

ACOUSTICAL LETTER

African American women's speech: Vowel inherent spectral change

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1. Introduction

Speaker dependent variation in vowel inherent spectral change (VISC) has been observed as a function of native language background [1] and as a function of regional dialect variation for White American English (WAE) speakers [2]. VISC refers to the change in spectral properties specific to the phonetic identity of the vowel [3]. For example, the phonetic difference between the North American English vowels /i/ and /ɪ/ can be spectrally quantified through measurement of the subtle spectral variations likely to occur during production of the monophthongs. The VISC measures trajectory length (TL), vowel duration and spectral rate of change (SROC) have been observed to effectively identify both phonetic variation as a function of vowel context (e.g. surrounding consonantal context) and speaker group membership (e.g. regional dialect variation in vowel production) for WAE women, but not men, speakers in the United States in western North Carolina, southern Wisconsin and central Ohio [2]. Another proposed measure of group variation in vowel production is the spectral angle, the direction of spectral shift from vowel onset to offset [1], which aligns with the direction hypothesis of vowel perception that suggests the direction of formant movement is necessary to account for listener vowel identification [4]. An analysis of spectral angle in vowel production may provide useful data in quantifying vowel identity and speaker group membership [5]. In this text VISC refers to the four vowel measures, duration, TL, SROC and spectral angle.

Research on VISC has shown that most English vowels, even monophthongs, show significant spectral change over the course of the vowel and finds that this change can vary systematically across dialects of the same language [6]; yet VISC measures have not been used to evaluate regional dialect variation in African American English (AAE). African American English (AAE) varies systematically from White American English (WAE) and is used primarily by Black Americans of historical African descent [7]. Static analyses of vowel production continue to dominate socio-phonetic evaluations of AAE in the United States [8].

Static measures of AAE vowels have been collected in central North Carolina; Brooklyn, NY; Columbus, Ohio; Milwaukee, Wisconsin; and Pittsburgh, Pennsylvania [8]. The collected data revealed that the AAE vowel spaces were similar for African Americans living in those geographically distant regions of the United States. The vowels produced by the AAE speakers did not show the regional dialect variation present in the speech of their WAE peers. For example, in Milwaukee, WI, the AAE speakers showed limited participation in the Northern Cities shift, a widespread regional vowel change expected in WAE. Similarly, in central North Carolina, AAE speakers showed limited participation in the Southern Vowel Shift, a widespread phenomenon for many, but not all southern WAE speakers. Comparisons of AAE speakers living thousands of miles apart and having no linguistic contact revealed similarly constituted vowel space areas. Unlike the distinctive North and South WAE vowel spaces, African Americans in both regions produced a common vowel space. The vowel configuration was termed, the African American Shift or the African American Vowel system [8–10].

In the African American Shift or the African American Vowel system (AAVS) [9,10] the front tense vowels /i, e/ are lowered, the front lax vowels /ɪ, ɛ, æ/ are raised and the low back vowel /ɑ/ is fronted. The back vowels /u/ and /o/ remain fully back. The AAVS is observed in Northern communities where the WAE vowel chain movement Northern Cities Shift (a clockwise rotation of /æ/ fronting and raising, /ɛ/ and /ʌ/ backing, /ɔ/ lowering and /ɑ/ lowering and fronting) is expected and in Southern communities where the WAE vowel chain movement Southern Vowel Shift (raising and fronting of /ɪ/ and /ɛ/ lowering and backing of /i/ and /e/) is expected. Nationwide, WAE speakers are fronting the back vowels /u/ and /o/ as illustrated in Fig. 1.

The AAE vowel space is typically measured using a static assessment of the F_1 and F_2 values of the vowels of interest. The static assessment of the AAE vowel space may not capture the subtle but salient monophthong variations that can be observed in measures of VISC. To date, no study has used the VISC measures, vowel duration, TL, SROC and spectral angle to evaluate regional vowel variation in AAE. This paper evaluated the utility of these measures to show regional variation in AAE vowel production in women from two geographically distant regions, eastern and western, North Carolina (NC).

The western NC participants were recruited from Statesville, NC a rural community with a population of 24,500 (13,000 White, 8,000 Black, 3,500 other races). Statesville is geographically located just south east of the Inland South dialect region, the only southern dialect region where the SVS has moved to completion [11]. Research has observed that

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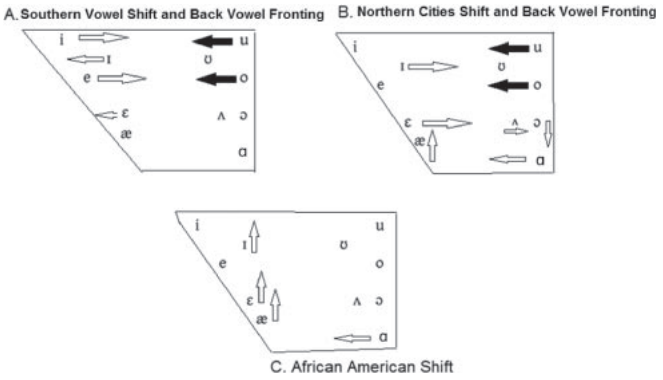

Fig. 1 Static vowel plots of the three vowel shifts. White arrows depict the vowel shifts, black arrows depict Back Vowel fronting, a widespread phenomenon in WAE but not AAE in the United States. (A) Southern Vowel Shift characterized by reversal of the tense/lax vowel pairs /i, ɪ, e, ɛ/ white arrows, (B) the Northern Cities Shift characterized by /æ/ raising, backing of the lax vowels /ɪ, ɛ/ and /ʌ/ with lowering of /ɔ/ as in hawed and fronting of /ɑ/ as in hod; (C) the African American Shift the lax vowels /ɪ, ɛ/ and /æ/ raise and /ɑ/ is fronted.

rural residents are more likely to use the dialect than urban dwellers [11]. Eastern NC participants were recruited from Greenville, NC, a small town three hundred miles east of Statesville. Greenville is a college town located in a rural region of the state with a population of 91,500 (47,500 White, 31,250 Black, 12,750 other races). Greenville is in the Southern dialect region, but far distant from the Inland South [11]. Evidence presented in the Atlas of North American English attests that the SVS has moved to completion for rural speakers in the Inland South; therefore, the western NC WAE women are expected to show greater participation in the SVS than their eastern NC WAE peers [11].

2. Materials and methods

Following IRB approval thirty-two women between the ages of 19–53 (average 37) were recorded reading the words (heed, hid, heyd, head, had, hod, whod, hood, hoed, heard, hawed, hide, howed, hoyed) representing the American English vowel monophthongs /i, ɪ, e, ɛ, æ, ɑ, u, ʊ, o, ɝ, ɔ/ and the diphthongs /aɪ, aʊ, ɔɪ/ three times each for a total of 42 vowels per participant. Eight AAE (test group) and WAE (control group) women were recorded in the eastern region and the same number were recorded in the west. Western recordings were completed in a quiet room. The ambient noise level was verified at less than 30dBSPL using a Speer Scientific 850014 Mini sound meter. All eastern recordings were completed in a sound-treated booth on the campus of East Carolina University.

Each participant read the previously listed words aloud as they appeared one at a time on a computer screen by a customized MATLAB presentation and recording program. The first author or a trained research assistant monitored the participants as their speech was digitally recorded to the hard drive of computer at 44.1 kHz using the installed sound card. Each recording was down-sampled to 11.025 kHz prior to acoustic analysis. Vowel data was extracted from each *hVd* word. Measurements of vowel duration, from first periodic waveform to cessation of periodicity, and formant frequency of F_1 and F_2 at five equidistant points (20, 35, 50, 65, 80 percent) along the vowel's duration were extracted and used to derive the measures *TL*, *SROC* and spectral angle as described in the listed formulas [2].

$$TL = \sum_{n=1}^{4} VSL_n \text{ where } VSL \text{ is} \tag{1}$$

$$VSL_n = \sqrt{(F_1 n - F_1 n + 1)^2 + (F_2 n - F_2 n + 1)^2} \tag{2}$$

$$SROC = TL/(0.60 * \text{vowel duration}) \tag{3}$$

Where vowel duration is the duration of the vowel in milliseconds (ms) from onset of periodicity to cessation of periodicity. Spectral Angle of direction was calculated using the formula [1]

$$\begin{aligned} \propto = {} & \text{arctangent}[(F_{2\,80} - F_{2\,20})/(F_{1\,80} - F_{1\,20})] \\ & \text{if } F_{2\,80} \geq F_{2\,20}, \\ \text{OR} = {} & \text{arctangent}[(F_{2\,80} - F_{2\,20})/(F_{1\,80} - F_{1\,20})] + 180, \\ & \text{if } F_{2\,80} \leq F_{2\,20} \end{aligned} \tag{4}$$

Values were calculated for each vowel by group. Repeated measures analysis of variance was completed with the dependent variable VISC (4 levels), vowel duration, *TL*, *SROC* and spectral angle and the independent variables VOWEL (14 vowels), representing each of the fourteen vowels and GROUP (4 groups) representing AAE and WAE women from eastern NC and western NC.

3. Results

There was a main effect of VOWEL $F(13, 392) = 36.77$, $p < 0.001$, $\eta^2 = 0.549$, GROUP $F(3, 392) = 21.29$, $p < 0.001$, $\eta^2 = 0.140$. The interaction between VOWEL and GROUP was not significant, indicating no group produced all vowels in a manner significantly different from another. This finding was expected. The main effect VISC was also significant $F(3, 390) = 7{,}302.4$, $p < 0.001$, $\eta^2 = 0.983$. The three-way interaction between VISC, VOWEL and GROUP was not significant. The Bonferroni corrected pairwise comparison of groups revealed a significant difference between VISC measures for eastern AAE compared to the other three groups, $p < 0.001$. In the west, there was no significant difference in VISC between western AAE and western WAE $p = 0.918$ and there was no significant difference between eastern WAE and western WAE $p = 1.0$. These findings were unexpected.

Separate ANOVAs by group revealed significant differences for *TL* $F(3, 392) = 3.31$, $p = 0.002$, $\eta^2 = 0.025$, *SROC* $F(3, 392) = 10.43$, $p < 0.001$, $\eta^2 = 0.074$, and duration $F(3, 392) = 61.08$, $p < 0.001$, $\eta^2 = 0.319$ but not spectral angle $F(3, 392) = 1.53$, $p = 0.207$. Bonferroni corrected pairwise comparisons revealed the TL (AAE east 132.91 > AAE west 112.13, $p = 0.041$) and vowel duration (AAE east 374.97 > AAE west 347.11, $p < 0.001$) was different for eastern and western AAE women (see Figs. 2 and 3).

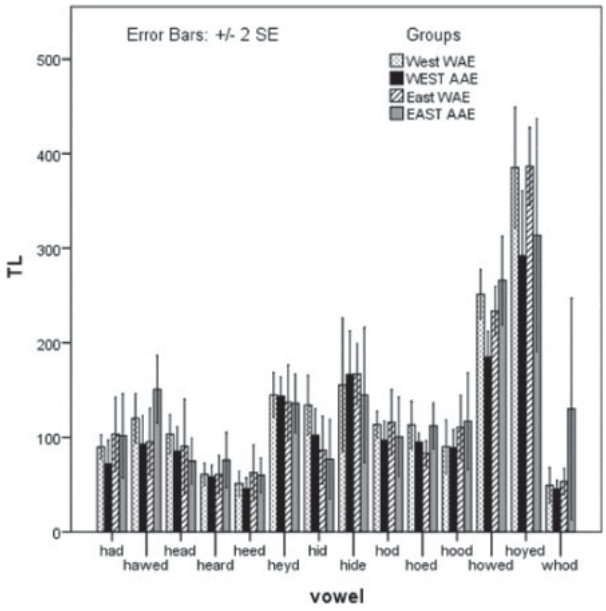

Fig. 2 Trajectory Length (*TL*) shows regional variation in AAE but not WAE. The TL of eastern AAE is greater than western.

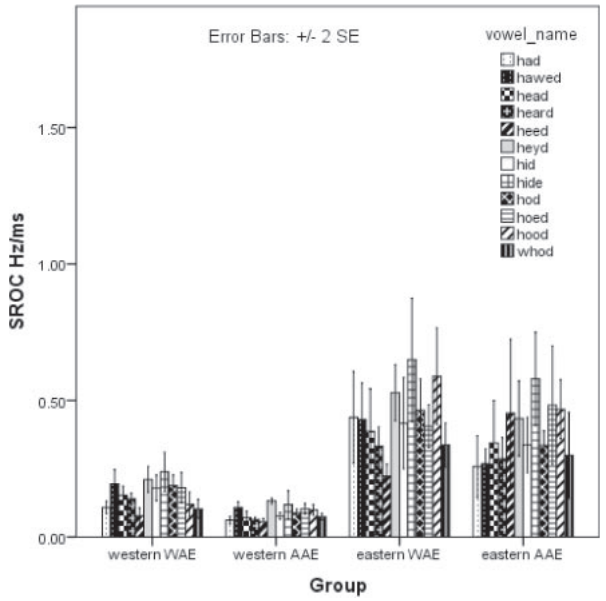

Fig. 3 Spectral Rate of Change in hertz over milliseconds shows greater change for eastern than western women. SROC differentiates west from east and AAE from WAE, but there is no significant regional difference between east and west AAE or east and west WAE.

SROC differentiated WAE from AAE but no regional variation in either AAE or WAE was observed. There was no significant difference in spectral angle by GROUP. No VISC measure was significantly different for eastern and western WAE women in North Carolina.

4. Discussion

Significant differences in VISC were observed for eastern and western AAE women in vowel duration and TL. SROC and spectral angle were not significantly different. For WAE women, no VISC measures were statistically different. The results show that the VISC measures can be used to identify regional variation in AAE that is not readily observed in static analyses of vowel space area. An unexpected result was that the measures did not effectively identify regional differences in the vowels produced by eastern and western WAE women. The VISC measures TL and SROC appear to be effective in revealing a subtle regional dialect variation in AAE that has not been easily observed in the commonly used static assessments of the F_1 by F_2 vowel space. It is unclear why VISC measures failed to show regional differences in WAE. It is possible the large age differences between participants, which spanned two generations (20 years old to 50 years old), may have obscured some differences. Fox and Jacewicz (2009) noted both generational and regional differences in VISC in their study which included WAE speaking women. The use of WAE women from two putatively different generations may have obscured subtle regional variation. Further research on VISC by group membership should be completed with eastern and western WAE women who are closer in age to further explore the efficacy of the current methods to discriminate regional vowel variation in both WAE and AAE.

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