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JASA ARTICLE

Differences in nasalance and nasality perception between Texas South and Midland dialects

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ABSTRACT:

While previous research has primarily concerned the dialectal influence on speakers' production of oral-nasal balance, quantitatively represented by nasalance, information on cross-dialectal variation in nasality perception is limited. This study investigated the effects of speakers'/listeners' dialectal background on oral-nasal balance characteristics estimated by nasalance, as well as nasality perception measured by direct magnitude estimation with modulus. Represented by two geographically distinct regions, Texas South and Midland dialects were of special interest given that the two dialects lie at opposite ends of normal nasalance variation [Awan, Bressmann, Poburka, Roy, Sharp, and Watts. (2015). J. Speech Lang. Hear. Res. **58**, 69–77]. Mean nasalance of various speech stimuli and direct magnitude estimation ratings on synthesized vowel stimuli with varying degrees of simulated nasalization were obtained from 62 participants (31 Texas South, 31 Midland). The results revealed that the two dialectal groups significantly differed in nasalance scores and nasality ratings, with Texas South exhibiting higher nasalance for standardized passage readings and assigning higher nasality ratings on the synthetic auditory stimuli than Midland. These findings indicate that, in addition to production variations of oral-nasal balance characteristics, perceptual variations of nasality exist at a dialectal level.

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I. INTRODUCTION

Regional dialectal characteristics of American English (AmE), with a primary focus on cross-dialectal variation in vowels, have been well documented (e.g., Hagiwara, 1997; Thomas, 2001; Clopper *et al.*, 2005; Labov *et al.*, 2006; Fox and Jacewicz, 2009). Labov *et al.* reported unique phonologic features of seven major dialects of North AmE: New England, New York/Mid-Atlantic, North, Midland, South, West, and Canada. Previous research has shown that speakers' oral-nasal balance characteristics, often quantitatively represented by nasalance, also vary cross-dialectally in North AmE (Seaver *et al.*, 1991; Awan *et al.*, 2015), primarily attributable to cross-dialectal variations in vowel production (Kummer, 2008).

Nasalance (%) refers to the ratio of nasal to total acoustic energy in speech and is commonly derived from nasometry as a quantitative measure of oral-nasal balance. Increased magnitude of differences in nasalance between dialect groups has been associated previously with a greater geographic distance separating the groups studied (Seaver *et al.*, 1991; Awan *et al.*, 2015). For example, Seaver *et al.* reported that Mid-Atlantic speakers showed higher nasalance than Southern, Mid-Western, or Ontario Canadian English speakers. In contrast, Awan *et al.* found that Southern speakers scored higher nasalance than Midland, Mid-Atlantic, Inland North, or Western dialect speakers. Different nasalance patterns between studies were partly attributed to within-regional dialect variation (i.e., a given dialect represented by speakers from different geographic regions within the dialect area). For example, the majority of Southern speakers in Seaver *et al.* were from Alabama, whereas those in Awan *et al.* were from Texas. Likewise, the majority of Mid-Atlantic speakers in Seaver *et al.* were from North Carolina, whereas those in Awan *et al.* were from northeastern Pennsylvania.

According to normative nasalance data provided by Awan *et al.* (2015), the South represents one end of normal variation in oral-nasal balance, and at the other end of normal variation lie Midland/Mid-Atlantic speakers. Their findings showed a consistent pattern of nasalance variation, with the South dialect speakers from Texas demonstrating higher nasalance than other dialect speakers. The largest nasalance differences, with mean differences ranging from 4 to 5.5%, were observed between the South and Midland/Mid-Atlantic dialects for the standardized passage readings. Increased nasalance in Southern speakers may be attributable to fronting (Awan *et al.*, 2015) and/or raising of certain vowels. Articulatory realization of vowels with raised and fronted lingual constriction points likely increases the acoustic impedance of the oral cavity, possibly resulting in heightened nasalance scores (Lewis *et al.*, 2000; Awan *et al.*, 2015; Bae, 2018). Features related to fronting/raising in the South dialect include (1) fronting of monophthongal

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/aɪ/, upgliding of diphthongal /æ/, and raising/fronting of lax front vowels, as part of the Southern Shift, (2) raising of /ɑ/, upgliding of the diphthongal /ɔ/, and fronting of the first vowel of the diphthong /aʊ/, as part of the Back Upglide Shift, and (3) fronting of /u, o/ (Labov, 1998; Shriberg and Kent, 2003; Clopper *et al.*, 2005; Labov *et al.*, 2006; Jacewicz and Fox, 2014). In contrast, the Midland dialect has been described as the "least marked" regional dialect (Clopper and Pisoni, 2006, p. 635), presenting neither homogeneous features of North nor South (Labov *et al.*, 2006).

A recent study by Velik *et al.* (2019) provided preliminary evidence suggesting that perceptual variations of nasality exist at a dialectal level. Two regional dialects, Inland North and Midland, were of particular interest in that study, where group comparisons were made with regard to the listeners' nasalance scores and their perceptual ratings of nasality on synthetic vowel stimuli with varying degrees of nasalization. Results from the study showed that, despite a lack of statistically significant cross-dialectal nasalance differences, listeners from the two dialect groups significantly differed from each other in their perceptual ratings of nasality, with Inland North listeners consistently assigning higher nasality ratings than Midland listeners on the same auditory stimuli. The lack of statistically significant between-group nasalance differences was in part attributed to geographic proximity between Inland North and Midland dialects. These dialects lie on adjacent sides of an isogloss which, in reference to the participants in Velik *et al.*, separates the Columbus, OH metropolitan area and rural central Ohio areas (Midland) from the metropolitan and rural surroundings of Chicago, IL and Cleveland, OH (Labov *et al.*, 2006). Velik *et al.* further speculated that a larger difference in the perceptual ratings of nasality may exist between dialects that have more distinct nasalance differences, and/or dialects at a greater geographic distance.

There is ample evidence suggesting interplay between speech production and perception (e.g., MacKain *et al.*, 1981; Gandour, 1983; Fox *et al.*, 1995; Svantesson and House, 2006; Casserly and Pisoni, 2010; Fridland and Kendall, 2012) at both the segmental (e.g., native vs non-native phoneme distinction) and suprasegmental (e.g., tone distinction for tonal language speakers vs non-tonal language speakers) levels (MacKain *et al.*, 1981; Gandour, 1983; Wayland and Guion, 2004). In brief, listeners' perception of an incoming stimulus appears to be influenced by idiosyncracies of the listeners' production, along with their experience in the language in which the stimulus is spoken. Similarly, production-perception interplay has been observed within speakers of the same language; listeners' perceptual sensitivity to certain phonetic cues (e.g., tone, vocal quality, or voicing) of a given language seems to vary with dialect production variations (Svantesson and House, 2006; Brunelle, 2009; Kirby, 2010).

When it comes to the production and the perception of AmE vowels, dialectal variation in production does seem to influence listeners' vowel perception (Hartley and Preston, 1999; Thomas, 2002; Clopper and Pisoni, 2004; Drager, 2010; Fridland and Kendall, 2012; Jacewicz and Fox, 2012). Fridland and Kendall (2012) explored the production-perception link with special emphasis on the mid-front vowels of AmE. Speaker/listener participants from three different dialect regions (North, South, and West) of the United States (US) took part in a dialect identification task and a mid-front vowel production task. Results from the study showed that regional vowel shifts were reflected in both production and perception, providing evidence for the interaction between the participants' phonetic production variation and their vowel perception. Another study (Clopper and Pisoni, 2004) investigated how well naive listeners identified speakers from different parts of the United States. In that study, listener participants from Indiana were asked to categorize speaker participants of various US regional dialects based on their sentence production into six geographic regions. The results showed that the listeners' overall performance of correctly identifying the speakers' regional dialects was better than chance, indicating that naive listeners utilize their knowledge of dialectal phonetic variants, including vowel characteristics, during speech perception and judgment of other speakers. Although the focus of previous research regarding the dialectal influence on speech production and perception variabilities has been largely limited to vowels, within the phonemic domain, it is reasonable to hypothesize that listeners' perception of nasality as a suprasegmental feature may vary across AmE regional dialects, given the cross-dialectal variation in oral-nasal resonance balance as indexed by nasalance. Inquiries into the variation in listeners' perception of nasality cross-dialectally have received little research attention, however.

The "more nasal" or "less nasal" description of a given dialect may be associated with its speakers' oral-nasal balance characteristics, and this cross-dialectal production variation indeed has been the primary research focus in previous normative nasalance studies (Seaver *et al.*, 1991; Awan *et al.*, 2015). Additionally, the "more or less nasal" perception of a given stimulus may vary across listeners from different dialects. To date, this hypothesis of dialectal variations in the listeners' nasality perception has only been tested by Velik *et al.* (2019), in which speakers of two geographically adjacent dialects, Inland North and Midland, displayed significant differences in their nasality perception but not in their nasalance production. The purpose of the present study was to investigate cross-dialectal variations in the perception of nasality, shifting the focus to a comparison between Texas South and Midland dialects, two dialects that are not only geographically distinct but also lie on the opposite ends of normal nasalance variation (Awan *et al.*, 2015). We first documented the two dialects' speakers' production characteristics via nasalance measurement, in a partial replication of the Awan *et al.* study. To examine between-dialect differences in the perception of nasality, the two dialect groups were compared with each other in regard to their nasality ratings on synthetic auditory stimuli. Although information on cross-dialectal variation in nasality perception is scarce, we hypothesized that speakers/

listeners from these two dialects would exhibit distinct patterns in their nasality perception as well as their production of oral-nasal balance.

II. METHODS

A. Participants

The study was approved by the institutional review board of two institutions: The Ohio State University and Texas Tech University Health Sciences Center. Informed consent was acquired from the participants prior to their participation. Sixty-two adults, aged 18–44 years [Mean (M) = 23.3; standard deviation (SD) = 5.9], participated in the study. All participants (42 females and 20 males) were native AmE speakers from two geographically distinct dialect regions, Texas South ($n = 31$) and Midland (n = 31), as defined by AmE dialectal isoglosses, according to the Atlas of North American English (Labov *et al.*, 2006). All participants had a negative history of speech/language/hearing issues and were free from any upper respiratory infection/cold symptoms on the day of the experiment. Information on the participant's 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 self-identified AmE dialect] was acquired during an interview. Inclusion criteria for each dialect group were determined based on (1) the participant's self-identification as speaking a dialect of a city/region 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. Figure 1 displays the cities of origin/hometowns of the participants. Our participants for the Texas South dialect geographically represented West and North Texas (e.g., Dallas-Fort Worth-Arlington, Abilene, and Lubbock metropolitan areas) as well as adjacent regions of New Mexico. Our participants for the Midland dialect were highly clustered in the central and the south-west quadrant of Ohio (e.g., Columbus, Cincinnati, and Dayton metropolitan areas). These participants served as speakers and listeners in the study and received monetary remuneration for their participation.

B. Production task

1. Speech stimuli

The speech stimuli for the production task comprised three reading passages and three sustained corner vowels /ɑ, u, i/. The Rainbow Passage, Nasal Sentences, and Zoo Passage were selected due to their varied phonemic makeup: the Zoo Passage containing 0% nasal phonemes, the Rainbow Passage containing nasal consonants that are 11.5% of the total phonemes in the passage, and the Nasal Sentences Passage containing nasal consonants that are 35% of the total phonemes in the passage (Kummer, 2008).

2. Nasometry

Participants' oral-nasal balance characteristics were assessed using the Nasometer II (model 6450, KayPENTAX^{TM}, Montvale, NJ). The Nasometer headset consists of a set of two microphones that collect acoustic energy from the oral and the nasal channels, with the two microphones being separated by a metal plate. The Nasometer headset was placed such that the metal plate comfortably stayed between the participant's nose and upper lip. Both oral and nasal acoustic signals recorded through the Nasometer microphone set are subject to a filtering process, passing through a band-pass filter with a 300 Hz bandwidth and a center frequency at 500 Hz.

C. Perception task

1. Auditory stimuli

The same auditory stimuli used in Velik *et al.* (2019) were employed in this study. Given the fact that nasality perception is affected by vowel types, particularly related to

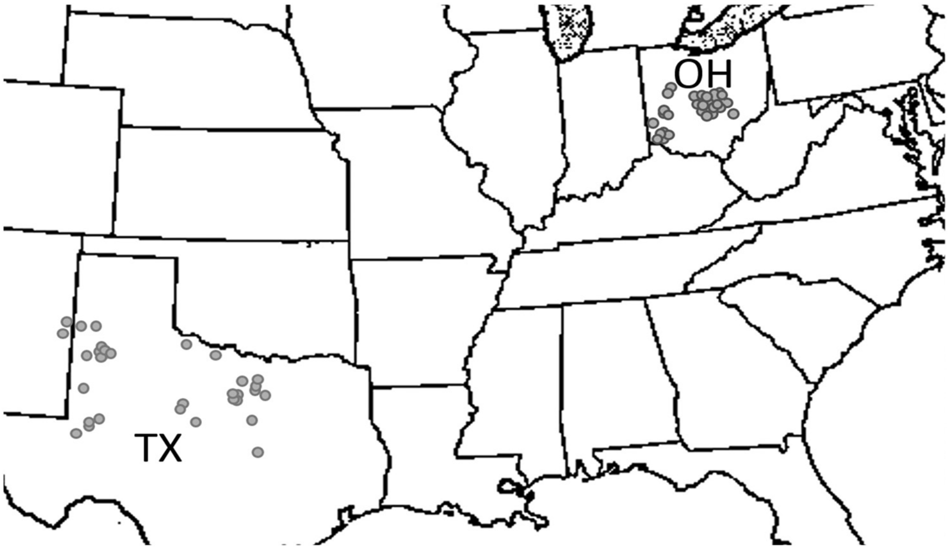

FIG. 1. Map of the cities of origin/hometowns of the participants (grey dots) representing two dialect groups: Texas South and Midland.

vowel height (e.g., Lintz and Sherman, 1961; Abramson *et al.*, 1998; Bunton and Story, 2012; Bunton, 2015), the inclusion of both high and low vowels was desired. As summarized by Velik *et al.*, however, the synthesized stimuli of high vowels (both /i/ and /u/) revealed the first resonance peak ($F1$) and the fundamental frequency to be completely merged due to their proximity, resulting in $F1$ shifts. Thus, creation of the auditory stimuli was limited to mid and low vowels only.

The auditory stimuli consisted of three different synthetic vowels, /ɑ, ɛ, ʌ/, with each vowel having four degrees of nasalization (12 different auditory stimuli = 3 vowels × 4 nasalization categories), generated through an online implementation of the Klatt speech synthesizer (Bunnell, 2015). In brief, the three vowels were created based on the formant data provided by Hawks (1994) with the f_0 at 100 Hz: /ɑ/ with $F1$ (921 Hz) and $F2$ (1329 Hz), /ɛ/ with $F1$ (583 Hz) and $F2$ (1785 Hz), and /ʌ/ with $F1$ (627 Hz) and $F2$ (1199 Hz). There is a general consensus that more consistent and prominent spectral changes (e.g., spectral flattening, the introduction of pole-zero pairs, and formant shifts) of a nasalized vowel occur in the lower frequency region than in the higher frequency region (Hawkins and Stevens, 1985). To simulate different degrees of nasalization in the synthetic vowel stimuli for the perception task, $F1$ bandwidth ($B1$) was modulated in the present study (House and Stevens, 1956; Hawkins and Stevens, 1985; Bae *et al.*, 2011; Styler, 2015, 2017). Modulation of $F1$ bandwidth ($B1$) subsequently altered $F1$ amplitude ($A1$) (Stevens, 2000), as seen in Table I. Stimuli corresponding to four nasalization categories were defined as follows: "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. The length of each stimulus was 1 s. Table I provides a summary of acoustic attributes of synthesized auditory stimuli, particularly related to $F1$ bandwidth, $F1$ amplitude, and overall intensity.

TABLE I. Acoustic attributes of synthesized auditory stimuli.

Auditory stimulus[a]		$F1$ bandwidth[b] (Hz)	$F1$ amplitude (dB)	Overall intensity (dB SPL)
/ɑ/	Oral	55	69.6	85.5
$F1$: 921 Hz	Nasal 1	110	64.8	83.3
$F2$: 1329 Hz	Nasal 2	220	59.6	82.6
	Nasal 3	440	55.5	81.6
/ɛ/	Oral	53	63.0	79.3
$F1$: 583 Hz	Nasal 1	106	58.0	77.7
$F2$:1785 Hz	Nasal 2	212	53.1	75.8
	Nasal 3	424	48.6	76.6
/ʌ/	Oral	49	64.1	80.0
$F1$: 627 Hz	Nasal 1	98	60.5	78.5
$F2$: 1199 Hz	Nasal 2	196	55.5	77.1
	Nasal 3	392	50.4	76.2

[a] Formant frequency values of the auditory stimuli based on Hawks (1994, p. 1082) with four discrete nasalization categories (Oral, Nasal 1, Nasal 2, and Nasal 3) modulated by $F1$ bandwidth ($B1$).

[b] Formant bandwidth: "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.

2. Perceptual rating of nasality

Participants were seated in a sound-attenuated booth and were first presented with a brief training session designed to ensure they could differentiate oral from nasalized vowel stimuli. Auditory stimuli were delivered through circumaural headphones at a peak level of approximately 65 dBA. Each participant was presented with the Oral and Nasal 3 stimuli for /ɛ/. Two Oral presentations and one Nasal 3 presentation were played in a random order for every "block." The participant was asked to show a "thumbs up" through the booth window when they heard the nasalized vowel sound. Participants were able to advance to the experimental rating task after correctly identifying the Nasal 3 stimuli and correctly rejecting the Oral stimuli for three "blocks" in a row.

The training session was followed by instruction on the use of direct magnitude estimation with modulus (DME-M). In brief, DME-M is a perceptual scaling technique, which requires that the investigator assigns a known value (i.e., modulus) to a standard stimulus and that listeners rate all subsequent stimuli in reference to the magnitude of the modulus. Previous research has shown this technique to be a valid scaling method for nasality perception (Zraick and Liss, 2000; Whitehill *et al.*, 2002; Brancamp *et al.*, 2010). Given that the standard stimulus generally represents the midrange of the target feature being examined (Weismer and Laures, 2002), Nasal 2 was chosen and served as the standard stimulus for each vowel category. Participants were instructed to rate the degree of nasality of each stimulus using a number mathematically related to the modulus value of 100. For example, the participant was told to assign 200 if the stimulus was perceived to be twice as nasal as the modulus, or 50 if the stimulus was perceived to be half as nasal.

Participants were presented with a total of 60 prerecorded listening events (three vowels × four nasalization categories × five repetitions) in random order. Each event comprised a presentation of a modulus and stimulus of the same vowel category. There was a three-second time interval between the modulus and the stimulus. A six-second time interval was provided between the consecutive listening events, during which participants rated and recorded the "nasality level" for each stimulus in reference to the modulus (100) on a rating form.

D. Nasalance and nasality rating measurements and considerations

In order to assess each participant's oral-nasal balance, arithmetic nasalance means were computed over repeated passage readings and repeated sustained vowels. With regard to nasality ratings, the use of geometric means has been recommended as a measure of central tendency due to the data skewness in a log-normal fashion commonly observed with direct magnitude estimation (DME) data (Schiavetti *et al.*, 1994; Whitehill *et al.*, 2002). Thus, geometric DME-M means were computed across 12 auditory stimuli for each participant.

Note that the production and the perception tasks clearly differed in the stimulus type and complexity: standardized passages and sustained vowels for the production task vs synthesized vowels for the perception task. The use of mean nasalance scores during the performance of a variety of speech tasks mirrored a conventional nasometry testing protocol (e.g., the MacKay-Kummer Simplified Nasometric Assessment Procedures Revised, SNAP-R, by Kummer, 2005). Normative nasalance data have previously been established across different dialects via measurement during standardized passage production (Seaver *et al.*, 1991; Awan *et al.*, 2015), and the same passages were employed in the present study. Production of sustained corner vowels was also included to test if any systemic cross-dialectal variations in nasalance could be observed, as cross-dialectal nasalance variations have been attributed to vowel production variations (Kummer, 2008; Awan *et al.*, 2015). An aggregated nasalance measurement, however, does not fully characterize time-varying changes in oral-nasal balance. This limitation also extends to any discussion concerning coarticulatory nasalization. For example, despite the presence of nasal consonants and anticipated coarticulatory nasalization in the Rainbow Passage or the Nasal Sentences, the extent of the speaker's coarticulatory nasalization cannot be gleaned from the aggregated nasalance score. That is, the nasalance score for either of these passages would reflect the combined effects of the speaker's oral-nasal balance with and without the influence of coarticulatory nasalization. In contrast, the nasalance score of the Zoo Passage or a sustained vowel, devoid of any nasal consonant context, would reflect the speaker's oral-nasal balance without the influence of coarticulatory nasalization. Thus, caution should be exercised when interpreting the aggregated nasalance measurement. With regard to the auditory stimuli, isolated synthetic vowels were chosen to simplify synthetic speech generation. These stimuli with simulated degrees of nasalization were found to successfully yield differential levels of nasality perception among listeners from different dialects (Velik *et al.*, 2019). Nonetheless, we acknowledge that isolated synthetic vowels are unnatural relative to connected speech, and very dissimilar from speech samples of varying complexity, typically incorporated into the perceptual evaluation of nasality. This further limits the applicability of our findings above low-level phonemic processing as none of the sociophonetic or other higher linguistic cues which may influence nasality perception are present.

III. RESULTS

A. Nasalance differences between Texas South versus Midland

Descriptive statistics summarized in Table II illustrate a consistent between-dialect nasalance pattern in which Texas South yielded higher nasalance than Midland, particularly for standardized passage readings, with the mean differences of 3.7% (Rainbow Passage), 4.0% (Nasal Sentences), and 4.2% (Zoo Passage). A similar pattern is observed in Fig. 2, which displays the density curves of nasalance data for Texas South and Midland across different speech stimuli. Results from a multivariate analysis of variance (MANOVA) showed that between-dialects nasalance differences were statistically significant, with moderate-to-large effect sizes, for the standardized passages only: Rainbow Passage [$F(1,60) = 8.5$, $p < 0.01$, partial $\eta^2 = 0.12$], Nasal Sentences [$F(1,60) = 8.2$, $p < 0.01$, partial $\eta^2 = 0.12$], and Zoo Passage [$F(1,60) = 13.5$, $p < 0.01$, partial $\eta^2 = 0.18$]. Although mean nasalance scores for the sustained vowels were higher for Midland speakers than Texas South speakers with mean differences of 1.3, 2.4, and 1.5% for /ɑ/, /u/, and /i/, respectively, the differences did not reach statistical significance.

B. DME differences between Texas South versus Midland

Descriptive data of DME ratings by Texas South and Midland listeners are presented across different vowel stimuli in Table III. As expected, overall DME ratings increased for both Texas South and Midland listeners as the degree of nasalization in the auditory stimuli increased (i.e., as nasalization category changed from Oral to Nasal 1, 2, and 3).

The two dialect groups, however, appeared to differ in the distribution of DME ratings. Data visualization was further attempted using the violin plots with quartile information for three different vowels (Figs. 3–5). A mixed analysis of variance (ANOVA) test was used to assess between-dialects differences in DME ratings across nasalization categories for each vowel: Dialect (between-subjects factor) and Nasalization Category (within-subjects factor). The Greenhouse-Geisser correction was used when the assumption of sphericity was violated.

For /ɑ/, no significant main effect for Dialect or Dialect by Nasalization Category interaction was found. Nasalization Category, however, was found to have a

TABLE II. Mean and standard deviations (in parentheses) of nasalance scores (%) for Midland and Texas across different speech stimuli.

	Rainbow Passage*	Nasal Sentences*	Zoo Passage*	/ɑ/	/u/	/i/
Midland	32.2 (4.7)	58.5 (5.4)	12.9 (3.9)	20.4 (10.2)	12.9 (7.9)	27.8 (14.8)
Texas South	35.8 (5.2)	62.6 (5.7)	17.1 (5.1)	19.1 (10.6)	10.5 (5.7)	26.3 (12.3)

*Speech stimuli that yielded statistically significant between-dialect differences in nasalance ($p < 0.01$).

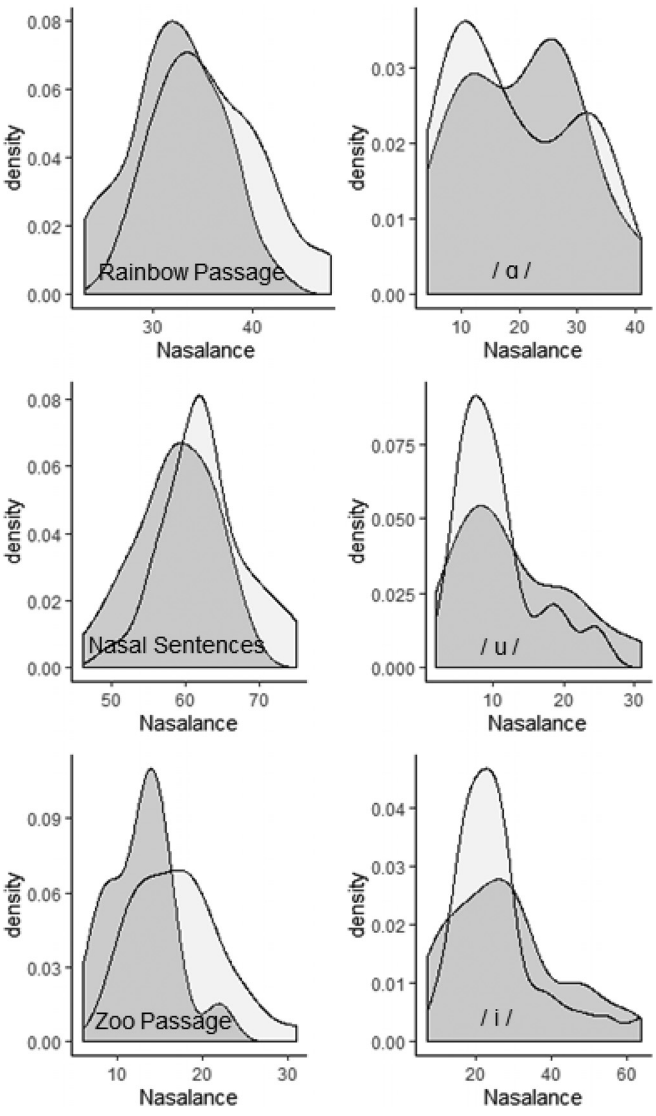

FIG. 2. Kernel density curves of nasalance data for Texas South (light grey) and Midland (dark grey) across different speech stimuli: Rainbow Passage, Nasal Sentences, Zoo Passage, and sustained corner vowels (/ɑ, u, i/).

TABLE III. Means and standard deviations (in parentheses) of DME ratings by Texas South and Midland listeners on synthetic vowel stimuli.

		Nasalization Categories			
Vowel	Dialect	Oral	Nasal 1	Nasal 2	Nasal 3
/ɑ/	Midland	79.9 (29.5)	96.8 (29.9)	102.6 (21.2)	111.0 (39.8)
	Texas South	91.9 (55.8)	97.1 (25.4)	108.8 (20.7)	122.8 (40.9)
/ɛ/	Midland	83.9 (39.2)	95.8 (33.0)	100.5 (31.1)	108.9 (36.9)
	Texas South	109.0 (48.6)	112.5 (48.8)	121.0 (40.7)	140.8 (48.3)
/ʌ/	Midland	81.0 (34.2)	86.9 (31.0)	94.4 (24.4)	100.2 (34.5)
	Texas South	79.6 (36.0)	95.6 (19.3)	106.2 (15.1)	134.9 (54.7)

significant main effect with large effect size [$F_{(1.5,91.2)} = 9.9$, $p < 0.01$, partial $\eta^2 = 0.14$], and the mean DME ratings increased in the predicted order: Oral (DME: 85.9), Nasal 1 (DME: 97.0), Nasal 2 (DME: 105.7), and Nasal 3 (DME: 116.9). Subsequent *post hoc* analyses showed that Nasal 3 had significantly higher DME ratings than Oral ($p < 0.01$) or Nasal 1 ($p < 0.05$). Nasal 2 had significantly higher DME ratings than Oral ($p < 0.05$). The DME rating difference between Oral and Nasal 1 was also statistically significant ($p < 0.05$). No significant differences were observed in the following contrasts: Nasal 1 vs Nasal 2 and Nasal 2 vs Nasal 3.

Both factors, Dialect [$F_{(1,60)} = 9.7$, $p < 0.01$, partial $\eta^2 = 0.14$] and Nasalization Category [$F_{(1.7,99.4)} = 8.2$, $p < 0.01$, partial $\eta^2 = 0.12$], were found to have statistically significant main effects on DME ratings of /ɛ/. Specifically, DME ratings were significantly higher in Texas South listeners (DME: 105.2) than Midland listeners (DME: 97.6). The effect size was considered to be large for Dialect. With medium effect size, the effect of the Nasalization Category on DME ratings was in the predicted direction: Oral (DME: 96.5), Nasal 1 (DME: 104.1), Nasal 2 (DME: 110.8), and Nasal 3 (DME: 124.9). *Post hoc* analyses showed that Nasal 3 vs Oral ($p < 0.01$) and Nasal 3 vs Nasal 1 ($p < 0.05$) were the only contrasts that had statistically significant differences in DME ratings. No significant interaction between Dialect and Nasalization Category was observed.

For /ʌ/, a statistically significant interaction was found between Dialect and Nasalization Category [$F_{(1.4,86.6)} = 4.0$, $p < 0.05$, partial $\eta^2 = 0.06$] in the DME ratings. This result indicated that the effect of Dialect on DME ratings would change depending on the level of the Nasalization Category. Subsequent simple main effects analyses revealed

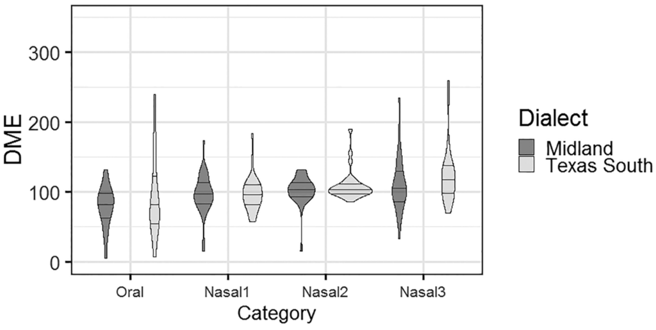

FIG. 3. Violin plots of DME ratings of /ɑ/ stimuli across nasalization categories. Three horizontal lines within each violin plot represent the lower (25th percentile), middle (median), and upper quartiles (75th percentile), respectively.

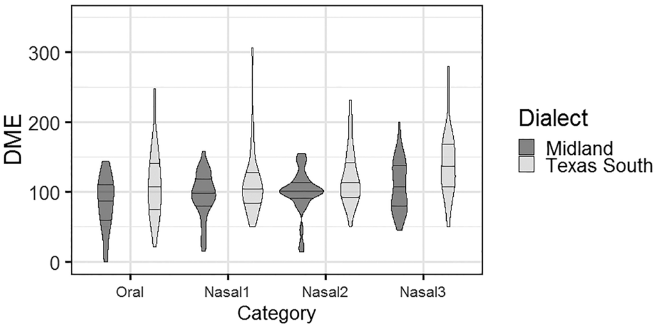

FIG. 4. Violin plots of DME ratings of /ɛ/ stimuli across nasalization categories. Three horizontal lines within each violin plot represent the lower (25th percentile), middle (median), and upper quartiles (75th percentile), respectively.

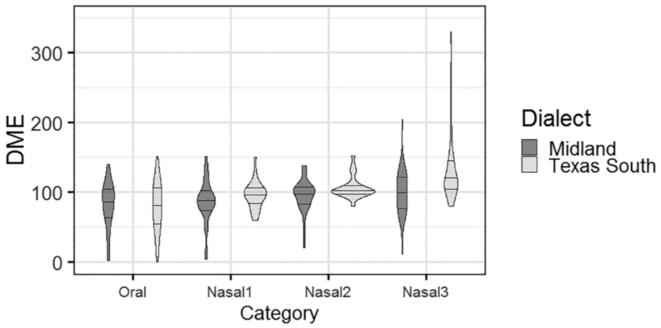

FIG. 5. Violin plots of DME ratings of /ʌ/ stimuli across nasalization categories. Three horizontal lines within each violin plot represent the lower (25th percentile), middle (median), and upper quartiles (75th percentile), respectively.

that the DME ratings of Texas South listeners were significantly higher than those of Midland listeners for Nasal 2 and Nasal 3 stimuli: Midland (DME: 94.4) vs Texas South (DME: 106.2) for Nasal 2 [$F_{(1,\ 60)} = 5.3$, $p < 0.05$] and Midland (DME: 100.2) vs Texas South (DME: 134.9) for Nasal 3 [$F_{(1,\ 60)} = 8.9$, $p < 0.01$]. No significant between-dialects difference was found for the Oral and Nasal 1 stimuli in the DME ratings of /ʌ/.

IV. DISCUSSION

While the influence of regional dialect on oral-nasal balance (i.e., production variation), as indexed by nasalance, has been of special interest in previous normative studies (Seaver *et al.*, 1991; Awan *et al.*, 2015), information on cross-dialectal variation in the perception of nasality is very scarce. Previous research has shown that, for standardized passage readings, speakers of the Texas South dialect demonstrate highest nasalance among speakers of various North AmE dialects, and that at the other end of normal variation lie the Midland/Mid-Atlantic speakers (Awan *et al.*, 2015). The present study examined the effects of speakers'/listeners' dialectal background (Texas South vs Midland) on their oral-nasal balance characteristics, estimated by nasalance, as well as nasality perception, represented by DME nasality ratings of synthetic auditory stimuli. The results of the study showed significant nasalance differences between the two dialect groups, with the Texas South speakers exhibiting higher nasalance than the Midland speakers for the standardized passage readings. In addition, the two dialect groups significantly differed from each other in perceptual ratings of nasality for the auditory stimuli of /ɛ, ʌ/, with the Texas South listeners assigning higher DME scores than the Midland listeners for the same synthetic auditory stimuli.

Our result corroborates prior results indicating Texas South speakers exhibit significantly higher nasalance than Midland speakers for standardized passage readings (Awan *et al.*, 2015). Along with statistical significance, the dialect factor was found to have moderate-to-large effect sizes, with partial η^2 ranging from 12 to 17%, indicating the practical significance of the dialectal influence on nasalance variations, especially with the use of reading passages that are comparable to connected speech. Although statistically non-significant, an opposite pattern of Midland speakers yielding higher nasalance than Texas South speakers was observed for sustained corner vowels. It is possible that heightened nasalance of Texas South speakers in the passage reading task may be due to vowels contained in the passages other than the corner vowels and/or that production of sustained vowels in isolation may not be most representative of dialect-specific oral-nasal balance characteristics and their influence on nasalance. Heightened nasalance in Texas South speakers for passage readings has been previously explained in relation to fronted and/or raised lingual positions of particular vowels affected by the Southern Vowel Shift (Awan *et al.*, 2015). However, no empirical evidence currently exists regarding how distinct vowel systems of AmE regional dialects affect nasalance patterns. Additionally, different spatio-temporal articulatory dynamics are expected for the production of vowels in phonetic context compared to the production of sustained vowels. That being said, the observed nasalance differences in standardized passage readings, which are not reflected in isolated vowels, support the view that contextual effects, such as different coarticulatory patterns, contribute to nasalance variations. Mayo *et al.* (1996) reported a significant nasalance difference between two racial groups of the same regional dialect (Mid-Atlantic) only for the production of Nasal Sentences, with no significant between-groups differences in nasal cross-sectional area. These researchers indeed postulated that nasalance differences between racial groups may be associated with "learned, culturally prescribed factors" (Mayo *et al.*, 1996, p.147), which modulate how these groups differently use the feature of nasalization, particularly in the temporal domain. To our knowledge, no cross-dialectal studies have been conducted with regard to the temporal variability of velopharyngeal valving or acoustic nasalization. Further study that comprehensively identifies sociolinguistic factors influencing nasalance variation, using speech stimuli of varying complexity, is warranted.

Overall, nasalance scores observed in the present study were comparable to those reported in Awan *et al.* (2015), except for the Zoo Passage. Both dialect groups in the present study yielded higher nasalance for the Zoo Passage than those in Awan *et al.* (2015) by approximately 3%; in fact, the observed means of the Zoo Passage in the present study fell outside of the 95% confidence intervals reported by Awan *et al.* (2015). This exemplifies additional within-dialect nasalance variability—the specific sub-groups of the South and Midland groups targeted in this study may differ in oral-nasal resonance balance characteristics from those investigated by Awan *et al.* In that regard, our data supplement the existing norms by adding nasalance data for specific sub-groups of the Texas South (West and North Texas as in Fig. 1) and the Midland (central and south-west quadrant of Ohio as in Fig. 1) dialects.

Both Texas South and Midland listeners' DME ratings increased as a function of nasalization categories, validating that modulation of $F1$ bandwidth reliably elicited perceptual differences in nasality across the auditory stimuli. One interesting observation was that Texas South listeners rated the Oral and Nasal 1 stimuli of /ɛ/ more nasal (i.e., DMEs higher than 100) than the modulus. A similar observation was reported by Velik *et al.* (2019), in which Inland North listeners rated the Oral and Nasal 1 stimuli more nasal than the modulus across all vowel types. Velik *et al.* hypothesized that this may be related to a reduced sensitivity to nasality within those listeners; that is, Inland North listeners may not discern the degree of nasality in the vowel stimuli as sensitively as Midland listeners. Similarly, the finding from the present study could be interpreted that Texas South listeners experienced difficulty discerning differential degrees of nasality, particularly for the /ɛ/ stimuli. One plausible explanation pertains to the mismatch between the presented auditory stimuli of /ɛ/ and the Texas South listeners' internal vowel archetype of /ɛ/, which is likely further raised and fronted, typical of the Southern dialect. Such a mismatch might have interfered with listeners' perceptual processing of the /ɛ/ stimuli in terms of nasality ratings. This finding subsequently implies that listeners' sensitivity to the degree of nasality may vary depending on vowel types.

Listeners from two dialects significantly differed in their perceptual ratings of nasality, particularly for the auditory stimuli of /ɛ, ʌ/, with moderate-to-large effect sizes (partial η^2 of 0.14 for /ɛ/ and 0.10 for /ʌ/). Texas South listeners also assigned higher DME ratings compared to Midland listeners on the auditory stimuli of /ɑ/ as well, although the differences were statistically non-significant. These results indicating a dialectal influence on nasality ratings are in agreement with Velik *et al.* (2019), lending additional support to the notion that perceptual variation of nasality exists at a dialectal level. A question then arises as to what accounts for cross-dialectal variations in perceptual ratings of nasality. Although speculative, it is perhaps cross-dialectal production variation in oral-nasal balance characteristics that may contribute to nasality perception variation. A systemic difference in nasality ratings was reported in a cross-linguistic study (Lee *et al.*, 2008), in which the Cantonese listeners consistently assigned higher DME ratings than the English monolingual listeners on the same Cantonese listening stimuli. The systemic nasality rating difference between listeners of different native languages was partly attributed to language-specific nasality (i.e., differences in nasal phoneme distribution and vowel nasalization patterns). Likewise, dialect-specific patterns of nasalization, as partly evidenced by between-dialects nasalance differences, may account for between-dialects nasality rating differences. Watterson *et al.* (2013) reasoned that listeners of a language exhibiting a greater degree of nasality may "tolerate higher nasality as a cultural distinction" (p. 96). This notion of tolerance of nasality may provide some insight into the production-perception connection. For example, listeners' DME ratings for Nasal 3 stimuli with $F1$ bandwidths near 400 Hz likely represent the upper end of their perceptual continuum of vowel nasality that is ratable. Hypothetically, Texas South listeners might have been able to tolerate higher degrees of nasality and assigned higher DME ratings than Midland listeners, because Texas South listeners with higher nasalance are 'used to' increased nasality within their own dialect group/speech community.

It is worth contemplating potential sources of variation in nasality perception in the context of speech perception research. A larger difference in the perceptual ratings of nasality was hypothesized between dialects that have more distinct nasalance differences (Velik *et al.*, 2019), a notion that was not supported in the present study. Rather, the DME rating differences between Texas South and Midland in the present study were comparable to or smaller than those between Inland North and Midland in the Velik *et al.* study. For instance, while Velik *et al.* found the largest DME rating differences between Inland North and Midland for the auditory stimuli of /ɑ/, the same vowel stimuli did not elicit statistically significant differences between Texas South and Midland listeners in the present study. These results highlight that the production-perception relationship may be dependent on vowel types as well as regional dialects, and thus, the inclusion of a variety of vowel types as auditory stimuli for nasality ratings is recommended for future studies.

Adding further complexity to the understanding of the production-perception relationship are other sociophonetic factors known to influence speech perception (e.g., Munro *et al.*, 1999; Evans and Iverson, 2007; Drager, 2011; Fridland and Kendall, 2012; Jacewicz and Fox, 2012, 2014). These factors can be broadly categorized into speaker-specific attributes (e.g., age/generation, prior experience/exposure to the dialect of interest, the extent of individual speaker participation in regional shifts, etc.), and speech community-specific attributes (e.g., regional shifts). Although data are sparse with regard to nasality perception variations, previous speech perception study designs and the aforementioned factors identified in the sociophonetic literature should serve as an experimental platform for future investigations.

Aside from sociophonetic considerations, Beddor *et al.* (2018) examined the production-perception link, in particular, coarticulatory nasalization at the individual speaker/listener level. The results from Beddor *et al.* showed that speakers whose production involved an earlier onset of anticipatory nasalization exhibited an earlier attention to anticipatory nasalization information. Their finding accounts for another source of nasality perception variation that is intrinsic to individual speakers/listeners. Such a direct within-speaker/listener production-perception link may exist in relation to a speaker's oral-nasal balance and his/her nasality ratings. Thus, an attempt was made to explore any discernable pattern between the participants' nasalance scores and their nasality ratings. As the production task and the perception task considerably differed in terms of the stimulus type and complexity, however, this supplemental analysis was limited to a subset of the data which closely matched in stimulus type (i.e., /ɑ/) and complexity (i.e., isolated vowel) between the production and perception tasks: comparisons between nasalance scores of /ɑ/ and DME ratings of /ɑ/ with the Oral, Nasal 1, Nasal 2, and Nasal 3 stimuli.

Data were first visually inspected using the scatterplot to detect any pattern that might exist between the participants' nasalance scores and their DME ratings for different nasalization categories (Fig. 6). Each data point in Fig. 6 represents a participant's nasalance score and his/her nasality rating. Although varying in terms of the scatteredness of data across nasalization categories, no clear changes in DME ratings were observed as the nasalance score increased, implying that the participants' nasality ratings may be irrelevant to their nasalance scores. The strength of the association between nasalance scores and DME ratings was assessed using Spearman's rank-order correlation analysis, which is distribution-free and not sensitive to outliers (Gideon and Hollister, 1987). The observed correlation coefficients (r_s) remained negligible, according to the Hinkle *et al.* (2003) guidelines: Oral ($r_s = -0.10$, $p = 0.43$), Nasal 1 ($r_s = -0.01$, $p = 0.96$), Nasal 2 ($r_s = 0.00$, $p > 0.99$), and Nasal 3 ($r_s = 0.06$, $p = 0.66$). Taken together, there was not enough evidence to conclude that the participants' nasalance scores covary with their nasality ratings, even in a monotonic fashion.

Nearly zero to negligible correlation results between the participants' nasalance scores of /ɑ/ and their nasality ratings of /ɑ/ with simulated nasalization should be interpreted with caution. It must be pointed out that the present study was not designed to examine a within-speaker/listeners production-perception link. The mismatch between the production and the perception tasks in stimulus type and complexity exerted constraint on the analysis of the direct production-perception link, limiting the supplemental analysis to the production-perception comparisons based on a single vowel /ɑ/. This, in turn, raises a question regarding the validity of the selected measures in adequately representing an individual speaker's overall degree of oral-nasal

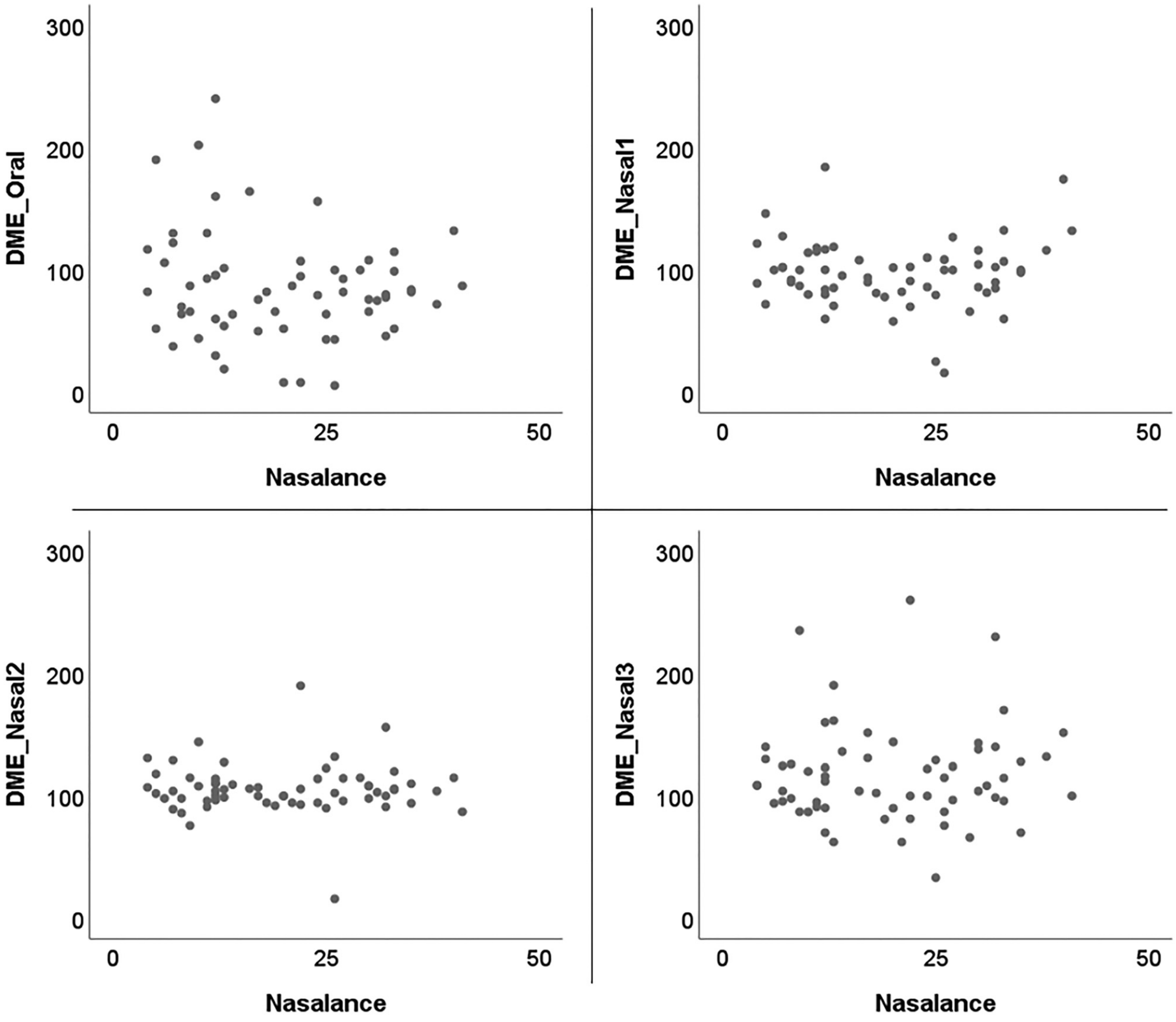

FIG. 6. A scatterplot of the participants' nasalance scores of /ɑ/ and DME ratings on the auditory stimuli of Nasal 1 /ɑ/ with a nonlinear line of best fit overlaid. Note that Nasal 1 is a stimulus that has a two-fold increase in the first formant bandwidth compared with the Oral counterpart.

balance and his/her nasality perception. Production-wise, nasalance of an isolated vowel /ɑ/ is not likely to carry as much information as nasalance of a passage reading does in regard to the speaker's overall degree of oral-nasal balance, as nasalance varies across vowels (e.g., Lewis *et al.*, 2000; Awan *et al.*, 2011; Thorp *et al.*, 2013). Likewise, listeners' perception of vowel nasality also varies depending on vowel height (Lintz and Sherman, 1961; Abramson *et al.*, 1998; Bunton and Story, 2012; Bunton, 2015) and, thus, perceptual ratings of nasality based on an isolated synthetic vowel /ɑ/ would provide an incomplete picture of the listener's perception of nasality. It is also unclear to what extent a perceptual nasality rating task would be able to reflect an individual speaker's own patterns of oral-nasal balance. Zellou (2017) reported that listeners' nasality rating performance did not portray their production patterns of coarticulatory nasalization. Zellou further argued that listeners would make perceptual judgments of nasality based on their speech community norms instead of their idiosyncratic patterns of coarticulatory nasalization. It is possible that our participants might have assigned nasality ratings in reference to the oral-nasal balance characteristics that were representative of their speech community norms. Looking towards future research investigating the within-speaker analysis between oral-nasal balance and nasality perception, careful selection of methodologic approaches is important. Use of a dynamic parameter of different vowel contexts (e.g., temporal aspects of oral-nasal balance based on the nasalance contour as in Bae *et al.*, 2007) paired with a vowel discrimination task may better elucidate the direct relationship between oral-nasal balance and nasality perception at the individual speaker/listener level. We argue that more nasality perception studies are necessary to understand the exact mechanism of how listeners' own oral-nasal balance intertwines with their perception of nasality, and how and what factors modulate the interplay between production and perception.

V. CONCLUSIONS

The present study examined the effects of regional dialect on the oral-nasal balance characteristics, estimated by nasalance, and perceptual ratings of nasality, measured using DME with modulus. Two dialects, Texas South and Midland, were of special interest in the present study. Results from the study showed that two dialect groups significantly differed from each other in nasalance scores for standardized passage readings, with Texas South scoring higher nasalance than Midland, as well as DME ratings, and Texas South generally assigning higher scores than Midland on the same synthetic auditory stimuli. Our findings provide support for the dialect group as a factor influencing both oral-nasal balance and nasality perception. Future research investigating the interconnections between listeners' own oral-nasal balance characteristics and their nasality perception would provide further insight into listener variability in judgments of nasality.

Abramson, A. S., Nye, P. W., Henderson, J. B., and Marshall, C. W. (**1998**). "Vowel height and the perception of consonantal nasality," J. Acoust. Soc. Am. **70**, 329–339.

Awan, S. N., Bressmann, T., Poburka, B., Roy, N., Sharp, H., and Watts, C. (**2015**). "Dialectal effects on nasalance: A multicenter, cross-continental study," J. Speech Lang. Hear. Res. **58**, 69–77.

Awan, S. N., Omlor, K., and Watts, C. R. (**2011**). "Effects of computer system and vowel loading on measures of nasalance," J. Speech Lang. Hear. Res. **54**, 1284–1294.

Bae, Y. (**2018**). "Nasalization amplitude-timing characteristics of speakers with and without cleft palate," Cleft Palate Craniofac. J. **55**, 45–56.

Bae, Y., Kuehn, D. P., Conway, C. A., and Sutton, B. P. (**2011**). "Real-time magnetic resonance imaging of velopharyngeal activities with simultaneous speech recordings," Cleft Palate Craniofac. J. **48**, 695–707.

Bae, Y., Kuehn, D. P., and Ha, S. (**2007**). "Validity of the nasometer measuring the temporal characteristics of nasalization," Cleft Palate Craniofac. J. **44**, 506–517.

Beddor, P. S., Coetzee, A. W., Styler, W., McGowan, K. B., and Boland, J. E. (**2018**). "The time course of individuals' perception of coarticulatory information is linked to their production: Implications for sound change," Language **94**, 931–968.

Brancamp, T. U., Lewis, K. E., and Watterson, T. (**2010**). "The relationship between nasalance scores and nasality ratings obtained with equal appearing interval and direct magnitude estimation scaling methods," Cleft Palate Craniofac. J. **47**, 631–637.

Brunelle, M. (**2009**). "Tone perception in Northern and Southern Vietnamese," J. Phon. **37**, 79–96.

Bunnell, H. T. (**2015**). *Low Level Synthesis Interface* (software) (University of Delaware, Newark, DE).

Bunton, K. (**2015**). "Effects of nasal port area on perception of nasality and measures of nasalance based on computational modeling," Cleft Palate Craniofac. J. **52**, 110–114.

Bunton, K., and Story, B. H. (**2012**). "The relation of nasality and nasalance to nasal port area based on a computational model," Cleft Palate Craniofac. J. **49**, 741–749.

Casserly, E. D., and Pisoni, D. B. (**2010**). "Speech perception and production," Wiley Interdiscip. Rev. Cogn. Sci. **1**, 629–647.

Clopper, C. G., and Pisoni, D. B. (**2004**). "Some acoustic cues for the perceptual categorization of American English regional dialects," J. Phon. **32**, 111–140.

Clopper, C. G., and Pisoni, D. B. (**2006**). "The Nationwide Speech Project: A new corpus of American English dialects," Speech Commun. **48**, 633–644.

Clopper, C. G., Pisoni, D. B., and de Jong, K. (**2005**). "Acoustic characteristics of the vowel systems of six regional varieties of American English," J. Acoust. Soc. Am. **118**, 1661–1676.

Drager, K. (**2010**). "Sociophonetic variation in speech perception," Lang. Linguist. Compass **4**, 473–480.

Drager, K. (**2011**). "Speaker age and vowel perception," Lang. Speech **54**, 99–121.

Evans, B. G., and Iverson, P. (**2007**). "Plasticity in vowel perception and production: A study of accent change in young adults," J. Acoust. Soc. Am. **121**, 3814–3826.

Fox, R. A., Flege, J. E., and Munro, M. J. (**1995**). "The perception of English and Spanish vowels by native English and Spanish listeners: A Multidimensional scaling analysis," J. Acoust. Soc. Am. **97**, 2540–2551.

Fox, R. A., and Jacewicz, E. (**2009**). "Cross-dialectal variation in formant dynamics of American English vowels," J. Acoust. Soc. Am. **126**, 2603–2618.

Fridland, V., and Kendall, T. (**2012**). "Exploring the relationship between production and perception in the mid front vowels of U.S. English," Lingua **122**, 779–793.

Gandour, J. T. (**1983**). "Tone perception in far eastern languages," J. Phon. **11**, 149–175.

Gideon, R. A., and Hollister, R. A. (**1987**). "A rank correlation coefficient resistant to outliers," J. Am. Stat. Assoc. **82**, 656–666.

Hagiwara, R. (**1997**). "Dialect variation and formant frequency: The American English vowels revisited," J. Acoust. Soc. Am. **102**, 655–658.

Hartley, L. C., and Preston, D. R. (**1999**). "The names of US English: Valley Girl, cowboy, yankee, normal, nasal and ignorant," in *Standard English: The Widening Debate*, edited by T. Bex and R. J. Watts (Routledge, London).

Hawkins, S., and Stevens, K. N. (**1985**). "Acoustic and perceptual correlates of the non-nasal—Nasal distinction for vowels," J. Acoust. Soc. Am. **77**, 1560–1575.

Hawks, J. W. (**1994**). "Difference limens for formant patterns of vowel sounds," J. Acoust. Soc. Am. **95**, 1074–1084.

Hinkle, D. E., Wiersma, W., and Jurs, S. G. (**2003**). *Applied Statistics for the Behavioral Sciences* (Houghton Mifflin, Boston).

House, A. S., and Stevens, K. N. (**1956**). "Analog studies of the nasalization of vowels," J. Speech Hear. Disord. **21**, 218–232.

Jacewicz, E., and Fox, R. A. (**2012**). "The effects of cross-generational and cross-dialectal variation on vowel identification and classification," J. Acoust. Soc. Am. **131**, 1413–1433.

Jacewicz, E., and Fox, R. A. (**2014**). "The effects of indexical and phonetic variation on vowel perception in typically developing 9- to 12-year-old children," J. Speech Lang. Hear. Res. **57**, 389–405.

Jacewicz, E., Fox, R. A., and Salmons, J. (**2011**). "Cross-generational vowel change in American English," Lang. Var. Change **23**, 45–86.

Kirby, J. (**2010**). "Dialect experience in Vietnamese tone perception," J. Acoust. Soc. Am. **127**, 3749–3757.

Kummer, A. W. (**2005**). *The MacKay-Kummer SNAP Test-R: Simplified Nasometric Assessment Procedures* (KayPENTAX$^{\mathrm{TM}}$, Montvale, NJ).

Kummer, A. W. (**2008**). *Cleft Palate and Craniofacial Anomalies: Effects on Speech and Resonance* (Cengage Learning, Clifton Park, NY).

Labov, W. (**1998**). "The three dialects of English," in *Handbook of Dialects and Language Variation*, edited by M. D. Linn (Academic Press, San Diego, CA).

Labov, W., Ash, S., and Boberg, C. (**2006**). *The Atlas of North American English: Phonetics, Phonology, and Sound Change* (Mouton de Gruyter, New York).

Lee, A., Brown, S., and Gibbon, F. E. (**2008**). "Effect of listeners' linguistic background on perceptual judgements of hypernasality," Int. J. Lang. Comm. Dis. **43**, 487–498.

Lewis, K. E., Watterson, T., and Quint, T. (**2000**). "The effect of vowels on nasalance scores," Cleft Palate Craniofac. J. **37**, 584–589.

Lintz, L. B., and Sherman, D. (**1961**). "Phonetic elements and perception of nasality," J. Speech Hear. Res. **4**, 381–396.

MacKain, K. S., Best, C. T., and Strange, W. (**1981**). "Categorical perception of English /r/ and /l/ in Japanese bilinguals," Appl. Psycholinguist. **2**, 369–390.

Mayo, R., Floyd, L. A., Warren, D. W., Dalston, R. M., and Mayo, C. M. (**1996**). "Nasalance and nasal area values: Cross-racial study," Cleft Palate Craniofac. J. **33**, 143–149.

Munro, M. J., Derwing, T. M., and Flege, J. E. (**1999**). "Canadians in Alabama: A perceptual study of dialect acquisition in adults," J. Phon. **27**, 385–403.

Schiavetti, N., Martin, R. R., Haroldson, S. K., and Metz, D. E. (**1994**). "Psychophysical analysis of audiovisual judgments of speech naturalness in nonstutterers and stutterers," J. Speech Lang. Hear. Res. **37**, 46–52.

Seaver, E. J., Dalston, R. M., Leeper, H. A., and Adams, L. E. (**1991**). "A study of nasometric values for normal nasal resonance," J. Speech Lang. Hear. Res. **34**, 715–722.

Shriberg, L. D., and Kent, R. D. (**2003**). *Clinical Phonetics* (Pearson, New York).

Stevens, K. N. (**2000**). *Acoustic Phonetics* (MIT Press, Cambridge, MA).

Styler, W. (**2015**). "On the acoustical and perceptual features of vowel nasality," Ph.D. thesis, University of Colorado, Denver, CO.

Styler, W. (**2017**). "On the acoustical features of vowel nasality in English and French," J. Acoust. Soc. Am. **142**, 2469–2482.

Svantesson, J.-O., and House, D. (**2006**). "Tone production, tone perception and Kammu tonogenesis," Phonology **23**, 309–443.

Thomas, E. (**2002**). "Sociophonetic applications of speech perception experiments," Am. Speech **77**, 115–147.

Thorp, E. B., Virnik, B. T., and Stepp, C. E. (**2013**). "Comparison of nasal acceleration and nasalance across vowels," J. Speech Lang. Hear. Res. **56**, 1476–1484.

Velik, K., Bae, Y., and Fox, R. A. (**2019**). "Effects of regional dialect on oral-nasal balance and nasality perception," Clin. Linguist. Phon. **33**, 587–600.

Wayland, R. P., and Guion, S. G. (**2004**). "Training English and Chinese listeners to perceive Thai tones: A preliminary report," Lang. Learn. **54**, 681–712.

Watterson, T., Lewis, K. E., Murdock, T., and Cordero, K. N. (**2013**). "Reliability and validity of nasality ratings between a monolingual and bilingual listener for speech samples from English-Spanish speaking children," Folia Phoniatr. Logop. **65**, 91–97.

Weismer, G., and Laures, J. S. (**2002**). "Direct magnitude estimates of speech intelligibility in dysarthria: Effects of a chosen standard," J. Speech Lang. Hear. Res. **45**, 421–433.

Whitehill, T. L., Lee, A. S., and Chun, J. C. (**2002**). "Direct magnitude estimation and interval scaling of hypernasality," J. Speech Lang. Hear. Res. **45**, 80–88.

Zellou, G. (**2017**). "Individual differences in the production of nasal coarticulation and perceptual compensation," J. Phon. **61**, 13–29.

Zraick, R. I., and Liss, J. M. (**2000**). "A comparison of equal-appearing interval scaling and direct magnitude estimation of nasal voice quality," J. Speech Lang. Hear. Res. **43**, 979–988.