VPU explanation for spontaneous nasalization, the source of vowel nasalization in Thai is the consonant. There is greater nasal airflow during /h/ for the syllable /haː/. For a vowel with less but still significant nasal airflow compared to non-nasal syllables, /hɔ/, the location of the maximum nasal airflow is still during the consonant most of the time; nasal airflow is also significantly greater during the consonant than the vowel. Based on our findings regarding greater nasal airflow during /h/ compared to the following vowel for all syllables, we reason that the onset consonant is likely the primary locus of nasalization that spreads to the following vowel. While we cannot assess the possibility of this pattern for syllables with /ʔ/, our results set the stage for an analysis that directly measures VPO during /ʔ/ and the following vowel.

We conclude that the the initial locus of spontaneous nasalization in Thai is the consonant for syllables beginning with /h/. VPU does not induce spontaneous vowel nasalization per se. Rather, it induces spontaneous glottal consonant nasalization that spreads. Given the relatively large degrees of nasal airflow during the consonant and following vowel of syllables beginning with /h/, we can conclude that the entire syllable /hV/ has undergone spontaneous nasalization.

Finally, that /ʔ/ exhibited minimal nasal airflow is important. This provides a possible explanation for why vowels after /h/ sound more nasal than vowels after /ʔ/: There is already increased nasal airflow during the start of the vowel after /h/. Even if /ʔ/ has greater VPO than non-nasal consonants, we observe reduced nasal airflow. Further perceptual testing is needed to confirm the complex relationship among perception of nasality, VPO, and nasal airflow.

5. CONCLUSION

We measured nasal airflow in native speakers of Thai to investigate whether the vowel or consonant has undergone spontaneous nasalization. After assessing relative degrees of nasal airflow and the temporal location of maximum nasal airflow, we conclude that in Thai the consonant undergoes spontaneous nasalization and that it is likely induced from VPU of the consonant itself.

Furthermore, increased nasal airflow during the preceding consonant may induce the perception of greater nasalization during the following vowel. This may explain why vowels after /h/ sound more nasal than vowels after /ʔ/ [5, 11]. Further perceptual testing is needed to assess this possibility.

6. REFERENCES

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