Ethnolectal and generational differences in vowel trajectories: Evidence from African American English and the Southern Vowel System

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1 Introduction

Formant contours contain essential perceptual cues for vowel discrimination and distinguish ethnolectal and regional varieties that show superficial alignment in steady-state measures (Hillenbrand et al. 1995, Jacewicz et al. 2011). The analysis of contour information allows for more fine-grained investigation of dialectal differences in effects of coarticulation and duration. Additionally, it obviates arbitrary selection of measurement landmarks under traditional static F1/F2 analyses. Although acoustic vowel analysis of static F1/F2 values are foundational to sociolinguistic analysis and dialectology, vowel trajectories remain neglected despite their value in these domains (Koops 2010b, Scanlon and Wassink 2010, Thomas 2002:172). Our study uses functional data analysis of multiple formant measurements across the duration of each vowel to examine variation in Southern English of Piedmont, North Carolina. We show that differences in vowel formant trajectories are a key marker of participation in regional sound systems and ethnolectal vowel variation, illustrating the effectiveness of using functional data analysis to incorporate trajectory information into traditional sociolinguistic analyses.

Our research investigates dialectal differences in front lax vowel contours among speakers of Southern varieties of African American and European American English (AAE and EAE respectively) in Piedmont, North Carolina (see Figure 1) using speech from sociolinguistic interviews. The diphthongization of the front lax vowels is a primary component of the Southern drawl thus serving as the perceptually salient cue of interest when looking at European American speakers in Raleigh. The Southern Vowel Shift (SVS) is receding in Raleigh, NC, leading to generational differences (Dodsworth and Kohn 2012). Among older speakers who participate in the SVS the front lax vowels BIT, BET, and BAT can be raised and subject to Southern breaking or diphthongization (e.g., [æ] becomes [æʲə]) while these vowels are lowered and monophthongal among younger European Americans in the region.

In contrast, the African American Vowel System (AAVS) has remained relatively stable for significant portions of the 20th century in this region (Kohn 2013). Among speakers who participate in the AAVS, front lax vowels are raised, in superficial alignment with SVS patterns; yet their vowel trajectories are distinct from European American raised variants. Generally speaking, these systems differ in that Southern EAE vowels are more subject to breaking resulting in greater diphthongization than AAE vowels (Holt 2011, Koops 2010a, Risdal and Kohn 2013). Although front lax vowel height of the AAVS and SVS are similar according to static F1 measurements, formant trajectories are a central component of linguistic diversity in the region. This comparison illustrates that analyses of formant trajectories capture sources of variation that may be missed by more common static measures employed in sociolinguistic analysis.

From a methodological standpoint, we believe that functional data analysis as a method for comparing aspects of curve-shaped data improves upon traditional formant analyses for a number of reasons. First, it does not require pre-defined landmarks for measurement, e.g., at a certain proportion of the vowel or a maxima/minima. Static analyses can be problematic as methods for comparing dialectal differences in F1/F2 values using measurements at fixed landmarks, for example Euclidean distances, are impacted by such *a priori* decisions. Instead, functional data analysis allows for more holistic descriptions and contrasts to be made using measurements of intrinsically smooth vowel trajectories. This approach eliminates the need to make *a priori* decisions about which section of the vowel most accurately represents the target and affords the opportunity to examine the full duration

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of the vowel. Second, it permits types of comparisons which are not readily made using traditional measures, even ones which utilize trajectory information. For example, by making a curvature estimate using a limited number of coefficients, qualitative differences in curve shape can be quantified and in turn, statistical comparisons can be made. Finally, because each curve is described by a small number of coefficients, functional data analysis is an appealing principled strategy for reducing the dimensionality of the data into discrete components. In addition to improving upon static analyses, these advantages of functional data analysis provide further descriptive power over other methods of vowel trajectory analysis such as smoothing-spline ANOVAs or trajectory length comparisons.

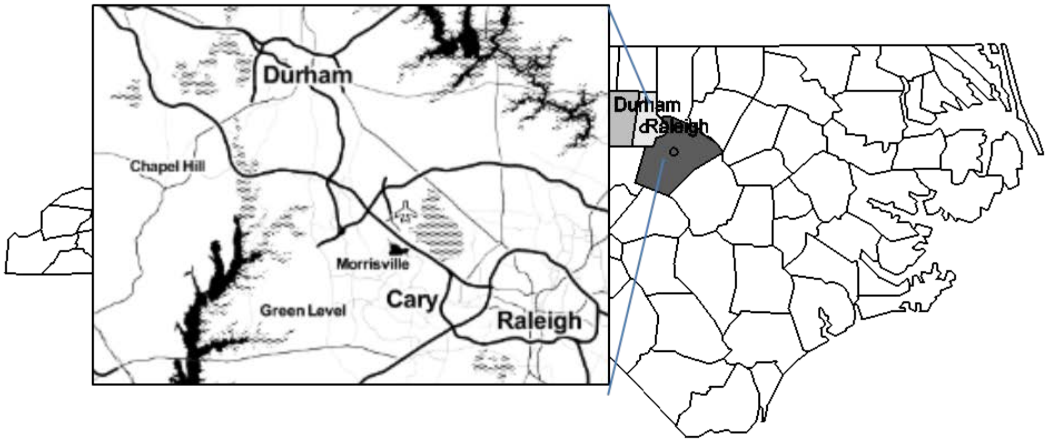

Figure 1: Piedmont, North Carolina.

2 Southern Vowels in Piedmont, North Carolina

This paper focuses on comparisons of contour shapes of the front lax vowels of the SVS and the AAVS. In this section, we describe these varieties and make predictions. Specifically, we hypothesize that duration will correlate positively with diphthongization in the SVS and that ethnolectal differences in the quality of front lax vowel trajectories will emerge for the communities under analysis.

2.1 European American English

Investigations of front lax vowel dynamics of the SVS compared to other regional varieties have revealed a number of patterns. Regional studies of controlled speech identify that duration differences distinguish SVS front lax vowels from other varieties. The vowels BET and BIT tend to have longer durations compared to Ohio and Wisconsin European American dialects of English (Clopper et al. 2005, Jacewicz et al. 2007). Fridland et al. (2013) identified regionally distinct duration effects in their comparison of Southern, Northern, and Western speech. Among Southern speakers in their study, duration covaries with vowel shift patterns (according to static F1/F2 measures) such that contrasts between tense and lax front vowel pairs are decreased rather than increased with increased duration. The authors note that "[i]t seems likely that the distinctions might be tied to vowel trajectory, not just onset position ..." (Fridland et al. 2013:5). Among speakers of Southern EAE, front lax vowel nuclei become more peripheral, resulting in increased diphthongization, with duration (Koops 2013). Also of relevance is the well known relationship between vowel duration and vowel openness such that BIT < BET < BAT. Cumulatively, these findings suggest that the unique interaction between formant trajectories and duration is a meaningful component of the SVS.

The SVS is typically described as occurring in three diachronic stages, adapted here from (Fridland 2012, Labov et al. 2006, Labov 1991):

Stage 1 Monophthongization of BIDE (served as the trigger for the SVS)

Stage 2 Centralization of BAIT and peripheralization of BET

Stage 3 Centralization of BEET and peripheralization of BIT

Stages 2 and 3 result in diphthongization of the front lax vowels as the process of raising and fronting primarily affects vowel nuclei. In Raleigh, stage 3 (reversal of the front vowels BEET/BIT) never reached completion (Dodsworth and Kohn 2012). We base a number of our predictions with respect to vowel dynamics among speakers of EAE in Piedmont, NC, on these three stages of the SVS, as well as on observed durational effects discussed above. With respect to stages 2 and 3 of the SVS in Raleigh, we expect to see that BET will be more diphthongal than BIT among older-generation European Americans as stage 2 is more advanced within the community. We also anticipate that increased vowel duration will be associated with more diphthongal formant trajectories.

2.2 The African American Vowel System

In this study, we investigate how participation in the AAVS is realized by individual speakers in Piedmont, NC, where this variety is present alongside the similar SVS. In this variety, the front lax vowels are raised and move forward along the vowel space diagonal. The raising of the front lax vowels in AAVS is associated with the SVS according to Thomas 2007.

Previous limited research suggests that AAE front lax vowels are more monophthongal than Southern varieties of European American English (Holt 2011, Koops 2010a). Given the relationship between the SVS and the AAVS, we ask whether the younger-generation AAE speakers in our study produce more monophthongal front lax vowels compared to EAE speakers, corroborating findings of previous studies. We are also interested in whether or not the relationship between duration and diphthongization found in the SVS is also present for the AAVS. Is there a similar relationship between formant trajectory shape and vowel duration? Not all Southern African Americans participate in the AAVS to the same degree (Kohn and Farrington 2013). To these ends we also ask, do individuals differ in terms of front lax vowel trajectories according to their use of other phonological features of the AAVS?

3 Method

Interview data come from eight older-generation EAE speakers and twenty-six younger-generation AAE speakers. The Southern EAE speakers were born between 1941 and 1959 and were all lifelong residents of Raleigh, North Carolina; AAE speakers were from the Piedmont region of North Carolina and were all born around 1991. Sociolinguistic interviews were conducted by researchers affiliated with the North Carolina Language and Life Project (NCLLP) (EAE) and the Frank Porter Graham longitudinal language study at UNC-Chapel Hill (AAE). Interviews with EAE participants consisted of a sociolinguistic interview and interviews with AAE participants consisted of three parts: an informal sociolinguistic interview, a formal mock job interview, and a metalinguistic awareness interview.

In order to evaluate the degree of participation in the AAVS, we calculated implicational scores for the AAE speakers based on individual use of features of the system as described in Table 1 below. This list of AAVS features is based on descriptions of African American vowels found in Bailey and Thomas (1998), Bernstein (1993), Thomas (2001, 2007), Labov et al. (2006), Koops and Niedzielski (2009, 2011), and selected papers from Yaeger-Dror and Thomas (2010). Participation in the AAVS was evaluated using a vowel chart based on approximately 200 vowel tokens per speaker. Means for the midpoint of monophthongs and the nucleus of dipththongs were plotted for each speaker. Each speaker was awarded a 1 for full participation in a feature described by these previous sources. A .5 was awarded for speakers who produced an intermediate variable. For example, if a speaker had overlapping values for the BAIT nucleus and the BET midpoint, then the speaker would receive a .5 for this feature. AAVS scores ranged from 1 to 9.5 ($M = 4.28$, $SD = 2.36$) and we used a median split to divide speakers into high ($M = 6.06$, $SD = 1.97, N = 9$) and low ($M = 2.48$, $SD = 0.92, N = 7$) AAVS groups. This metric serves as a heuristic value to indicate the degree of participation in AAVS features, similar to metrics used in Koops and Niedzielski (2011).

Vowels	AAVS (score 1, .5, 0)
BEET/BIT F1	Reversed
BEET/BIT F2	Reversed
BET/BAIT F1	Reversed
BET/BAIT F2	Reversed
BAT Raised	Closer to BET than BOT
BUT Raised	Above BOAT/BOWL
BOUGHT	Closer to BOAT than BOT
BOAT	Behind BOT on F2
BOOK	Behind BOT on F2
BOOT	Behind BOT on F2
BIDE	Glide weakened
PIN/PEN	Merged
	Total possible score: 12

Table 1: African American Vowel System implicational scoring system.

F1 and F2 were semi-automatically measured using a Praat script and force-aligned TextGrids (Yuan and Lieberman 2008), at 21 equally-spaced time-points from onset to offset of each vowel token for all speakers.[1] Measurements from preceding or following liquids, glides, nasals, or vowels were excluded as unfavorable. A total of 3906 vowel tokens were extracted and normalized using Lobanov's (1971) z-scoring method: 1121 BIT, 1010 BET, and 1775 BAT.

3.1 Functional Data Analysis

We fitted measurements from each time-series F1 and F2 trajectory to orthogonal cubic polynomial functions from which we extracted the coefficients (in other words, "parameters") to make independent comparisons of contour shapes. A cubic polynomial function of the form $f(x) = ax^3 + bx^2 + cx + d$ is defined by four parameters: *constant* (equivalent to F1/F2 values at the midpoint measurement), *linear* (slope), *quadratic* (a single "curve" with one turnpoint), and *cubic* (the "curvilinear" shape of a formant contour; it has two turnpoints and one inflection point). With respect to our data, we are most interested in the cubic coefficient of F2 contours as we examine front lax vowel trajectories; highly positive values should correspond to greater diphthongization whereas values close to zero indicate the vowel contour is not composed of a curvilinear component. Previous studies have employed functional data analysis to make statistical comparisons of similar "curve-shaped" data including pitch contours (Grabe et al. 2007), formant trajectories (Mielke 2013, Morrison 2008), and eye-tracking data (McMurray et al. 2010). Median R^2 values of .92 and .91 were achieved for F1 and F2 formant trajectory measurements respectively indicating successful fits to the data. All data analysis was performed in R.

4 Results

In a traditional analysis a single point of measure would typically be chosen to compare varieties. For example, European American SVS vowels are typically measured at the nucleus, frequently estimated to be located 25% to 35% in from the beginning of the vowel, as the nucleus has been described as the most peripheral portion of the front lax vowels for this system. In contrast, a traditional analysis might select the midpoint of AAVS front lax vowels for measurement due to previous descriptions that categorize these vowels as monophthongal. A comparison of these two

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[1] The Praat script was written by Jeff Mielke and adapted for the present study.

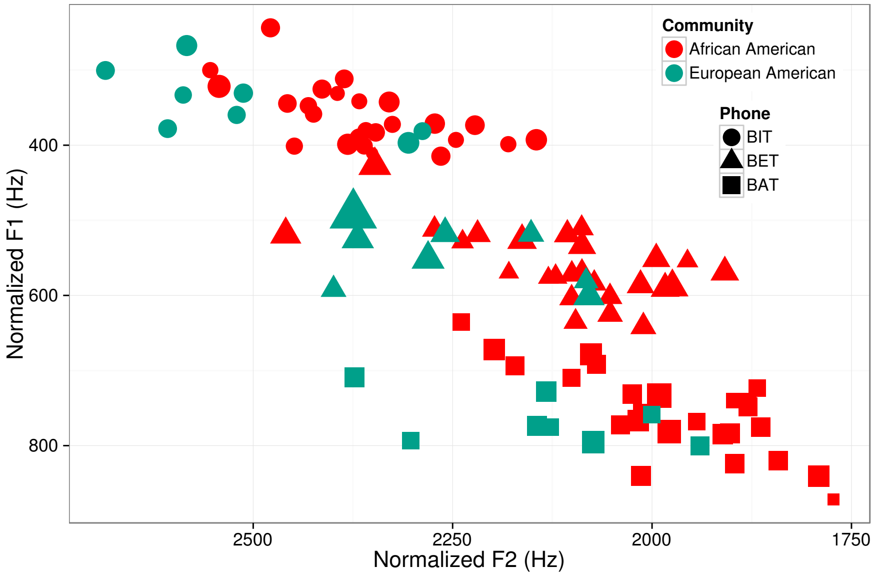

Figure 2: BIT, BET, and BAT single time-point measurements for individual AAE and EAE speakers. Size reflects standard deviation.

measures illustrates static differences in nuclei (EAE) and midpoint (AAE) measures. Figure 2 shows that nuclei measurements from the EAE speakers reach more peripheral targets than the midpoint measurements of the AAE speakers.

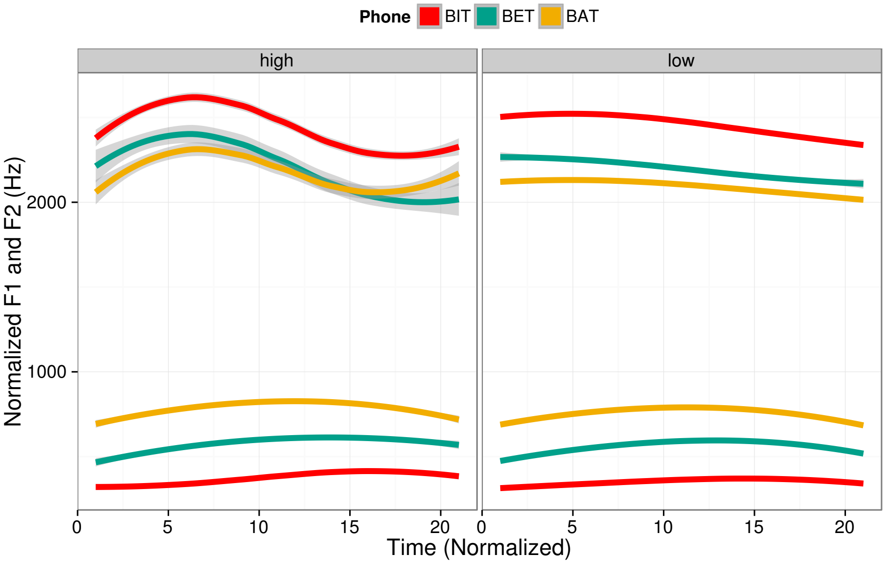

Figure 3: Aggregate BIT, BET, and BAT F1 and F2 trajectories for EAE speakers faceted by high and low F2 cubic coefficients.

This method of comparison does not capture the dynamic information about trajectory shape that is of interest to our study. Additionally, the selection of predefined landmarks for measurement are problematic as we are required to make *a priori* assumptions about differences between dialect groups. Instead, we rely on statistical comparisons of the coefficients extracted from orthogonal cubic polynomial functions fit to F1 and F2 front lax vowel trajectories.

Our first hypothesis concerns the diphthongal shape of the front lax vowels among EAE speakers with respect to stages 2 and 3 of the SVS. As previously stated, F2 cubic coefficients correspond to the diphthongal shape which we expect to characterize front lax vowel peripheralization in the SVS. For EAE speakers, F2 cubic coefficients from all vowel tokens range from -0.389 to 0.643 ($M = 0.045$, $SD = 0.122$). To demonstrate that vowel tokens with high F2 cubic coefficients do in fact correspond to formant trajectories with clear diphthongal shapes, we plot tokens of BIT, BET, and BAT from EAE speakers with F2 cubic coefficients 1.5 standard deviations above the mean in Figure 3 alongside all other EAE vowel tokens. Vowel trajectories were plotted using `ggplot2` in R using loess smoothing. The coefficient split resulted in 70 vowel tokens with high F2 cubic coefficients ($M = 0.330$, $SD = 0.103$) and 949 tokens with non-high coefficients ($M = 0.024$, $SD = 0.094$). The tokens with the most extreme cubic coefficients correspond with a curvilinear shape with two apparent targets at the vowel nuclei and offset.

To test whether or not BET would be more diphthongal (higher F2 cubic coefficients) than BIT among the older-generation EAE speakers in our study, we constructed a mixed effects linear regression model with speaker as a random effect. Log of vowel duration was included as an interaction term in order to account for the expectation that intrinsically longer vowels are more diphthongal. Results of the model are presented in Table 2 below with p-values generated using the `lmerTest` R package.

Variable	*Estimate*	*StdError*	t-*values*
log(duration)	0.123	0.016	7.528∗∗∗
BET	−0.099	0.058	−1.706
BAT	−0.152	0.045	−3.350∗∗∗
BET:log(duration)	−0.034	0.026	−1.304
BAT:log(duration)	−0.050	0.021	−2.411∗

Table 2: Results of a mixed effects linear model predicting F2 cubic coefficients among EAE speakers. Reference level = BIT. *** = significant at $p < 0.001$; ** = 0.01; * = 0.05

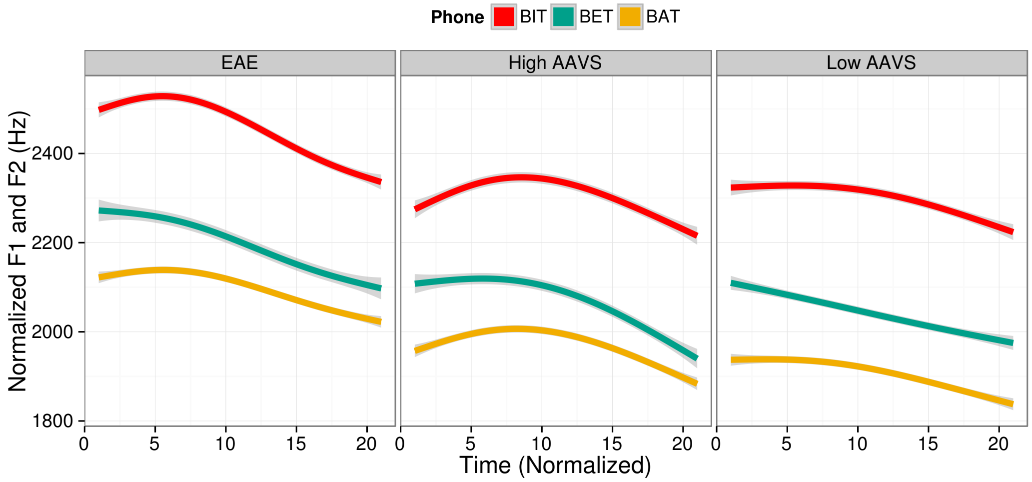

Figure 4: Front lax vowel contours from EAE and high and low AAVS speakers. Contours were smoothed in `ggplot2` using generalized additive model fits.

As expected, the log of vowel duration emerges as the most important factor in predicting F2 cubic coefficients among EAE speakers; as vowel duration increases, front lax F2 contours become more diphthongal in shape. Concerning our hypothesis, BET is not significantly more diphthongal than the reference level BIT and model statistics trend in the direction opposite of our prediction.

Results do show a statistically significant difference between BIT and BAT such that F2 cubic coefficients are higher for the high front lax vowel. Overall, we fail to confirm our prediction that BET is more diphthongal than BIT among these speakers when we control for the effects of duration. This does not follow in accordance with the historical advancement of the stages of the SVS in Raleigh, NC, where BEET and BIT were never completely reversed. It remains that the effect in question is small and warrants further investigation with a larger sample size. Duration, rather than stage in the SVS, is the primary factor influencing diphthongization for this group.

Next, we address the question of how older-generation EAE speakers' front lax vowel contours compare to those of younger-generation AAE speakers in high and low AAVS groups. Specifically, we use orthogonal cubic polynomial fits to visually compare vowel trajectories for each community. As predicted, Figure 4 shows that EAE speakers have distinct contours for BIT, BET, and BAT, compared to AAE speakers who participate in the AAVS. High AAVS speakers have trajectories that conform to a quadratic function (parabolic shape) while the EAE speakers produce trajectories more consistent with a cubic function, a pattern consistent with descriptions of diphthongization. This finding aligns with previous studies that describe the AAVS front lax vowel shift as more monophthongal compared to EAE varieties of the SVS.

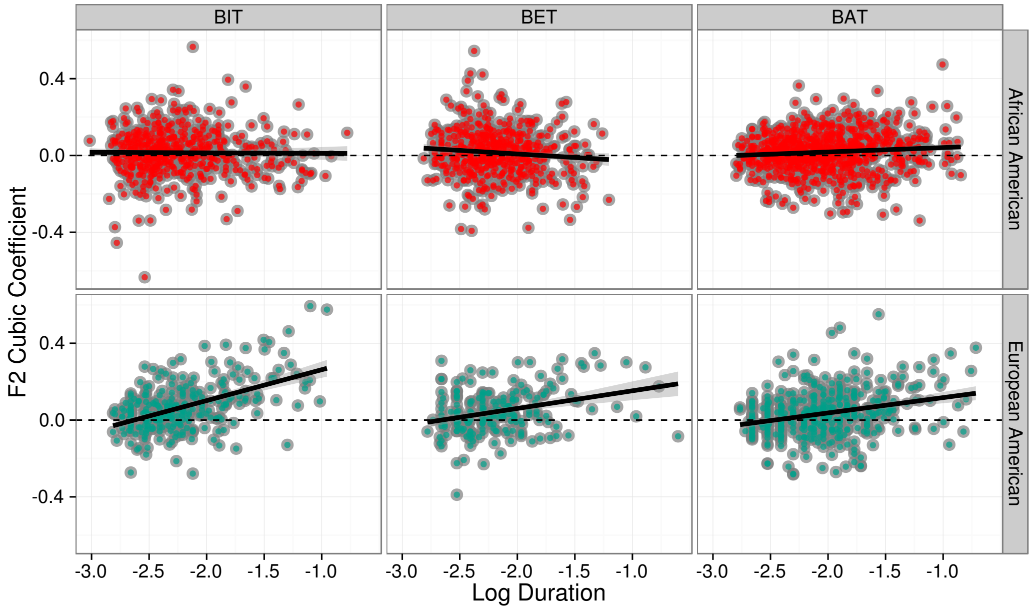

Figure 5: F2 cubic coefficients over log of vowel duration for AAE and EAE speakers.

We also predicted that increased vowel duration would be associated with more diphthongal formant trajectories among older-generation EAE speakers compared to AAE speakers. To test this hypothesis, we compare F2 cubic coefficients (i.e., degree of curvilinear shape) across the log of vowel duration between the two communities. As shown in Figure 5, the curvilinear shape of front lax vowels increases along with duration for European Americans, but not African Americans. The distinctive relationship between duration and diphthongization found in previous studies of the SVS is absent for the AAVS indicating that these two systems are qualitatively distinct. Although both EAE and AAE raise the front lax vowels, the systems differ in the manner in which they raise.

Finally, we compare AAE speakers who appear to participate to a greater degree in the AAVS (high) versus those who participate less (low) based on implicational scores. To address the question of whether or not high participators achieve front lax vowel raising in the manner exploited by EAE speakers, we contrast constant and cubic coefficients from F1 and F2 polynomial fits respectively for both groups of AAE speakers. From the scatterplot in Figure 6 below, we observe that AAE speakers in high and low AAVS groups exhibit a greater degree of variation along the distribution

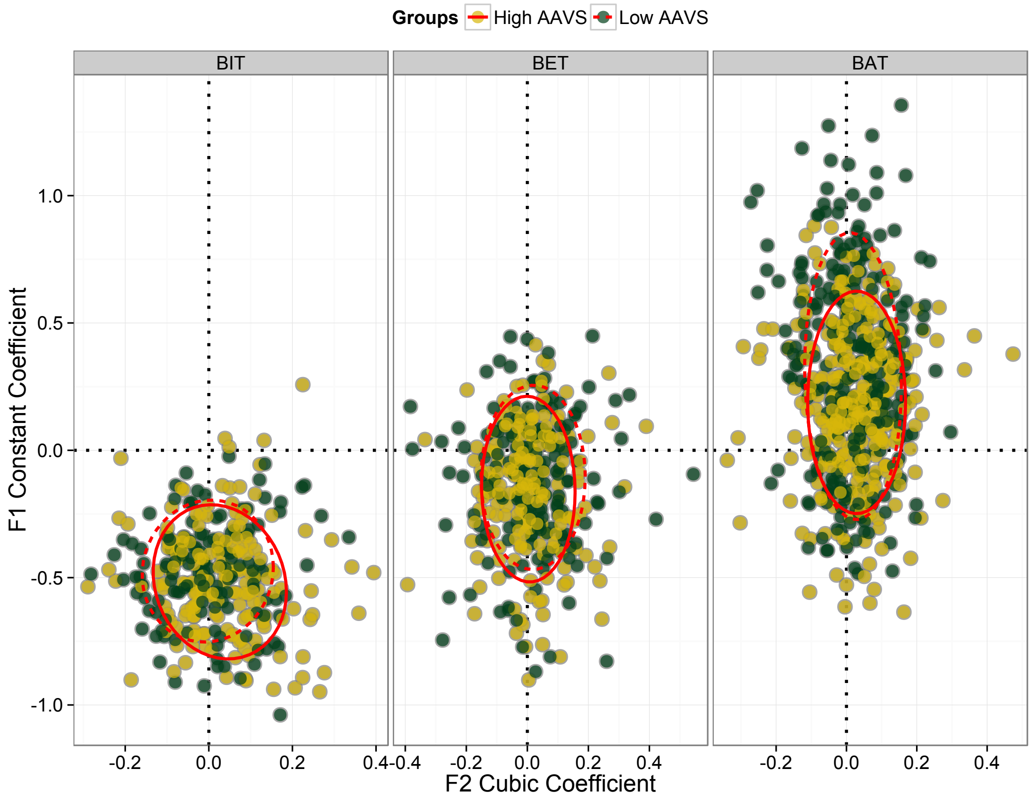

Figure 6: High and low AAVS speakers' F2 cubic by F1 constant coefficients for BIT, BET, and BAT. Ellipses represent 95% confidence intervals. Black dotted lines delimit quadrants.

of F1 constants for BET and BAT compared to F2 cubic coefficients. Visual inspection of the 95% confidence interval ellipses suggests that high AAVS speakers have more F1 constant coefficients concentrated in the lower range for at least BAT which translates to a higher degree of front lax vowel raising. Although high AAVS participants may have more raised lax vowels compared to low AAVS speakers, it is not visually apparent that their trajectories are more diphthongal in shape than low AAVS participants as indicated by the distributions of F2 cubic coefficients. Raising of the front lax vowels for this group does not result in a greater degree of diphthongization.

5 Discussion and Conclusion

Among varieties of English which exhibit superficial alignment at steady-state measures, complex relationships emerge when formant contour shape and vowel duration effects are considered. With respect to EAE speakers, we find that all front lax vowels are diphthongal at longer durations and that BIT and BET are equally diphthongal when controlling for duration. AAE and EAE speakers differ in formant contours in two ways. For EAE speakers, F2 cubic polynomial coefficients are greater than for AAE speakers which indicates that EAE speakers exhibit more diphthongal front lax vowels.

Increased duration also correlates with increased diphthongization for EAE, but not AAE speakers. Although both systems raise front lax vowels, the dynamic quality and the interaction with duration associated with raising is distinct. These qualitative differences raise questions about the relationship between the SVS and the AAVS. Given differences in the quality of raising, how similar are these two systems? What is the relationship between the two patterns of raising in the community?

Differences between the AAVS and SVS described above would be missed by traditional analyses that would only capture a distinction in the amount of raising occurring for each group. Trajectory analyses used in this study improve upon static analyses by creating a measure of the dynamic qualities that distinguish each group and providing a more detailed account of linguistic variation and change. Vowel dynamics are especially important in dialect contact situations where two groups do not share a common vowel target such as is the case in Raleigh, NC (Dodsworth and Kohn 2012). For this reason, we intend to incorporate measurements from younger EAE speakers from this community in future analyses.

Finally, the present study demonstrates that functional data analysis has a place as a valuable tool for analyzing vowel trajectory information within sociophonetics. This method of analysis allows researchers to move closer to capturing fine-grained, sociolinguistically important cues by reducing the dimensionality of a large number of vowel measurements and illuminating differences which are not readily visible using static techniques of acoustic analysis. Importantly, information outside of steady-state F1/F2 measurements are essential to vowel perception and the possibility to more easily examine dynamic qualities of vowels should encourage sociophoneticians to rely less on the "target" model of production. Additionally, among the nascent studies within sociophonetics that examine vowel dynamic information, nearly all focus on regional or cross-linguistic variation; certainly further examinations of ethnic varieties should follow.

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