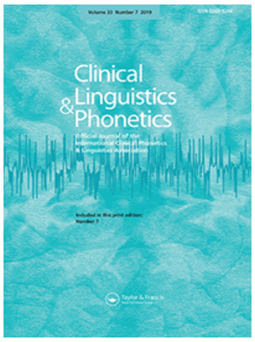

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# Effects of regional dialect on oral-nasal balance and nasality perception

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**ABSTRACT**

While cross-dialectal variations in nasalance have been investigated in previous studies, the influence of regional dialect on listeners' perceptual ratings of nasality has received limited research attention. This study explored cross-dialectal differences in the production of oral-nasal balance and the perception of nasality, with special emphasis on Inland North (IN) and Midland (M) dialects in the USA. Twenty-six adults representing the IN ($n$ = 15) and M ($n$ = 11) dialects participated in the study. Oral-nasal balance characteristics and nasality perception were compared between dialects using mean nasalance of various speech stimuli, measured via nasometry, and perceptual ratings of nasality of synthetic vowel stimuli, measured using direct magnitude estimation (DME). Despite similar mean nasalance scores between two regional dialects for standardized passage readings and sustained vowels, IN and M groups significantly differed in their perceptual ratings of nasality, with the DMEs of IN listeners being consistently and significantly higher, i.e. more nasal, than those of M listeners. Our findings provide evidence for perceptual variations of nasality that may exist at a dialectal level in addition to cross-linguistic variations in the perception of nasality as reported by Lee et al. (2008). Further research is needed to determine to what extent perceptual variations of nasality exist in other dialects and how these variations manifest in perceptual judgments of hypernasality and its severity ratings.

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Dialect; nasality; direct magnitude estimation (DME); nasalance

## Introduction

Nasalance, the ratio between nasal acoustic energy and total, is the most commonly derived measure from nasometry, and has been widely used as a quantitative acoustic measure of nasality in research and clinical settings. Several published normative studies for the English language have shown that nasalance varies across different regional dialects (Awan et al., 2015; Seaver, Dalston, Leeper, & Adams, 1991); according to Awan et al. (2015), dialectal variation in American English (AmE) accounts for about 7–9% of variation in nasalance. The Mid-Atlantic (Seaver et al., 1991) and Texas South (Awan et al., 2015) dialects have been found to yield higher nasalance scores than others for standardized passage readings, an effect primarily attributable to variation in the production of English vowels (Kummer, 2008).

While dialects of AmE are often delineated in linguistics and speech science by features of their vowel systems, nonexperts have characterized dialectal divisions in other ways, including perceived level of speaker nasality. One such 'nasal' dialect is the Inland North

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(IN), which includes speakers from metropolitan and rural areas immediately surrounding the Great Lakes (Labov, Ash, & Boberg, 2006, pp. 187–194). The IN and surrounding dialect areas (e.g. the Mid-Atlantic region) have been consistently characterized as more nasal than other dialect regions in USA (Hartley & Preston, 1999, pp. 235–236). A distinctive vowel system feature of the IN dialect and the larger Northern dialect is the raising of /æ/, which is considered to be the trigger of a larger chain shift, the Northern Cities Vowel Shift (Labov et al., 2006, p. 193). In addition to /æ/ raising, data from Clopper, Pisoni and de Jong (2005) demonstrated an ordered set of four further vowel shifts in Northern speakers: (1) fronting of /ɑ/ to approximate /æ/, (2) fronting/lowering of /ɔ/ to approximate /ɑ/, (3) backing of /ʌ/ to approximate /ɔ/ and (4) backing of /ɛ/ to approximate /ʌ/. By contrast, Midland (M) speakers, in an adjacent dialect region, lacked this vowel shift, with the only distinguishing feature noted among all speakers being the *cot-caught* low-back merger of /ɑ/ and /ɔ/ (Clopper et al., 2005). Articulatory realization of /æ/ by IN speakers in a high front position may possibly increase oral acoustic impedance due to lingual constriction of the oral passage. This constriction may further alter oral-nasal balance characteristics and subsequently affect nasalance scores (Awan et al., 2015; Lewis, Watterson, & Quint, 2000). Tamminga and Zellou (2015) provided some acoustic evidence suggesting that Mid-Atlantic speakers (from Philadelphia, PA) indeed speak with a greater degree of nasalization than the M speakers (from Columbus, OH), estimated by the difference between the amplitude of the low-frequency nasal formant and the amplitude of the first formant (F1) (Chen, 1997). The results corroborate those in Seaver et al. (1991), in which significantly higher nasalance scores were observed for Mid-Atlantic speakers than for other AmE speakers. While the aforementioned studies had major emphasis on production variation of oral-nasal balance, limited literature is available regarding perception variation of nasality between AmE dialects.

Previous cross-linguistic studies have shown that a listener's linguistic background has negligible effects on their perceptual judgments of hypernasality (Lee, Brown, & Gibbon, 2008; Watterson, Lewis, Murdock, & Cordero, 2013). For example, the English monolingual listeners in the Lee et al. (2008) study rated Cantonese hypernasal stimuli in a similar rank order as did Cantonese listeners. Similarly, Watterson et al. (2013) found that two judges, a monolingual English listener and a bilingual Spanish–English listener, demonstrated strong inter-rater agreement in nasality ratings for both English ($r$ = .86) and Spanish ($r$ = .78) sentences recorded from bilingual Spanish–English-speaking children. Findings from both studies demonstrated that the listener's (or clinician's) level of proficiency of the language spoken by the speaker (or patient) may have little effect on severity ratings of hypernasality. A noteworthy finding from Lee et al. (2008) is that the same Cantonese stimuli were rated consistently as more nasal by the Cantonese listeners than they were by the English listeners. This resulted in statistically significant differences in the perception of nasality between the two listener groups. The researchers speculated that this systematic nasality rating difference between speakers of different native languages may be associated with language-specific nasality. It is perhaps phonological and phonetic-acoustic differences in production across speakers of different language varieties that account for language-specific nasality and subsequently listeners' nasality ratings. For example, differences may exist cross-linguistically in phonotactic constraints, affecting distribution of nasal phonemes (phonological difference), or in the precise articulatory positioning employed to generate nasal phones or suprasegmentals such as vowel nasalization (phonetic-acoustic difference). Watterson et al. (2013, p. 96) indeed posed a question regarding language-specific nasality differences, suggesting that, if a given language is produced with greater nasalization, speakers of that language likely 'tolerate higher nasality as a cultural distinction' as listeners. Likewise, systematic nasality rating differences across AmE dialects may exist, perhaps connected to the known cross-dialectal variations in oral-nasal resonance balance characteristics. Whether or not and to what extent listeners from different dialects vary in their perception of nasality is unknown. To the best of our knowledge, no studies have examined the effects of AmE dialectal variation on listeners' nasality ratings.

Therefore, the present study aimed to explore the effects of regional dialects on the production of oral-nasal balance and the perception of nasality, with special emphasis on two regional dialects, IN and M. To investigate differences in oral-nasal resonance balance, nasalance was compared between speakers from those dialects; this procedure partially replicated previous normative studies (e.g. Awan et al., 2015; Seaver et al., 1991). To investigate perception, nasality ratings of synthetic listening stimuli were compared between listeners from those dialects. It was hypothesized that speakers/listeners from two regional dialects would differ from each other in oral-nasal balance characteristics, represented by nasalance, and perception of nasality, represented by nasality ratings.

## Method

### *Participants*

The study was approved by the university institutional review board, and informed consents were acquired from the participants prior to their participation. Thirty adult native AmE participants (5 males and 25 females) were recruited through convenience sampling (mean age: 20.7 years, SD: 1.5). As the geographic location of the campus lies relatively close to the isogloss separating the IN and M dialect groups (Labov et al., 2006, p. 142), it was anticipated that convenience sampling of University students would provide an adequate participant pool for both dialect groups. All participants completed a questionnaire which detailed their residential history, i.e. birthplace, hometown, other places lived and length of time lived in each location, and linguistic background, i.e. native language(s), languages spoken around the home, and their self-identified AmE dialect. The questionnaire also ruled out potential participants who had speech, language, or hearing issues, including a cold/upper respiratory infection on the day of examination. Data from three participants had to be excluded due to marked hypernasality noted in their speech; for example, all three participants had nasalance at or greater than 45% for the Zoo Passage reading. Additionally, data from a participant who had 7-year residential history outside USA were excluded. Thus, subsequent data analyses on nasalance and nasality ratings were performed based on 26 participants.

The participants were divided into two dialectal groups, M and IN. Inclusion criteria for each dialect group were based on (1) the participant's self-identification as speaking a dialect of a city inside the isogloss for each dialect group identified by Labov et al. (2006, p. 142) and/or (2) the participant's residential history in a region within the isogloss of each dialect. Labov et al. identified that the isogloss dividing these dialect regions runs between these metropolitan centers: M represented by 11 participants from rural southern Ohio and the

Columbus, OH metropolitan area and IN represented by 15 participants from metropolitan and rural surroundings of Chicago, IL, Cleveland, OH, and Detroit, MI (Labov et al., 2006, pp. 187–194). The sample sizes for each dialect group were limited by the necessary exclusions due to high nasalance and anomalous residential history.

### Nasometry

Each participant's oral-nasal balance was assessed using the Nasometer II (Model 6450, KayPENTAX™, Montvale, NJ). The Nasometer headgear was comfortably yet snugly secured against the participant's face. The metal plate of the headgear was placed such that it stayed between the participant's nose and upper lip, allowing the microphones on either side of the plate to separately record oral and nasal acoustic energy. Speech samples included repetitions of three standardized passages (Rainbow Passage, Nasal Sentences, and Zoo Passage) as well as three sustained corner vowels, /ɑ, i, u/ for 3 s per sample. All samples were gathered separately, one after another. In brief, the Rainbow Passage contains nasal consonants that are 11.5% of the total phonemes in the passage; the Nasal Sentences passage is heavily loaded with nasal consonants with 35% of phonemes being nasal; and the Zoo Passage is devoid of nasal phonemes (Kummer, 2008). Participants read each passage in its entirety. Average nasalance scores over each passage reading and sustained vowel were used to represent each participant's oral-nasal resonance balance.

### Perceptual rating of nasality

#### Listening stimulus creation

Twelve listening stimuli were created, consisting of three synthesized vowels with four degrees of nasalization, with one exemplar per vowel at each nasalization degree. These stimuli were generated through an online implementation of the Klatt speech synthesizer (Bunnell, 2015). Corner vowels were initially considered; however, high vowels (e.g. /i, u/) had to be avoided due to the fact that proximity between the fundamental frequency (F0) and F1 caused the spectral peaks to entirely merge, altering F1 values in the synthesized stimuli (e.g. Shadle, Nam, & Whalen, 2016). Thus, three vowels, /ɛ, ɑ, ʌ/, were selected based on the frequency and bandwidth values of the first three formants reported from Hawks (1994, p. 1082) with stimulus length of 1,000 ms. Among various acoustic features of vowel nasalization reported in the literature (e.g. spectral flattening, shifting of the formant frequencies, introducing additional pole-zero pairs, etc.), there is a general consensus that more consistent and prominent spectral effects of vowel nasalization have been observed in the lower frequency region than in the higher frequency region (Arai, 2006; Bae, Kuehn, Conway, & Sutton, 2011; Chen, 1997; Dang & Honda, 1996; Dang, Honda, & Suzuki, 1994; Hawkins & Stevens, 1985; House & Stevens, 1956; Olive, Greenwood, & Coleman, 1993; Rong & Kuehn, 2012; Watterson & Emanuel, 1981). Thus, modulation of the first formant bandwidth (B1) was chosen as the parameter to simulate vowels with varying degrees of nasalization, which successively altered first formant amplitude (A1). Other acoustic attributes remained consistent within each vowel. Acoustic attributes of synthesized listening stimuli are summarized in Table 1. Marked changes across varying degrees of

**Table 1.** Summary of acoustic attributes of synthesized listening stimuli.

| Stimulus | F0 (Hz) | F1 (Hz) | F2 (Hz) | F3 (Hz) | B1 (Hz) | B2 (Hz) | B3 (Hz) | A0 (dB) | A1 (dB) | A2 (dB) | Overall intensity (dB SPL) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| /ɛ/ | | | | | | | | | | | |
| Oral | 100 | 583 | 1,785 | 2,528 | 53 | 80 | 119 | 55.4 | 63.0 | 57.1 | 79.28 |
| Nasal 1 | 100 | 583 | 1,785 | 2,528 | 106 | 80 | 119 | 55.7 | 58.0 | 57.1 | 77.66 |
| Nasal 2 | 100 | 583 | 1,785 | 2,528 | 212 | 80 | 119 | 55.8 | 53.1 | 57.2 | 75.76 |
| Nasal 3 | 100 | 583 | 1,785 | 2,528 | 424 | 80 | 119 | 55.2 | 48.6 | 57.9 | 76.64 |
| /ɑ/ | | | | | | | | | | | |
| Oral | 100 | 921 | 1,329 | 2,528 | 55 | 66 | 119 | 54.9 | 69.6 | 66.7 | 85.47 |
| Nasal 1 | 100 | 921 | 1,329 | 2,528 | 110 | 66 | 119 | 55.2 | 64.8 | 66.8 | 83.32 |
| Nasal 2 | 100 | 921 | 1,329 | 2,528 | 220 | 66 | 119 | 55.0 | 59.6 | 66.5 | 82.60 |
| Nasal 3 | 100 | 921 | 1,329 | 2,528 | 440 | 66 | 119 | 55.0 | 55.5 | 65.8 | 81.55 |
| /ʌ/ | | | | | | | | | | | |
| Oral | 100 | 627 | 1,199 | 2,528 | 49 | 53 | 119 | 55.8 | 64.1 | 59.5 | 80.00 |
| Nasal 1 | 100 | 627 | 1,199 | 2,528 | 98 | 53 | 119 | 55.6 | 60.5 | 60.0 | 78.46 |
| Nasal 2 | 100 | 627 | 1,199 | 2,528 | 196 | 53 | 119 | 55.5 | 55.5 | 59.6 | 77.08 |
| Nasal 3 | 100 | 627 | 1,199 | 2,528 | 392 | 53 | 119 | 55.3 | 50.4 | 60.0 | 76.23 |

Frequency and bandwidth values of the first three formants were based on Hawks (1994, p. 1082) with four discrete categories representing B1 modulations: 'Oral' with B1 at 100% of Hawks' values, 'Nasal 1' with B1 at 200% of Hawks' values, 'Nasal 2' with B1 at 400% of Hawks' values, and 'Nasal 3' with B1 at 800% of Hawks' values.

nasalization categories are best depicted in B1 and A1 values (Table 1). For each vowel, four discrete categories representing varying degrees of nasalization were defined and one stimulus in each category was created: 'Oral' with B1 at 100% of Hawks' values, 'Nasal 1' with B1 at 200% of Hawks' values, 'Nasal 2' with B1 at 400% of Hawks' values, and 'Nasal 3' with B1 at 800% of Hawks' values. These stimuli were reviewed by a panel of students majoring in Communication Sciences and Disorders to ensure that the level of nasality in each category was perceptually distinct from the others.

### *Training session*

Prior to the listening session, a training session was provided to ensure that the participant could detect the difference between oral and nasalized vowel stimuli. Participants were seated in a sound-attenuated booth and presented with listening stimuli through Sennheiser circumaural headphones (Model HD-429, Old Lyme, CT) at a peak level of approximately 65 dB A. During the training session, each participant was presented with the Oral and Nasal 3 stimuli for /ɛ/, each 'block' consisting of two Oral presentations and one Nasal 3 presentation in random order. The participant was asked to respond visually by giving a 'thumbs-up' sign through the booth window when a nasalized stimulus was presented. Participants were allowed to advance to the experimental rating session only after they made no mistakes in correctly identifying Nasal 3 and correctly rejecting Oral for two such 'blocks' successively. Additionally, participants were presented with instruction on the use of direct magnitude estimation with modulus (DME-M) as a scaling technique. In brief, DME-M involves participating listeners rating individual stimuli with regard to the strength of the variable in question in reference to a standard stimulus, called the modulus, with a known value. This perceptual scaling technique is commonly used to estimate variables in speech perception (e.g. Schiavetti, 1992; Whitehill, Lee, & Chun, 2002), and has been found to be a valid measure for scaling nasality perception (Brancamp, Lewis, & Watterson, 2010; Whitehill et al., 2002; Zraick & Liss, 2000).

### *Listening session*

Participants were presented with a total of 60 listening events in random order. Each listening event consisted of the presentation of a 1 s modulus, a 3 s silent gap, a 1 s stimulus, and a final 6 s silent gap to allow time before the next listening event. The modulus and stimulus were always related: always the same vowel, but the modulus always in the Nasal 2 category and the stimulus in any category, i.e. any of Oral or Nasal 1, 2, 3. The nasality in the modulus was assigned a scale value of 100. In the 6 s silence at the end of each listening event, participants were instructed to rate the nasality of the just-heard stimulus using a number mathematically related to the just-heard modulus' nasality value of 100. For example, a participant may record 200 if the stimulus was perceived to be twice as nasal as the modulus, 50 if the stimulus was perceived to be half as nasal, 67 if the stimulus was perceived to be only two-thirds as nasal, etc. The total number of listening events was 60, reckoned from 5 instances of each nasalization category of each vowel as the stimulus (3 vowels × 4 categories).

### *Reliability*

Intra-listener and inter-listener agreement were assessed using the intraclass correlation coefficient (ICC) and the Cronbach's coefficient alpha, respectively. The ICC was calculated based on two repeated ratings that were randomly selected out of five repeated ratings for each listening stimulus. Good (ICC = .76, two-way mixed-effects model, absolute-agreement) within-listener reliability on repeated DME ratings was observed (Koo & Li, 2016). The standardized Cronbach's coefficient alpha ($\alpha = .75$) indicated satisfactory internal consistency among the listeners' DME ratings (Bland & Altman, 1997).

### *Statistical treatment*

Arithmetic nasalance means across speech samples and geometric DME means across listening stimuli were calculated for each participant. Use of geometric mean follows established practice for DME-M rating (e.g. in Schiavetti, 1992; Whitehill et al., 2002); geometric mean is favored for DME-M reporting because DME-M responses tend to skew in a log-normal fashion, which is better accounted for by geometric mean than by arithmetic mean (Schiavetti, Martin, Haroldson, & Metz, 1994, p. 49). Nasalance differences between IN and M were tested using a series of Welch's adjusted *t*-tests. The effects of regional dialect on perceptual ratings of nasality for the listening stimuli of each vowel were examined using a two-way mixed-design analysis of variance, in which regional dialect (IN vs. M) served as a between-subjects factor and stimulus category (Oral, Nasal 1, Nasal 2 and Nasal 3) served as a within-subject factor. All statistical tests were performed using SPSS Statistics (version 22.0; IBM Corp, Armonk, NY) at an alpha ($\alpha$) level of .05.

## Results

### *Nasalance differences between regional dialects*

Figure 1 plots mean nasalance scores representing two regional dialects across various speech samples. Between-groups nasalance differences were statistically nonsignificant for the standardized passage stimuli, ranging from .4% to 1.4%: Rainbow Passage ($t(19.42) = -.3$, $p = .77$), Nasal

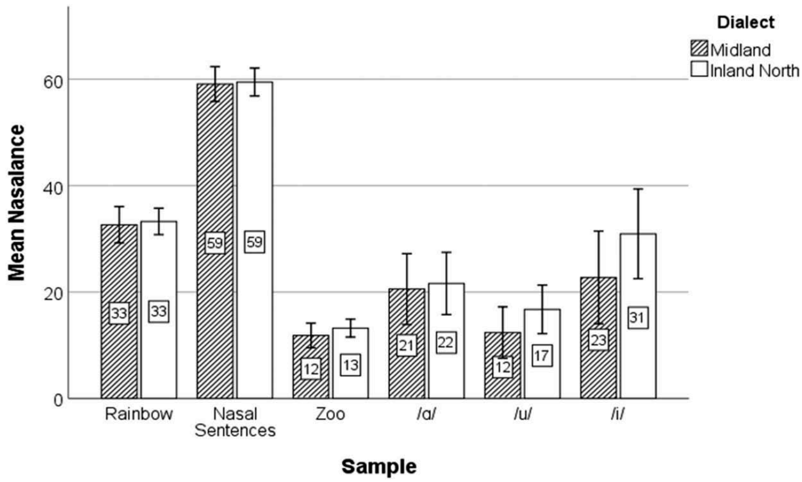


**Figure 1.** Mean nasalance scores (±2 SE) of standardized reading passages and sustained vowels for speakers from Inland North (white bars) and Midland (slashed bars).

Sentences ($t(20.80) = -.18$, $p = .86$), and Zoo Passage ($t(19.45) = -.97$, $p = .35$). Between-groups nasalance differences for production of sustained vowels ranged from 1.1% to 8.2% with the IN group having higher nasalance than the M group overall; however, no statistically significant between-groups differences were found: /ɑ/ ($t(22.04) = -.24$, $p = .81$), /u/ ($t(22.82) = -1.31$, $p = .20$), and /i/ ($t(23.05) = -1.35$, $p = .19$).

## *Effects of regional dialect on nasality DMEs*

DME data of listeners representing IN and M are separately plotted against listening stimuli with varying degrees of nasalization for three synthetic vowels in Figures 2–4. The first mixed model analysis examined the effects of regional dialect and stimulus category on DME ratings for the listening stimuli of /ɑ/. A statistically significant main effect was found for regional dialect ($F(1,104) = 7.52$, $p < .05$), in which the mean DME ratings assigned by the IN listeners (112.4) were significantly higher than those assigned by the M listeners (91.5). Although the main effect for stimulus category did not reach statistical significance ($F(3,104) = 2.61$, $p = .06$), a trend was observed in which the DME ratings for the listening stimuli of /ɑ/ seemingly increased as the degree of nasalization increased in both IN and M listeners (Figure 2). No significant interaction effect was observed between the regional dialect and the stimulus category in the listening stimuli.

A statistically significant main effect for regional dialect on DME ratings was also observed in the listening stimuli of /ɛ/ ($F(1,104) = 4.26$, $p < .05$). Specifically, the mean DME ratings assigned by IN listeners (109.3) were significantly higher than those assigned by M listeners (93.1), illustrating a consistent nasality rating pattern related to the listeners' regional dialects. Neither the main effect for stimulus category nor the interaction effect between the regional dialect and the stimulus category were statistically significant. As shown in the slopes of the regression lines, the DME ratings by IN listeners remained nearly unchanged across different listening stimuli of /ɛ/ (Figure 3). The M listeners, on the other hand, assigned higher DMEs as the degree of nasalization increased in the listening stimuli of /ɛ/.

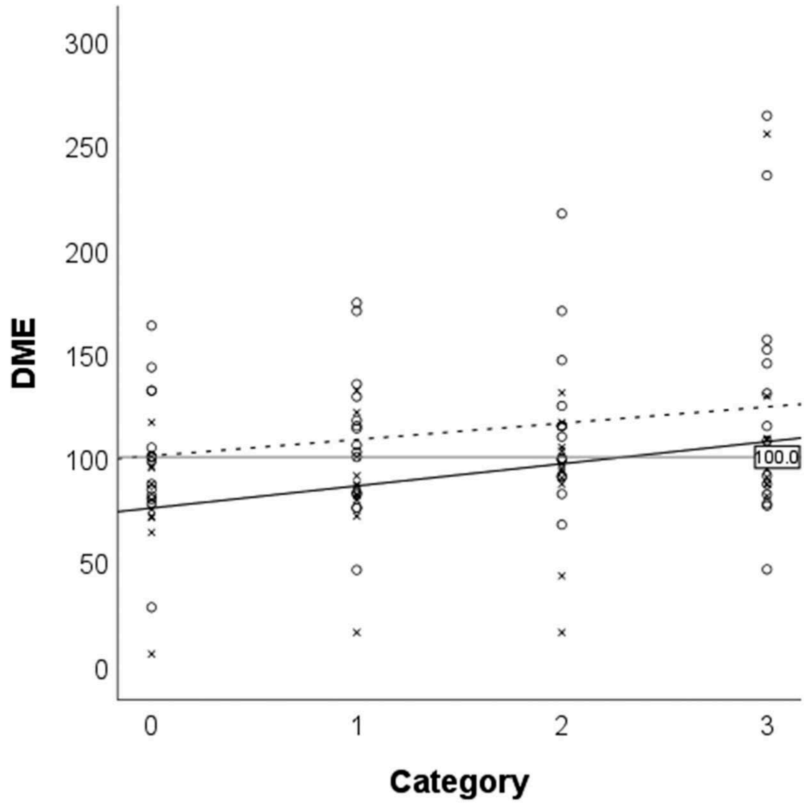


Figure 2. Scatterplot of direct magnitude estimates with modulus (DME-M) ratings for the listening stimuli of vowel /ɑ/ across different stimulus categories (0: Oral, 1: Nasal 1, 2: Nasal 2, and 3: Nasal 3) from the Inland North (○, dotted regression line) and the Midland listeners (×, solid regression line). The grey line indicates the modulus of 100.

The main effect for regional dialect on DME ratings was statistically significant for the listening stimuli of /ʌ/ ($F(1,104) = 9.59$, $p < .05$). Consistent with the pattern observed in the other vowel stimuli, overall DME ratings of IN listeners (106.6) were significantly higher than those of M listeners (83.3). No statistically significant main effect for stimulus category or interaction effect between the regional dialect and the stimulus category were observed. With regard to the listening stimuli of /ʌ/, the slopes of the regression lines indicated that the DME ratings by M listeners slightly increased as the degree of nasalization increased, whereas the DME ratings by IN listeners did not change across different categories (Figure 4).

## Discussion

Although the effects of AmE regional dialect on nasalance variations have been studied in previous normative studies (e.g. Awan et al., 2015; Seaver et al., 1991), the effects of regional dialect on listeners' perceptual ratings of nasality have received little attention. This study investigated two particular regional dialects, IN and M, with regard to their effects on the oral-nasal balance characteristics and perceptual ratings of nasality. The

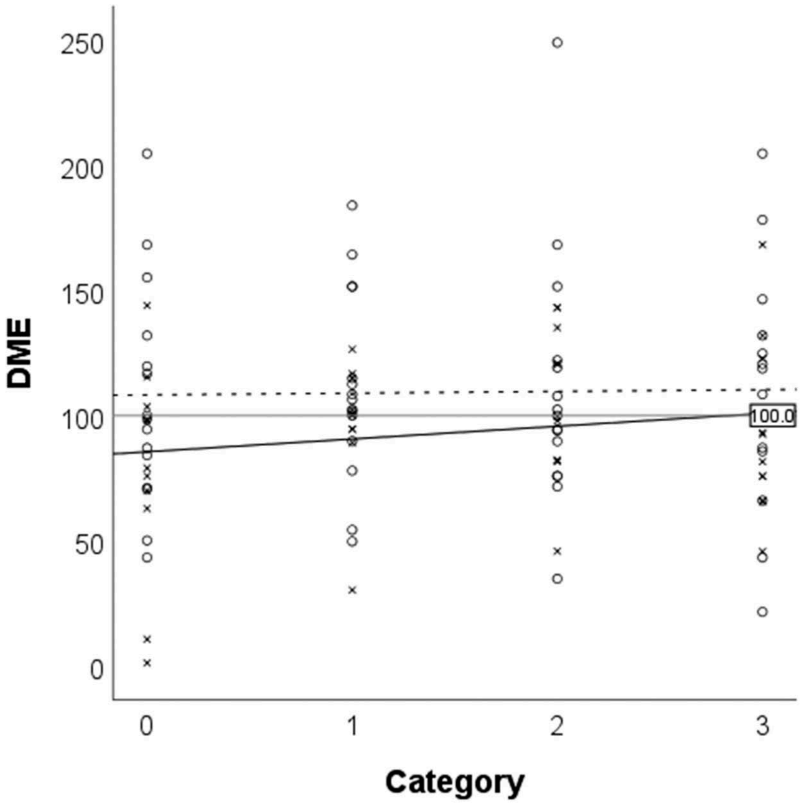


**Figure 3.** Scatterplot of direct magnitude estimates with modulus (DME-M) ratings for the listening stimuli of vowel /ε/ across different stimulus categories (0: Oral, 1: Nasal 1, 2: Nasal 2, and 3: Nasal 3) from the Inland North (○, dotted regression line) and the Midland listeners (×, solid regression line). The grey line indicates the modulus of 100.

main finding of the study is that listeners from two regional dialects significantly differed from each other in their perceptual ratings of nasality despite statistically nonsignificant differences in their oral-nasal balance characteristics estimated by nasalance scores of a variety of speech samples.

Given that IN speakers are considered by laymen to speak more nasally (Hartley & Preston, 1999), one could reasonably expect to observe appreciable differences in oral-nasal resonance balance between IN and other dialects. However, the present study failed to detect meaningful oral-nasal resonance balance differences between the IN and M dialects. Specifically, between-dialects nasalance differences were minimal for the standardized passage readings. This finding is consistent with Awan et al. (2015), in which similar nasalance means were observed in the speakers from the western lower peninsula of Michigan (representing IN) and the speakers from the northeast Pennsylvania (representing M and Mid-Atlantic). The present study provided additional nasalance data of the IN and the M dialects based on different geographic locations. Our IN participants were from metropolitan and rural surroundings of Chicago, IL, Cleveland, OH, and Detroit, MI, and the M participants were from rural southern Ohio and the Columbus, OH metropolitan area. One possible explanation for minimal nasalance differences may be geographic proximity between the IN and the M dialects;

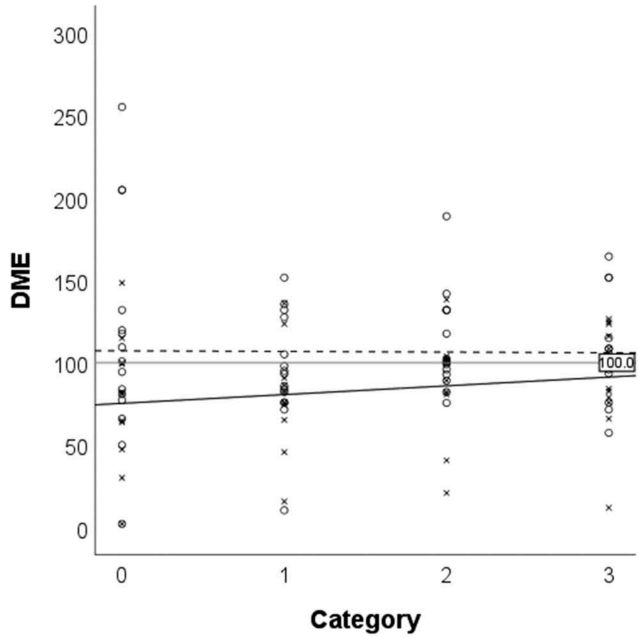


**Figure 4.** Scatterplot of direct magnitude estimates with modulus (DME-M) ratings for the listening stimuli of vowel /ʌ/across different stimulus categories (0: Oral, 1: Nasal 1, 2: Nasal 2, and 3: Nasal 3) from the Inland North (○, dotted regression line) and the Midland listeners (×, solid regression line). The grey line indicates the modulus of 100.

Awan et al. (2015) noted increased nasalance differences between two dialects that are geographically distinct from each other. While the IN participants had higher nasalance than the M participants in the production of sustained high vowels, these between-dialects differences (8.2% and 4.4% nasalance differences for /i/ and /u/, respectively) did not reach statistical significance. The null finding of the present study at least suggests that the IN dialect being perceived as more nasal than other dialects may not be grounded in the IN speakers' oral-nasal balance characteristics, especially during connected speech as illustrated by minimal between-dialects differences for standardized passage readings. The question of what features make other dialect speakers perceive and rate the IN dialect as nasal (e.g. Hartley & Preston, 1999) remains unanswered yet, which warrants future research.

Listeners' perception of nasality on the synthetic vowels of /ɑ, ɛ, ʌ/ with varying degrees of nasalization was measured using DMEs. The results showed that listeners from IN and M significantly differed from each other in their perceptual ratings of nasality, with the DMEs of IN listeners being consistently higher, i.e. more nasal, than those of M listeners. Note that each listening stimulus was paired and presented with Nasal 2 (modulus of 100). Given this experimental condition, one would expect ratings for Oral and Nasal 1 stimuli as less nasal than the modulus, yielding DME scores likely below 100. As depicted in Figures 2–4, however, only M listeners followed this predicted pattern by rating Oral and Nasal 1 stimuli less nasal than the modulus. In contrast, IN listeners' DME scores for Oral and Nasal 1 stimuli were substantially inflated, remaining above 100. This result suggests that IN listeners might not have been able to discern different degrees of nasality as sensitively as M listeners in the modulus–stimulus pairs for Oral and Nasal 1 listening stimuli. Although it is difficult to reconcile these different patterns of response, the perception of vowel archetypes may provide some insight into perceptual rating differences between two groups of listeners. In Lengeris (2016), speakers of three Greek dialects were presented with synthetic vowel stimuli and were asked to rate how well those samples approximated the best exemplar of each vowel. The results showed cross-dialectal variations in vowel exemplars and subsequently in perceptual vowel spaces. Similarly, previous studies demonstrated the effects of regional dialects of the English language on listeners' vowel identification accuracy and perceptual vowel space maps (Evans & Iverson, 2007; Jacewicz & Fox, 2012). While these studies characterized stimulus vowels primarily based on the formant frequencies, it is possible that the degree of nasalization may in part contribute to the perceptual dimensions of vowel archetypes. In other words, if IN and M listeners have different internal vowel archetypes with distinct degrees of nasalization, such differences might have somehow interfered in the perceptual ratings of vowel nasality. More evidence is yet needed to elucidate the role of nasalization in the perception of vowel archetypes across different dialects of AmE. Although it is difficult to determine the source of perception variation of nasality given the scarce information available in the literature, our findings lend support for perceptual variations of nasality that may exist at a dialectal level in addition to cross-linguistic variations in the perception of nasality as reported by Lee et al. (2008). A large-scale study is necessary to determine if dialectal variations of nasality perception are replicable in other AmE dialects, especially through comparing nasality rating patterns, between two regional dialects that are geographically distinct and have different oral-nasal balance characteristics, which is underway in our laboratory. A larger difference in the perceptual ratings of nasality is hypothesized between dialects that are more distinct from each other with regard to oral-nasal balance characteristics. We expect that these differences would be additionally related to geographical distance between dialect regions.

As illustrated in Figures 2–4, the changing pattern of DME ratings across four categories was most consistent and robust for the perception of /ɑ/, with both IN and M listeners reporting fairly consistent increases in DMEs from the Oral stimulus through Nasal 1, Nasal 2 and Nasal 3. This finding was expected to some extent, as the low-back vowel /ɑ/ is known to yield high inter-listener reliability of nasality (Watterson, Lewis, Allord, Sulprizio, & O'Neill, 2007). Gradual DME changes as a function of nasalization increases in the listening stimuli of /ɑ/, in particular, could be attributed to the limited acoustic and perceptual effects of nasalization in low vowels as demonstrated in previous studies (Bae, 2018; Bunton & Story, 2012; Carney & Sherman, 1971; Lewis et al., 2000; Lewis & Watterson, 2003). Additionally, intrinsic vowel durations may provide an additional explanation. Lax vowel nuclei such as /ɛ, ʌ/ in natural speech have been found to have shorter durations than tense vowel nuclei such as /ɑ/, by a difference of up to 40% (Klatt, 1976, p. 1213). Presentation of lax vowel (/ɛ, ʌ/) stimuli with the same duration as tense vowel (/ɑ/) stimuli might have introduced vowel length as a confound, leading to rating response variability across vowels. This finding has practical implications relative to selection of listening stimuli for future studies; specifically, the use of listening stimuli of /ɑ/ is recommended given the consistency in the changing pattern of DME ratings across different nasality categories with appreciable increments.

There are several limitations in this study. Manipulation of F1 bandwidths resulted in an F1 amplitude change by 15 dB and overall intensity change by 4 dB (Table 1). That being said, the effects of acoustic damping by nasalization and decreased overall stimulus intensity on the perception of nasality could not be teased apart in this study. In addition, the use of Nasal 3 stimuli with B1 values at 800% of the Oral stimuli may have weak ecological validity, as such wide bandwidths may not be representative of nasalized vowels in natural speech (e.g. Styler, 2017). Bandwidths of F1 used in the present study were arbitrarily determined based on convenient mathematic intervals (doubling of bandwidth frequency), change by which produced perceivable differences in nasality as rated by a panel of students majoring in Communication Sciences and Disorders. Future work in terms of optimizing listening stimuli will be important; further considerations should be taken with regard to factors such as naturalness, stimulus length, overall intensity, and adequate interval selections of nasalization categories. The largest between-dialects nasalance differences reported by Awan et al. (2015) ranged between 4% and 5.5% for standardized reading passages. Given the known moderate effect size of regional dialect, the smallest number of participants required to maintain statistical power is 58 when comparing two dialect groups. Small sample size consisting of 26 participants in the present study is a clear limitation. Comparisons of two dialects that have geographic proximity with such small sample size limit the generalizability of the findings. More studies with large sample sizes covering various regional dialects will further elucidate associative relationships between the speakers' oral-nasal balance and their perception of nasality.

## *Conclusion*

In summary, the present study compared two regional dialects, IN and M, with regard to oral-nasal balance characteristics (nasalance) and perceptual ratings of nasality on synthetic vowel stimuli. While the two regional dialect groups had similar mean nasalance scores, IN and M listeners significantly differed from each other in their perceptual ratings of nasality. DME ratings from IN listeners were consistently and significantly higher than those from M listeners. These findings provide evidence suggesting perceptual variations of nasality that may exist at a dialectal level. To what extent perceptual variations of nasality exist in other dialects of AmE and how these variations manifest in clinical judgments of oral-nasal balance/imbalance would be questions for future research.

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## Disclosure Statement

The authors report no conflicts of interest.

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