Listener Tolerance of Nasality: A Dialectal and Comparative Perspective

Research Thesis

Presented in partial fulfillment of the requirements for graduation *with research distinction* in Speech & Hearing Science in the undergraduate colleges of The Ohio State University

by

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Chapter 1: Introduction

1.1. Parameters of nasal articulation and nasalization

In common parlance, one's speech while suffering from nasal congestion is called 'nasal.' According to the fields of speech physiology and speech perception, this is a misnomer. Nasality is the perceptual correlate of the acoustic effects of nasal resonance (NR) in speech (Awan et al., 2015). These acoustic effects are the result of opening of the velopharyngeal (VP) port and the subsequent coupling between the oral and nasal cavities. Nasal congestion, manifested as a complete blockage or a constriction of nasal cavity volume, leads to lower NR, making it challenging for 'nasal'-sounding cold-sufferers to produce speech with sufficient NR when necessary. Niedzielski and Preston (2000), in a review of a finding by Labov, found that laypeople may use "nasal" as a descriptor for such speech because they either perceive excessive and insufficient nasality similarly, or perceive insufficient nasality in a separate manner from excessive nasality, but lack a satisfactory non-jargon descriptor for such speech (pp. 4-6). Thus, "nasal" in common parlance may in fact be a catch-all term used to describe any variance in perceived nasality from the norm.

During the articulation of nasal and nasalized sounds, the VP port remains open. For the production of nasal consonants, such as /m n ŋ/ in English, the oral cavity is canonically blocked off by articulators (e.g., lips or tongue) while the VP port opens. Simultaneous VP port opening and oral opening occurs during the articulation of nasalized (non-phonemic) and nasal (phonemic) vowels, such as those in French (Carignan et al., 2015). Nasalization of vowels also naturally occurs in English when a vowel is adjacent to a nasal sound in the speech stream. This assimilation is either anticipatory or carry-over in nature, and results from partial VP port opening during vowel articulation (Shriberg & Kent, 2013; Small, 2015; Bell-Berti and Krakow, 1991; Bell-Berti et al., 1995). For vowels, the acoustic effects of nasalization include widening of the bandwidth of the first formant (F1) and a drop in the amplitude of the first formant (Arai, 2006; Olive et al., 1993; Rong & Kuehn, 2012). Additional pole-zero pairs are also introduced around the F1 spectral region (Chen, 1997). Less consistent effects of vowel nasalization have been shown to appear at frequencies above F1 (Hawkins & Stevens, 1985). These acoustic effects are the result of the coupling of the oral and nasal cavities, and the increase of NR in the speech signal.

1.2. Perception of nasal resonance as nasality

1.2.1. Introduction to nasalance

The ratio of NR to total resonance, which comprises NR and oral resonance (OR), is known as nasalance (Awan et al., 2015), i.e. nasalance (%) = 100 × NR / (NR + OR). This is the most frequently derived measurement from nasometry. The Nasometer is a commercially-available instrument which allows for quantification of the speaker's degree of NR, and has been widely used in clinical and research settings. Clinically, the Nasometer serves as a supplement to perceptual evaluation when assessing speech and resonance characteristics of individuals born with cleft palate or other craniofacial abnormalities.

Factors known to influence nasalance include vowel height (Lewis et al., 2000; Awan et al., 2011), length of the speech stimulus (Watterson et al., 1999), and vocal intensity (Watterson et al., 1994; Van Lierde et al., 2011; Jennings & Kuehn, 2008). Additionally, increased NR is not the only factor that has been shown to affect degree of perceived nasality. Interarticulatory movement timing between the VP port and other articulators has been shown to affect degree of nasality perceived. Longer duration of nasalization was found to relate to an increase in degree of nasality perceived by Ha and Kuehn (2011). While NR is not the only contributing factor to the perception of nasality, speakers may still use nasality as a measure of NR in their own speech when making articulatory decisions.

1.2.2. Dialectal variance in nasal resonance

There is evidence that NR may vary dialectally. Among normal speakers, Awan et al. showed that nasalance can vary in a dialect-dependent fashion, with dialectal variation in American English (AmE) accounting for 7-9% of variation in nasalance (2015). Significant differences in NR have been shown between AmE dialects, especially between Midlands and Mid-Atlantic, with the Mid-Atlantic dialect speakers generally found to employ higher NR overall. Tamminga and Zellou conducted a comparison in NR between the Buckeye Corpus, containing samples from middle-class white native Midlands AmE speakers from Columbus OH, and the Philadelphia Neighborhood Corpus, containing samples from middle-class white native Mid-Atlantic AmE speakers from Philadelphia PA, and found significantly greater NR among the Mid-Atlantic speakers (2016). These results corroborate those in Seaver et al., (1991), in which significantly higher nasalance scores were found for Mid-Atlantic speakers than for other AmE speakers.

Additionally, ethnic variation in nasalance score has been observed by Mayo et al., (1996). Their investigation of nasalance scores and physiological measurements of VP port function found that white AmE speakers in general had significantly greater nasalance scores than African-American AmE speakers for the same passage (Nasal Sentences), and that white male AmE speakers specifically scored higher in nasalance than African-American males for the same passage (Zoo Passage) -- these differences were found by Mayo et al. not to be associated with a difference in cross-sectional nasal area (p. 146). Comparatively little research has investigated contrasts in level of NR between other dialect or ethnolect groups. On the whole, however, current findings suggest that one or more regulators of NR varies dialectally.

Certain dialects are also considered to be 'nasal' as an overt topic of public comment. One such dialect is the Inland North (IN), which essentially includes speakers from metropolitan and rural areas immediately surrounding the Great Lakes (Labov et al., 2006, pp. 187-194). The Inland North and surrounding dialect areas such as the Mid-Atlantic region have been shown by Hartley and Preston to be consistently characterized as more perceptually “nasal” (1999). In a folk dialectology study, Hartley and Preston asked a sample of 147 participants from Michigan, 123 participants from Indiana, 65 participants from Oregon and 50 participants from South Carolina to hand-draw dialectal regions on a map of the United States and provide a description for each. Hartley and Preston’s results show that speakers from outside the Inland North, particularly from South Carolina and Oregon, characterize Northern and Northeastern speech as nasal more commonly than those from Michigan and Indiana do (pp. 235-236). This suggests that there is some feature salient to an outside listener which marks IN speech as more nasal.

One feature of the IN dialect is the raising of /æ/ to approximate /ɛ/, resulting from a lowering in the frequency of the F1 of /æ/ (Labov et al., 2006, p. 193). This shift is considered to be the trigger of a larger chain shift, the Northern Cities Vowel Shift, common to the Inland North and larger Northern dialect region (pp. 188-190). Labov et al found that there is a stronger regression coefficient between the raising of /æ/ and the presence of /æ/ before a nasal coda for IN speakers (189) than other AmE speakers (154), as well as a stronger regression coefficient between the raising of /æ/ and the presence of /æ/ after a nasal onset for IN speakers (70) than other AmE speakers (40) (2006, p. 195). Additionally, one reflex of /æ/-raising, found by Callary in an area of Northern Illinois included in the IN dialect area, is characterized by partial nasalization, even when not found in an environment for anticipatory or carry-over nasalization (1975, p. 157). These findings suggest that laypeople who identify IN speech as ‘nasal’ may associate the raised /æ/ feature with carryover or anticipatory nasalization – therefore, IN speech may be thought to be more ‘nasal’ because one of its features is associated with nasalization. Further investigation was taken in this study to determine whether IN speakers speak with greater NR, serving as a possible impetus for increased perception as nasal.

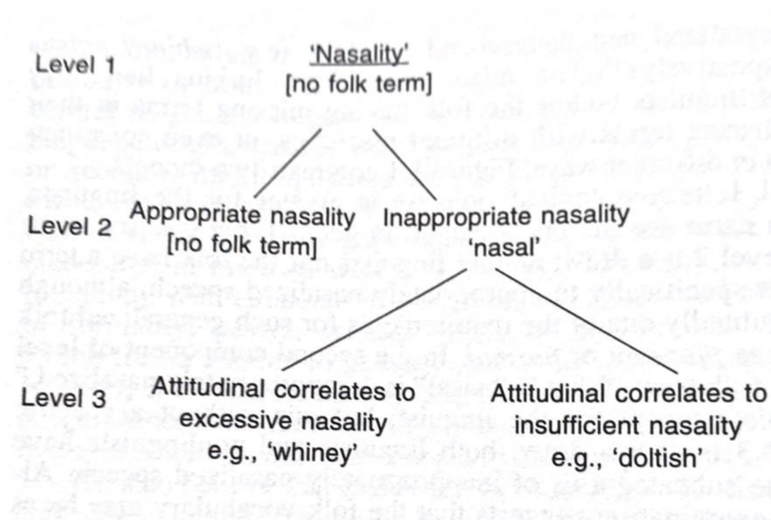
1.2.3. Awareness of nasality

Studies have shown that speakers perceive nasality in their own speech and are able to make compensatory adjustments accordingly. De Boer and Bressman (2017) showed that speakers who listened to artificially-modulated NR in a feedback loop made simultaneous compensatory adjustments to their own NR in response to that feedback. Specifically, speakers took compensatory action to reduce NR in their speech when artificially-increased NR was presented to them in the feedback loop. This suggests that speakers, to some degree, perceive nasality in their own speech, from above or below the level of linguistic awareness, through an oral-aural feedback channel. The inverse relationship, however, was not observed to be as strong; speakers did not as consistently increase their level of NR in response to presentation of artificially-decreased NR through the feedback loop (de Boer & Bressman, 2017). This suggests that while speakers are sensitive to NR in their own speech, they are more sensitive to detecting greater-than-normal nasality than lesser-than-normal nasality.

In addition to de Boer and Bressman’s deduction that speakers can reliably use compensatory techniques to attenuate NR, Story et al. (2001) showed that speakers are able to make articulatory adjustments to amplify NR as well. The study investigated the acoustic and physiologic parameters of speech produced by trained vocal performers. These performers were asked to produce a speech sample with a ‘normal,’ ‘yawny,’ and ‘twangy’ voice quality. 'Twang' is often associated in layman's terms with the perception of excessive nasality, but also often references vowel shifts relevant to dialects considered 'twangy' (Rodgers, 2016; Story et al., 2001). While not all subjects were observed by Story et al. to have greater NR for the ‘twangy’ voice quality, those that did made articulatory adjustments to increase NR. These adjustments included fronting the tongue and shortening and constricting the oral cavity (Story et al., 2001). Other studies have shown that increased oral acoustic impedance, such as that present in high vowel articulation, yields higher nasalance (Lewis et al., 2000). While nasalance data was not collected by Story et al., one would expect an increase in nasalance in such speakers’ ‘twangy’ production as the OR component of nasalance would be reduced relative to the NR component. Awan et al found that among Southern AmE speakers an increase in nasalance was partly attributed to ‘twangy’ features, corroborating Story’s findings, but no direct physiologic data were collected (2015). These studies show that speakers can make articulatory adjustments to NR in their speech, which suggests they use perceptions of nasality to judge their level of NR and make adjustments accordingly. Arguments that speakers perceive differences in NR, both greater than and lesser than normal, are therefore well founded.

Additionally, when rating others’ speech, speakers have been found by Labov to categorize nasalized (i.e. greater-than-normal NR) and denasalized (i.e. lesser-than-normal NR) speech together as ‘nasal’ (referenced in Niedzielski & Preston 2000, p. 4). In a review of this finding, Niedzielski and Preston caution that Labov’s generalization may indicate that there is not popular term outside of scientific jargon to describe denasalized speech (2000, p. 4-5). This vocabulary gap may cause all speech that is perceived to vary from expected nasality, whether greater or lesser, to be described as nasal, although speakers may still perceive lesser-than-normal nasality and greater-than-normal nasality differently (p. 5-6). Due to lack of descriptive vocabulary for perceived variance from standard levels of nasality, Niedzielski and Preston found that speakers substitute attitudinal descriptors such as "whiney" for greater nasality and "doltish" for lesser nasality (p. 5-6). Figure 1, from Niedzielski and Preston (2000, p. 6), provides a visual aid for this proposal.

Figure 1: Folk vocabulary taxonomy for "nasality". (Niedzielski & Preston, 2000, p. 6).



1.3. Listener tolerance of nasality

Given that studies such as de Boer and Bressman's (2017) and Story et al.'s (2001) have demonstrated that speakers can make compensatory articulatory adjustments to adjust levels of NR in their speech, which further suggests that speakers on some level perceive nasality in their speech through an oral-aural feedback loop, it seems reasonable to hypothesize that speakers' perception of nasality may be affected by their own production as perceived through such a feedback loop. Thus, this study explored the connection between perceptions of nasality and the speaker's NR.

Particularly, we suppose that a 'tolerance effect' may exist for nasality. This tolerance effect would result in speakers with a greater degree of NR perceiving less nasality in the same stimulus as speakers with a lower degree of NR. Our notion of listener tolerance of nasality could occur from a mechanism wherein consistent oral-aural feedback of heightened NR is related to an increase in the listener's threshold for the acoustic effects of NR to be perceived as nasality. Essentially, listeners might be 'used to' nasality in their own speech and thus not rate a stimulus with increased nasalization as highly nasal as a listener with a lesser degree of NR would.

Sensory adaptation, wherein repeated or extended exposure to the same stimulus affects perception of that stimulus, has been demonstrated in vision (Webster, 2012) and hearing (Anstis & Saida, 1985), with diverse effects. In vision, an afterimage can persist for some time in one's vision after lengthy exposure to the same image (Webster, 2012), and in hearing, Anstis & Saida demonstrated that continual exposure to a frequency-modulated (FM) square wave, initially perceived as one tone jumping from a higher to lower frequency, a perception called *coherence*, is eventually perceived as two concurrent (one high-pitched, one low-pitched) interrupted tones, a perception called *fission* (1985). Complex auditory signals like nasalization might also be perceived differently over time due to the buildup of adaptation in some portion of the auditory system to the unique acoustic parameters of nasalization. The existence of a listener tolerance effect for nasality would be suggested if speakers with greater degrees of NR reliably rate the same nasalized stimuli as less nasal than the average speaker would.

Therefore, the purpose of this study was two-fold: 1) to determine if speakers of the IN dialect produce speech with greater degree of NR compared to speakers of other dialects, and 2) to examine the relationship between the speakers' NR and their nasality perception of synthetic listening stimuli with varying degrees of nasality.

Chapter 2: Methods

The study was approved by the Ohio State University Institutional Review Board, and informed consents were acquired from the participants prior to their participation.

2.1. Participants

A total of 40 adult native American English speakers (5 males and 35 females) were recruited through convenience sampling. The age of the participants ranged from 18 years to 44 years (mean age: 20.88 years, standard deviation: 4.10 years). All participants had no history of speech, language, or hearing issues. In addition, participants were free from any symptoms of colds or upper respiratory infections on the day of the scheduled session. Participants were compensated monetarily and/or with academic credit in appreciation of their time.

2.2. Experimental protocol and data collection

The experiment consisted of a cross-sectional survey in three parts, assessing each participant's linguistic background (i.e. AmE dialect), NR embedded in his/her speech (production), and perceptual judgment of listening stimuli with varying degrees of nasality (perception).

2.2.1. Task 1: Linguistic background interview

The linguistic background interview aimed to probe environmental factors that might have influenced each participant's language and dialect use, allowing for adequate identification of each participant's dialectal status. Questions concerned one's native dialect of AmE, the language and dialect spoken at home, the subject's region of origin and regions in which they have lived, worked or studied in for a time greater than one year. Given the particular geographic location of the Ohio State University, it was anticipated that many of the participants may be speakers of the IN dialect, as this dialect group includes the metropolitan and rural areas surrounding Cleveland, OH; Toledo, OH; etc. (Labov et al., 2006, pp. 187-194). Thus, identification of speakers who are influenced by the IN dialect, or are native speakers thereof, was of particular interest, especially due to the associations between IN speakers and nasality previously discussed.

Speakers were identified as speaking or being influenced by IN dialect if they met any one of these criteria:

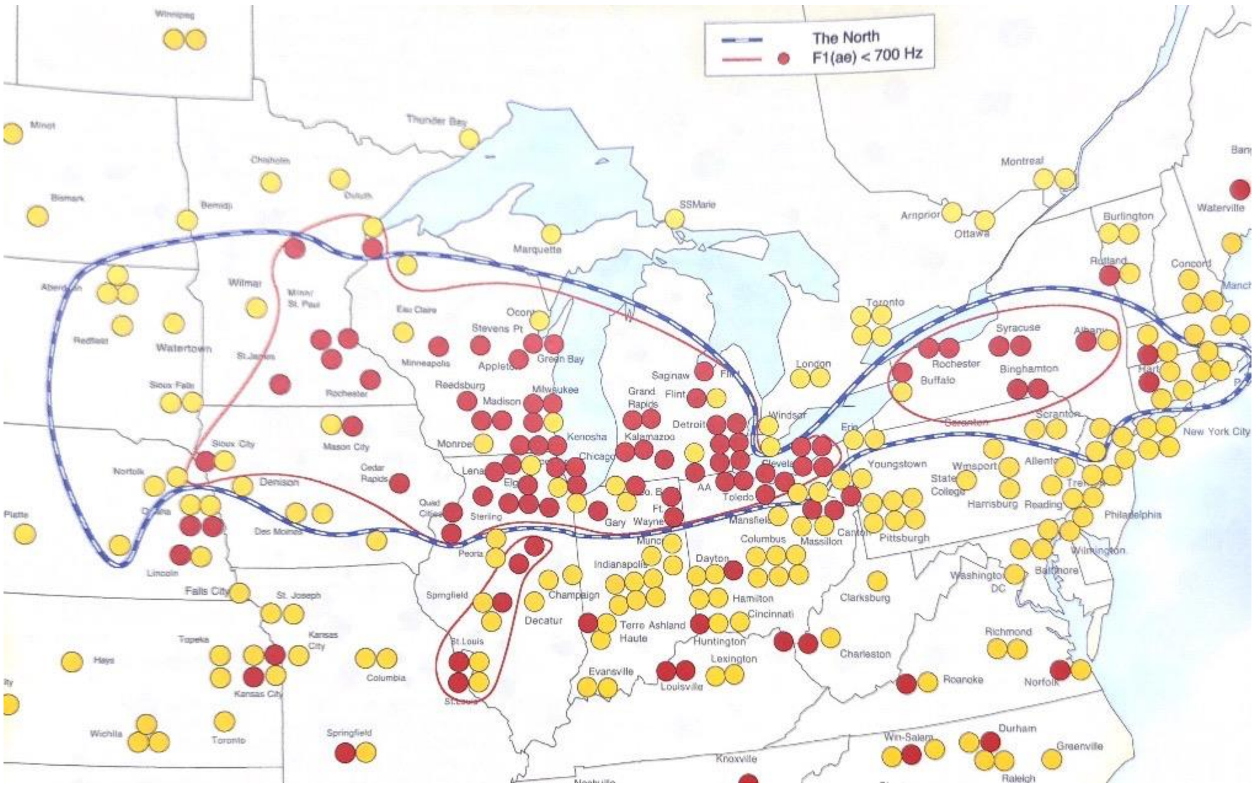
1) any speaker who identified himself/herself as speaking a dialect of a city inside the isogloss for the IN dialect as identified by Labov et al. (2006, p. 194),

2) any speaker who was raised in a region within this isogloss, or

3) any speaker who has lived in a region inside this isogloss for a time greater than one year.

To determine whether participants matched these criteria, their indicated regions of origin and living for criteria 1, 2 and 3 were plotted on a map overlaid with Labov et al.'s IN dialect area isogloss. The map showing this isogloss from Labov et al. (2006, p. 194) is shown below as Figure 2. The blue line represents the criterion isogloss.

Figure 2: Inland North dialect area (blue). (Labov et al., 2006, p. 194).



2.2.2. Task 2: Speaker nasal resonance evaluation

Participant speech was recorded using the Nasometer II (Model 6450, KayPENTAX™, Montvale, NJ). This instrument measures speaker NR by separately measuring a speaker's nasal and oral acoustic energy levels, using two physically-separated microphones. All acoustic signals recorded by the Nasometer are subject to a filtering process through a bandpass filter with a center frequency at 500 Hz with a 300 Hz bandwidth. The Nasometer headgear was comfortably, yet snugly secured against the participant's face. The headgear included a metal barrier which sat on and projected from the participant's philtrum, allowing the microphones on either side of the barrier to separately record oral and nasal acoustic energy, as described.

Speech samples obtained from participants included three standardized passages (Rainbow Passage, Nasal Sentences, and Zoo Passage, the text of which may be found in Appendix A) as well as syllable repetitions and prolonged sounds listed in MacKay-Kummer SNAP-R (Simplified Nasometric Assessment Procedures-Revised, MacKay & Kummer, 2005). SNAP-R syllable repetitions and prolonged sounds comprise a series of repetitions of open CV syllables with an oral obstruent onset (from the set /p t k s ʃ/) and a nucleus of /ɑ/ or /i/, a series of repetitions of open CV syllables with a nasal onset of /m/ or /n/ and a nucleus of /ɑ/ or /i/, and prolonged articulations of the sounds /a i u m/. Participants were instructed to produce each speech sample at a rate and intensity comfortable to them.

2.2.3. Task 3: Perceptual rating of nasality

2.2.3.1. Stimulus creation

Participants rated the level of nasality they perceived in synthesized speech stimuli. The stimuli consisted of 12 clips of synthesized vowel articulations. The vowels chosen were /ɛ ɑ ʌ/, and the clips were generated through an online implementation of the Klatt speech synthesizer (Bunnell, 2015). The F1, second formant (F2), and third formant (F3) formant frequency and bandwidth (B1, B2, B3, respectively) values were derived from Hawks (1994, p. 1082), and the stimuli lasted 1000 ms.

B1 was modulated in each stimulus in order to simulate vowels with varying degrees of nasalization. All other values were kept at the default for the synthesizer, and the frequencies of F1, F2 and F3, and B2 and B3 were kept consistent for each vowel. Four discrete categories were defined, and one stimulus in each category was created. The category names and B1 values were as follows: ‘flat’ (i.e., non-nasal) at 100% of Hawks’ value, ‘mid-flat’ at 200%, ‘mid-nasal’ at

400% and ‘nasal’ at 800%[1]. These stimuli were reviewed by an expert panel of research assistants to ensure that the level of nasality in each category was perceptually distinct from the others.

The selection of /ɛ ɑ ʌ/ was informed by a desire to avoid confounding variables. At first, an attempt was made to use the vowels at the corners of the vowel space (i.e., /i ɑ u/), so that the vowels would be as perceptually distinct as possible. As the stimuli were generated, it was noted that high vowels /i u/ could not be presented with our modulation of F1 in each of the four categories. Our pilot analysis revealed that proximity between the fundamental frequency (F0) and F1 in these high vowels caused the F0 and F1 spectral peaks to entirely merge for the more-nasalized categories, which, in fact, has been reported as a source of the common formant measurement errors (e.g. Shadle et al., 2016). In addition to the F1 shifts that potentially threaten the identity of these high vowels, the rounding of /u/ introduced acoustic effects that could lurk as an additional confound. To remedy these issues, high vowels /i u/ were substituted for their mid-low unrounded counterparts /ɛ ʌ/. After synthesis, each vowel stimulus was spectrally analyzed, and it was determined that F0, F1 and F2 always peaked separately regardless of diminished F1 prominence, thus avoiding the spectral issues introduced by high vowel stimuli. Acoustic attributes of synthesized speech stimuli are summarized in Table 1. Table 2 shows the relative amplitudes of vowel formants, notably showing across stimuli for each vowel an approximate 5 dB drop in amplitude of F1 (A1) with each doubling of F1 frequency, while A0 and A2 remain quite stable.

[1] Note that the names for these categories are not meant to suggest that, for example, only at 800% of the normal bandwidth of F1 are vowels perceived as nasal. They are instead shorthand used to refer to the stimuli as one would expect them to be perceived – the flat stimulus to be perceived as less nasal than the mid-flat stimulus, the mid-flat less nasal than the mid-nasal, and so forth.

Table 1: Relative frequency and bandwidth of stimulus vowel formants.

Stimulus	*F0 (Hz)*	*F1*	*F2*	*F3*	*B1 (Hz)*	*B2*	*B3*
/ɛ/ flat	100	583	1785	2528	53	80	119
/ɛ/ mid-flat	100	583	1785	2528	106	80	119
/ɛ/ mid-nasal	100	583	1785	2528	212	80	119
/ɛ/ nasal	100	583	1785	2528	424	80	119
/ɑ/ flat	100	921	1329	2528	55	66	119
/ɑ/ mid-flat	100	921	1329	2528	110	66	119
/ɑ/ mid-nasal	100	921	1329	2528	220	66	119
/ɑ/ nasal	100	921	1329	2528	440	66	119
/ʌ/ flat	100	627	1199	2528	49	53	119
/ʌ/ mid-flat	100	627	1199	2528	98	53	119
/ʌ/ mid-nasal	100	627	1199	2528	196	53	119
/ʌ/ nasal	100	627	1199	2528	392	53	119

Table 2: Relative amplitude of stimulus vowel formants.

Stimulus	*A0 (dB)*	*A1*	*A2*	*Overall intensity*
/ɛ/ flat	55.4	63.0	57.1	79.28
/ɛ/ mid-flat	55.7	58.0	57.1	77.66
/ɛ/ mid-nasal	55.8	53.1	57.2	75.76
/ɛ/ nasal	55.2	48.6	57.9	76.64
/ɑ/ flat	54.9	69.6	66.7	85.47

/ɑ/ mid-flat	55.2	64.8	66.8	83.32
/ɑ/ mid-nasal	55.0	59.6	66.5	82.60
/ɑ/ nasal	55.0	55.5	65.8	81.55
/ʌ/ flat	55.8	64.1	59.5	80.00
/ʌ/ mid-flat	55.6	60.5	60.0	78.46
/ʌ/ mid-nasal	55.5	55.5	59.6	77.08
/ʌ/ nasal	55.3	50.4	60.0	76.23

2.2.3.2. Stimulus rating

To rate the stimuli, participants were seated in a sound-attenuated booth. The stimuli were presented through Sennheiser circumaural headphones (Model HD-429, Old Lyme, CT) at a peak level of approximately 65 dB A. The rating task was preceded by a practice session to ensure that the participant could detect the difference between nasalized and non-nasalized stimuli. During the practice session, the administrator presented the flat and nasal stimuli for /ɛ/ repeatedly. The participant was asked to respond visually (e.g. giving a ‘thumbs-up’ sign through the booth window) when the nasal stimulus was presented. Participants were advanced to the experimental rating session only after they were judged by the administrator to be able to reliably distinguish these stimuli during the practice session. Participants were so judged once they correctly identified the nasal stimulus presentation and correctly rejected at least two non-nasal stimulus presentations three times in order.

Participants were presented with a total of 60 listening stimuli, consisting of the 12 stimuli described in 2.2.3.1. presented 5 times per stimulus. The stimuli were grouped by vowel identity. Within each vowel identity, the stimuli were presented in random order. Additionally, the three vowel identity groups were presented in random order.

Listening stimuli were rated using direct magnitude estimation with modulus (DME-M) as a perceptual scaling technique. In brief, DME-M involves repeatedly exposing a participant to a stimulus, called the modulus, with a known value for the variable in question. The participant is then asked to record a numerical value that relates other stimuli to the modulus in terms of the strength of the variable in question. This methodology is commonly used to estimate variables in speech perception (e.g. Schiavetti, 1992; Whitehill et al., 2002).

Each stimulus presentation was immediately preceded by a modulus presentation. That is, participants were exposed to a mid-nasal stimulus (modulus), and told the modulus's 'nasality level' was 100. Three seconds after presentation of the modulus, the stimulus was presented. Six seconds of silence passed between each modulus-stimulus pair. During that six-second pause, participants recorded the 'nasality level' in each stimulus relative to the 100 'nasality level' of the modulus. The modulus' vowel identity matched the vowel identity of the stimulus. Participants were informed that stimuli would be presented at 'nasality levels' below, above, and at the same degree as the modulus. They were also informed that after each 20th stimulus, the vowel identity of the stimulus and modulus would change.

2.3. Data analysis

Based on linguistic background survey data, participants were sorted into IN and non-IN groups. Each participant's NR was represented by mean nasalance obtained from the acquired nasometric data for each speech sample. Each participant's perception of nasality was represented by mean nasality ratings (DME-M) computed for each vowel across varying categories.

2.3.1. Reliability

Inter-rater reliability was assessed by comparing measurement from the student researcher with that from a second rater on a randomly selected set comprising 23% of the entire data. The two-way mixed, absolute agreement and single-measure intraclass correlation coefficients (ICCs) for nasalance measurements was 1. The mean nasalance difference between two raters was .2% (SD: .7). Two raters agreed on 88% of measurements within 1% nasalance.

2.3.2. Statistical treatment

To determine whether levels of NR varied by dialect, the participant data were divided into two groups, the experimental group with speakers of the IN dialect as identified by the linguistic background interview, and the control group with no such influence. A one-way multivariate analysis of variance (ANOVA) was performed. Between-groups comparisons were made with mean nasalance scores across different speech stimuli.

To determine whether a tolerance effect for nasality is extant, a series of non-parametric Spearman's Rank correlation coefficients were obtained between all possible sets of NR-DME-M variables. All statistical tests were performed using SPSS Statistic 22.0 (IBM Corporation, Armonk, NY) at an alpha level of .05.

Chapter 3: Results

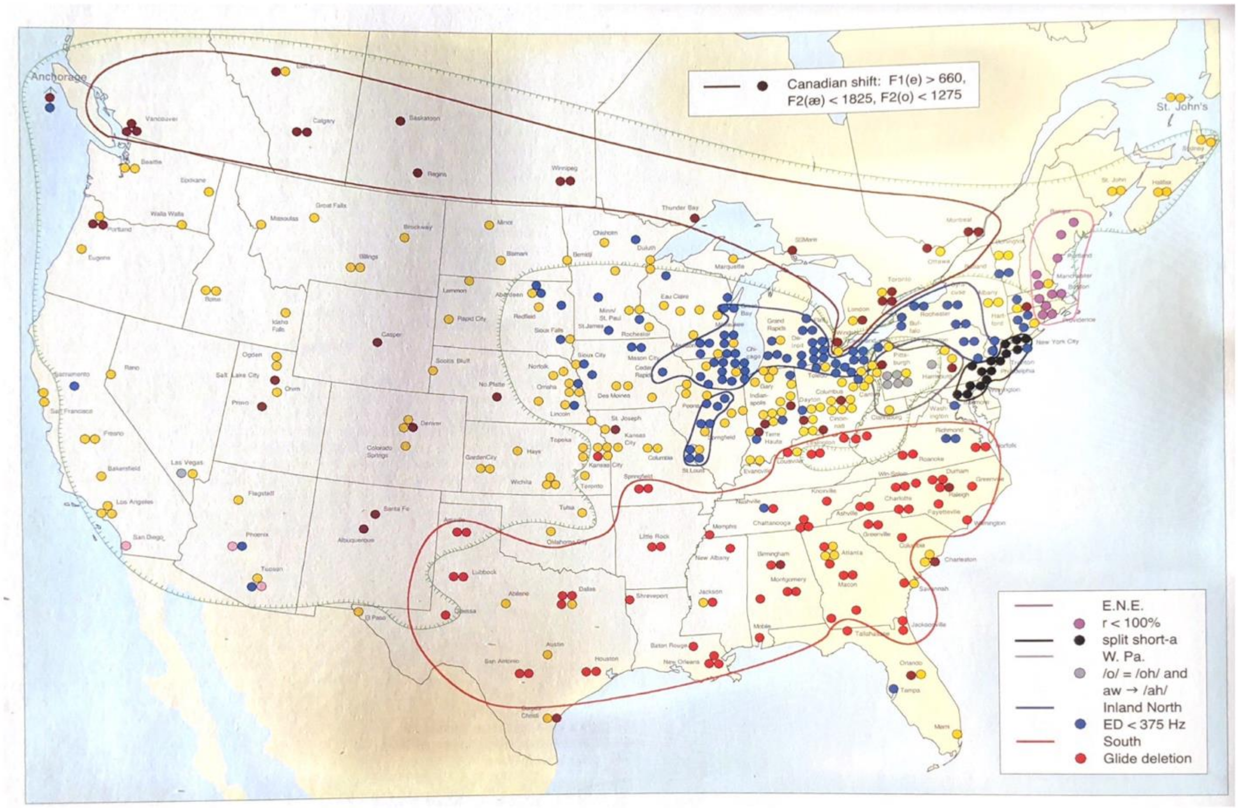
3.1. Participant exclusion considerations

Convenience sampling resulted in a sex distribution of 5 male participants and 35 female participants within a total of 40 participants. In order to control for sex-related variations in NR (e.g. Seaver et al., 1991), data from the small number of male participants were excluded from the subsequent analyses, but summary statistics of their NR and DME-M stimulus ratings may be found in Appendix B.

Similarly, speakers of the Mid-Atlantic (MA, n=6) and Southern/Appalachian (S, n=2) dialects were excluded; these dialects have also been found to be socially associated with increased nasality (Hartley and Preston 1999) with some supportive acoustic evidence (Awan et al., 2015; Seaver et al., 1991). Such participants were identified using the same criteria detailed in 2.2.1. to identify IN speakers, but using the isoglosses found on the map in Labov et al. (2006, p. 132), seen below as Figure 3; the black line represents the isogloss for the MA dialect region, and the red line represents the isogloss for the S dialect region. Summary statistics for MA and S participants are provided in Appendix B.

Four participants were additionally excluded from the study for their atypically high or low levels of nasalance, suggestive of possible resonance disorders.

Figure 3: Mid-Atlantic (black), Southern (red) dialect areas. (Labov et al., 2006, p. 132).



3.2. Nasal resonance in Inland North vs. general American English groups

Table 3 provides descriptive data of NR, represented by the nasalance score (%), for the IN and general AmE groups across various speech stimuli. While the IN group had slightly higher nasalance for prolonged vowels and repetitions of /mɑ/ than the general AmE group, mean between-groups differences were limited to 0 to 4%. Results showed that dialect had no statistically significant effects on nasalance across various speech samples ($F_{(11,10)} = 2.80$, $p = .058$, Wilk's Lambda = .245).

Table 3: Summary statistics of nasal resonance by dialect group.

Group	*IN dialect (n=14)*	*General AmE (n=8)*
Nasometry sample	*Nasalance (%)*	*Nasalance*
Rainbow Passage	34	34
Nasal Sentences	60	61
Zoo Passage	13	13
SNAP-R oral obstruent + /ɑ/[2]	10	11
SNAP-R oral obstruent + /i/[3]	19	21
SNAP-R nasal stop + /ɑ/[4]	57	54
SNAP-R nasal stop + /i/[5]	78	78
Prolonged /ɑ/	22	19
Prolonged /u/	17	15
Prolonged /i/	31	27
Prolonged /m/	96	96

3.3. Listener tolerance of nasality

Table 4 provides descriptive data of DME-M ratings for all non-excluded participants (n=22) across the prepared synthesized stimuli. Linear associations between the participants' NR and DME-M ratings were explored to test listener tolerance of nasality. Results showed statistically significant negative associations in the following three pairs:

[2] Five repetitions each of /pɑ/, /tɑ/, /kɑ/, /sɑ/, /ʃɑ/
[3] Five repetitions each of /pi/, /ti/, /ki/, /si/, /ʃi/
[4] Five repetitions each of /mɑ/, /nɑ/
[5] Five repetitions each of /mi/, /ni/

- SNAP-R oral obstruent + /ɑ/; /ɛ/ mid-flat: Spearman's rho (r_s = -.57, p < .05)

- SNAP-R oral obstruent + /ɑ/; /ɑ/ flat: Spearman's rho (r_s = -.57, p < .05)

- SNAP-R oral obstruent + /ɑ/, /ɑ/ mid-nasal: Spearman's rho (r_s = -.53, p < .05)

Table 4: Mean nasality ratings across stimuli by dialect group.

Group	*IN dialect (n=14)*	*General AmE (n=8)*
DME-M stimulus	*Mean rating (standard dev.)*	*Mean rating (standard dev.)*
/ɛ/ flat	120 (47)	92 (52)
/ɛ/ mid-flat	125 (51)	105 (43)
/ɛ/ mid-nasal	120 (43)	107 (45)
/ɛ/ nasal	128 (53)	112 (37)
/ɑ/ flat	116 (48)	85 (35)
/ɑ/ mid-flat	121 (47)	89 (32)
/ɑ/ mid-nasal	125 (46)	103 (37)
/ɑ/ nasal	136 (48)	121 (37)
/ʌ/ flat	124 (47)	82 (37)
/ʌ/ mid-flat	103 (42)	92 (44)
/ʌ/ mid-nasal	123 (49)	109 (49)
/ʌ/ nasal	112 (38)	97 (30)

Chapter 4: Discussion

This study investigated the links between production of heightened NR embedded in speech over time and the potential that exposure to that heightened NR through speech monitoring over time could diminish a listener's ability to perceive nasality. The nasometric evaluation quantified each participant's level of NR, and the subsequent DME-M rating of synthesized speech stimuli quantified each participant's perception of nasality. Capturing both production and perception through valid measurements allowed a statistical analysis comparing these factors. Additionally, to investigate whether IN speakers are characterized in popular conception as more highly nasal (Hartley & Preston, 2000) due to increased NR production in that dialect group, a linguistic background interview allowed IN speakers to be separated from speakers of other dialects of AmE. This interview set the stage for a between-groups comparison of NR to determine if dialectal variation in NR affects IN speech acoustics.

Overall, results from the study showed that there is no statistically significant dialectal effect (IN vs. general AmE) on nasalance score across various speech stimuli, which suggests that IN speakers do not, in general, speak with higher levels of NR. Secondly, should the notion of listener tolerance of nasality exist, one would expect to find statistically significant negative correlation coefficients between nasalance scores and DME-M ratings of listening stimuli. This pattern was observed in three nasalance sample / DME-M rating pairs, providing limited empirical support to the notion of listener tolerance of nasality.

4.1. Nasal resonance in Inland North vs. general American English groups

No statistically significant nasalance differences between the IN and general AmE groups across various speech stimuli suggest that IN speakers do not speak with increased NR relative to

AmE speakers overall. This does not serve as evidence against dialectal or ethnolectal variance in NR, but instead refines the AmE speaker groups between which exists a difference in NR. As explained in 1.2.2., it is conceivable that dialectal and/or ethnolectal differences observed in NR by other studies (Awan et al., 2015; Tamminga & Zellou, 2016; Seaver et al., 1991; Mayo et al. 1996) might be accounted for by variance in the function of some regulator of NR, such as VP port opening. This result shows that this variance does not separate the IN dialect from general AmE in terms of NR.

However, popular notions that cast the Inland North as more highly 'nasal' still clearly exist (Hartley & Preston 1999). Other documented differences between IN and general AmE, such as vowel shifts noted by Labov et al. (2006), Callary (1975), etc., may ultimately be responsible for such notions. For example, Labov et al.'s finding that the salient IN feature of /æ/-raising is more strongly associated with contexts for anticipatory or carry-over coarticulatory nasalization in IN speakers than in general AmE speakers (2006, p. 195), or Callary's finding that one IN reflex of /æ/-raising is also partially nasalized even outside such contexts (1975, p. 157), might provide evidence that the characterization that the IN dialect is more nasal than general AmE stems from listeners associating /æ/-raising with nasalization. This difference in the distribution of /æ/-raising in the IN dialect than in general AmE may affect NR, as vowel height has been shown to influence nasalance (Lewis et al., 2000; Awan et al., 2011). However, this study's finding that IN speakers do not speak with greater NR suggests that if the association between /æ/-raising and coarticulatory nasalization does affect NR, it does so only minimally, as the standardized speech samples included /æ/ in a variety of contexts for nasalization, such as '*and'* /ænd/ and '*man'* /mæn/ in the Rainbow Passage and '*jam'* /dʒæm/ and '*rang'* /ɹæŋ/ in the Nasal Sentences.

So, on the whole, an association between /æ/-raising and nasalization in IN speakers due to phonological distributional differences may exist among the public without an increase in IN speakers' NR, explaining the popular characterization of IN speakers as nasal without reference to NR. Further study should be devoted to the relationships between nasalization, /æ/-raising and other features of the IN dialect, to verify such relationships and further determine whether they influence perception of IN speakers as nasal.

4.2. Listener tolerance of nasality

For listener tolerance of nasality to exist, one would suppose that a 'threshold level' of nasality, perhaps quantified in the amplitude of the acoustic effects of nasalization, would exist. Below such a threshold, speakers are perceived to be non-nasal, and above such a threshold, speakers are perceived to be nasal. In the case of listener tolerance of nasality, constant exposure to high levels of nasal resonance from one's own speech would raise the threshold for perception of nasality over time. Sensory adaptation offers a potential mechanism by which listener tolerance of nasality could occur, perhaps similarly to the afterimage effect in vision, where a persistent visual stimulus is perceived for some time after the stimulus is removed (Webster, 2012). Degradation in ability to perceive complex auditory signals over time was demonstrated by Anstis & Saida, who found that the perception of an FM square wave over time changed from one tone jumping between two frequencies, *coherence*, to two tones interrupting each other, *fission* (1985), suggesting that complex auditory patterns, perhaps including the acoustic effects of nasalization, can be subject to sensory adaptation. Listener tolerance of nasality would suppose that sensory adaptation over time to nasalization induces a change in the threshold for perception of nasality.

The dearth of statistically significant negative associations between nasalance scores and DME-M ratings of nasalized stimuli suggest that listener tolerance of nasality is not strongly supported by the results of our analysis. The three nasalance sample / DME-M speech rating pairs which yielded statistically significant negative associations between these variables provide some, if a small, degree of support for the notion of listener tolerance of nasality. These findings suggest that such a tolerance either plays a small role in the judgment of the nasality of other speakers, or that such tolerance plays a larger role, but was obfuscated by the particulars of this study.

An additional pattern, deserving more attention in further study, is that IN participants consistently rated *each* stimulus as more nasal as general AmE participants did on average, as shown in Table 4. Because no association between dialect and NR was found, this pattern does not provide support for listener tolerance of nasality, but suggests that nasal perception thresholds perhaps vary dialectally without influence from NR. Few conclusions should be distilled from this result without further investigation.

The cautiousness in describing the conclusions to be drawn from this study's findings stems from the fact that participants were asked to rate computer-synthesized vowel articulations. Even if listener tolerance of nasality in others' speech exists, its appearance may be obfuscated by the use of sustained vowel stimuli or synthesized stimuli, which differ significantly from live speech, the selection of certain vowels for inclusion in stimuli over others, or the familiarity of participants with identifying and quantifying nasalization. Nonetheless, it may be that a listener tolerance of nasality effect exists in other judgment scenarios that this study did not test for, i.e. not for the judgment of a third party's speech, but perhaps in other situations.

One such scenario may be the judgment of one's own speech. This scenario is particularly interesting because of the findings of de Boer & Bressman (2017), which suggest that nasality information about one's own speech is indeed used by speakers in order to enact articulatory alterations to reduce NR. The wide standard deviations listed in Table 4 for average DME-M nasality ratings of synthesized speech stimuli may also suggest that speakers are not able to reliably and correctly judge nasality in other speakers. This contrasts de Boer & Bressman's results, which suggest that speakers are accurately sensitive to nasality information in their own speech on the level of speech monitoring (2017).

Further inquiry should also be made into whether listener tolerance of nasality affects judgments of one's own speech. Such a study may essentially replicate de Boer & Bressman's (2017) methodology, but refocus it on speech judgment rather than speech monitoring. Additionally, an analysis of the participant's NR would be conducted. Such an NR analysis can be conducted in an identical manner to that in this study, asking participants to produce standardized passages while their speech is recorded via nasometry, and nasalance scores derived therefrom. Then, participants' recorded readings of standardized passages would be acoustically modified to modulate NR. Production of NR and perception of nasality would be compared similarly to the analysis conducted in this study, i.e. participants would rate the level of nasality they perceive in each modulated live speech sample, and these ratings would be analyzed against nasalance measurements to determine whether a statistically significant relationship exists between those factors. A result that would support the notion of listener tolerance of nasality in self-judgment would be a statistically-significant negative association found between participant nasalance and average perceived nasality ratings of one or more modulated live speech sample categories (e.g. 100% NR of original sample, 200%, etc.) across participants.

4.3. Miscellania: Response patterning

While some (10 of 22) listeners did judge at least one vowel set of stimuli in the ‘expected’ manner, that is, assigning the lowest average nasality rating to the flat stimulus, the second lowest to the mid-flat stimulus, the second highest to the mid-nasal stimulus, and the highest to the nasal stimulus, it is notable that the majority of participants’ scores did not match this expected pattern. Instead, some (4 of 22) listeners instead rated at least one vowel set of stimuli *exactly opposite* to the expected pattern, with the nasal stimulus being rated on average with the lowest nasality rating, the mid-nasal with the second-lowest, etc. – for brevity, a ‘flipped’ response pattern. This suggests that listeners are unable to judge the level of nasality in isolated vowel samples with accuracy.

As explained, this inability may result from unfamiliarity with synthesized speech or prolonged vowel articulations. Unfamiliarity with stimulus type used in this study causing decreased ability to judge nasality is supported by previous research. Ali et al. showed that listeners can reliably use nasality perceived in vowels nasalized in anticipatory nasalization to predict that a CVVN stimulus with the nasal consonant coda clipped away indeed ends with a nasal consonant coda (1971). This predictive ability requires that listeners extract nasality information from nasalized vowels in some way, but our result may indicate that listeners are less able to extract this information from non-natural speech, i.e. the synthesized and prolonged vowel stimuli used in this study.

Additionally, the relative prevalence of the flipped response pattern may serve as evidence of Niedzielski and Preston’s refinement of Labov’s suggestion that ‘nasal’ serves as a layman term for any aberration from the norm in perceived nasality (2000), and those participants returning a ‘flipped’ response pattern may have learned to associate ‘nasal’ with hyponasal aberration rather than hypernasal aberration.

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Appendix A: Standardized passages

A.1. The Rainbow Passage

"When the sunlight strikes raindrops in the air, they act as a prism and form a rainbow. The rainbow is a division of white light into many beautiful colors. These take the shape of a long round arch, with its path high above, and its two ends apparently beyond the horizon. There is, according to legend, a boiling pot of gold at one end. People look, but no one ever finds it. When a man looks for something beyond his reach, his friends say he is looking for the pot of gold at the end of the rainbow."

A.2. The Nasal Sentences

"Mama made some lemon jam. Ten men came in when Jane rang. Dan's gang changed my mind. Ben can't plan on a lengthy rain. Amanda came from Bounding, Maine."

A.3. The Zoo Passage

"Look at this book with us. It's a story about a zoo. That is where bears go. Today it's very cold out of doors, but we see a cloud overhead that's a pretty, white, fluffy shape. We hear that straw covers the floor of cages to keep the chill away; yet a deer walks through the trees with her head high. They feed seeds to birds so they're able to fly."

Appendix B: Summary statistics for excluded participant groups

Table B.1.: Summary statistics of nasal resonance for excluded participant groups.

Group	*Males (n=5)*	*MA dialect (n=6)*	*S dialect (n=2)*
Nasometry sample	*Nasalance (%)*	*Nasalance*	*Nasalance*
Rainbow passage	30	35	39
Nasal sentences	58	65	68
Zoo passages	10	15	18
SNAP-R oral obst. + /ɑ/[6]	15	8	11
SNAP-R oral obst. + /i/[7]	19	21	32
SNAP-R nasal stop + /ɑ/[8]	47	60	56
SNAP-R nasal stop + /i/[9]	78	78	83
Prolonged /ɑ/	22	16	20
Prolonged /u/	10	17	23
Prolonged /i/	19	25	44
Prolonged /m/	95	96	97

Table B.2.: Mean nasality ratings across stimuli for excluded participant groups.

Group	*Males (n=5)*	*MA dialect (n=6)*	*S dialect (n=2)*
DME-M stimulus	*Mean rating (st. dev.)*	*Mean rating (st. dev.)*	*Mean rating (st. dev.)*
/ɛ/ flat	69 (31)	130 (65)	95 (25)

[6] Five repetitions each of /pɑ/, /tɑ/, /kɑ/, /sɑ/, /ʃɑ/
[7] Five repetitions each of /pi/, /ti/, /ki/, /si/, /ʃi/
[8] Five repetitions each of /mɑ/, /nɑ/
[9] Five repetitions each of /mi/, /ni/

/ɛ/ mid-flat	98 (30)	132 (58)	108 (28)
/ɛ/ mid-nasal	112 (17)	94 (50)	94 (26)
/ɛ/ nasal	126 (35)	98 (42)	89 (24)
/ɑ/ flat	78 (33)	117 (70)	113 (48)
/ɑ/ mid-flat	100 (39)	111 (61)	92 (26)
/ɑ/ mid-nasal	96 (34)	109 (40)	122 (51)
/ɑ/ nasal	120 (25)	127 (26)	94 (40)
/ʌ/ flat	60 (30)	99 (53)	98 (30)
/ʌ/ mid-flat	80 (34)	96 (55)	102 (31)
/ʌ/ mid-nasal	93 (32)	98 (60)	105 (46)
/ʌ/ nasal	100 (25)	86 (55)	94 (17)