Laboratory Phonology
Journal of the Association for Laboratory Phonology

Bissell, M., & Carmichael, K. 2022. "Dialect B" on the Mississippi: An acoustic study of /aw/ raising patterns in Greater New Orleans, Louisiana. *Laboratory Phonology: Journal of the Association for Laboratory Phonology*, 13(1): 7, pp. 1–24. DOI: https://doi.org/10.16995/labphon.6453

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"Dialect B" on the Mississippi: An acoustic study of /aw/ raising patterns in Greater New Orleans, Louisiana

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"Dialect B," a diphthong raising pattern conditioned by a following obstruent's surface voicing, was first observed by Joos (1942) among Canadian schoolchildren. It has rarely been documented for /ai/ (Berkson, Davis, & Strickler, 2017) and has never been documented for /aw/ in any North American English variety. Phonetic /aw/ raising, which has raised nuclei in words like "out" but not in words like "loud" or "outer," contrasts with more widely documented phonological /aw/ raising, which has raised nuclei in words like "out" and "outer" but not in words like "loud." In the current study, we examined /aw/ productions from 36 white suburban speakers of Greater New Orleans English, a variety where /aw/ raising before voiceless consonants is a change in progress (Carmichael, 2020b). We classified speakers into three raising patterns: none, phonetic, and phonological. All three raising patterns were present in our data set. This study thus constitutes the first acoustic documentation of a phonetic /aw/ raising pattern produced by a North American English speaker. Additionally, we probe the acoustic implementations of the patterns to analyze phonetic enhancement post-phonologization. These analyses add to descriptions of Greater New Orleans English patterns and build on recent work examining incipient vowel shifts.

1. Introduction

The raising of the nucleus of /aw/ before voiceless obstruents has been studied extensively in Canada, even termed ‘Canadian raising’ by some (Chambers, 1973). However, this feature has also been observed far from Canada in the deep South metropolis of New Orleans, Louisiana (Carmichael, 2020b). In this paper, we examine the development of pre-voiceless /aw/ raising in the New Orleans suburb of Chalmette, demonstrating that this change over time is best understood via dynamic statistical modeling of the acoustic signal. This analysis provides evidence for two distinct types of raising patterns among Chalmatians (phonetic and phonological), adding to the conversations about /ai/ raising (sometimes called ‘American raising’) across the United States, and providing a model for gaining a more nuanced look at formant dynamics in this acoustic phenomenon which has mostly been examined either impressionistically or by use of a single measurement (often F1 of the nucleus at a predetermined time point). Ultimately, we argue in this paper that phonologization of prevoiceless /aw/ raising among speakers in the community of Chalmette has not only implicated pre-flap productions but has also crucially altered the acoustic dimensions of raised productions, including the strength of the allophonic split by following voicing environment.

1.1. Previous research

Pre-voiceless /ai/ raising has been the subject of extensive discussion among researchers studying American English varieties for at least the last forty years (Vance, 1987; Dailey-O’Cain, 1997; Fruehwald, 2016; Berkson, Davis, & Strickler, 2017; Fruehwald, 2017; Hualde, Luchkina, & Eager, 2017; Thomas & Mielke, 2019; Davis, Berkson, & Strickler, 2020; Davis & Berkson, 2021), but observations about pre-voiceless /aw/ raising among American English speakers have been much sparser. While pre-voiceless /ai/ raising and /aw/ raising have been observed to co-occur in most Canadian English varieties (Chambers, 1989; Chambers, 2006; Labov, Ash, & Boberg, 2006; Rosenfelder, 2007), researchers studying American English varieties have noted that, in particular, incipient /ai/ raising appears to occur without concomitant /aw/ raising (Vance, 1987; Labov et al., 2006). Studies that have examined ‘American raising,’ a term more recently coined to differentiate prevoiceless raising in American English varieties from the corresponding process(es) in Canadian English varieties (Davis, Berkson, & Strickler, 2019), have largely focused on the /ai/ vowel class with a few exceptions. We follow Davis et al.’s (2019) precedent, among others’ (Thomas & Mielke, 2019; Dodsworth, Forrest, & Kohn, 2020; Berkson & Davis, 2021), in using this terminology for the American English phenomenon examined in the current study.

Although pre-voiceless /aw/ raising has been extensively documented in Canadian English varieties (Joos, 1942; Chambers, 1973; Boberg, 2005; Labov et al., 2006; Boberg, 2008; Sadlier-Brown, 2012), the process had not been robustly documented in American English varieties until relatively recently: Swan (2017) reported what she termed ‘weak’ pre-voiceless /aw/ raising among American English speakers in Seattle, Washington, and she attributed this finding to those speakers’ close contact with neighboring Canadian English speakers in Vancouver, British Columbia. More recently, Carmichael (2020b) noted pre-voiceless /aw/ raising among American English speakers in Chalmette, a linguistically conservative suburb of New Orleans, Louisiana. Of particular interest is that Carmichael’s findings were not directly attributable to close contact with Canadian English speakers as Swan’s were. Carmichael’s analysis raised important questions about the nature of pre-voiceless /aw/ raising as a burgeoning process in American English varieties, including whether these changes reflect similar trajectories of phonologization to those documented for incipient pre-voiceless /ai/ raising elsewhere in American English varieties (Berkson et al., 2017; Davis et al., 2020).

Pre-voiceless diphthong raising in English has been theorized to originate in post-vocalic voicing effects on preceding vowel duration (House & Fairbanks, 1953; Peterson & Lehiste, 1960). One theory is that shorter pre-voiceless diphthongs are produced with more undershot nuclei (i.e., are less diphthongal) than longer pre-voiced diphthongs (Joos, 1942; Pycha & Dahan, 2016). However, Moreton and Thomas (2007) provided acoustic evidence that pre-voiceless /ai/ productions by Cleveland, Ohio English speakers were not less diphthongal than pre-voiced /ai/ productions, suggesting that nuclear undershoot may not be responsible for the observed pattern. Instead, Moreton and Thomas (2007) proposed that pre-voiceless diphthongs assimilate to their offglides and pre-voiced diphthongs to their nuclei. Although there is sundry evidence supporting and refuting both of these theories, they both place the origin of pre-voiceless diphthong raising squarely in the realm of phonetics via gestural dynamics.

Phonologization, a process in which a phonetic property becomes a phonological property (Hyman 1976, 2008), has been the focus of several studies of pre-voiceless /ai/ raising in North American English varieties (Berkson et al., 2017; Fruehwald, 2017; Davis et al., 2020). Hyman (1976) theorized that phonologization consisted of two stages: a phonetic or coarticulatory stage, and then an acoustic exaggeration beyond a phonetic effect stage. The ordering of these two stages of phonologization is grounded in theories about the life cycle of phonological processes more generally: Bermúdez-Otero (2007, 2013) has argued that more abstract (i.e., phonological) representations must be gradually bootstrapped from a phonetic level to a phonological level. For pre-voiceless diphthong raising in North American English varieties, these two stages (phonetic and phonological) have historically been differentiated by examining productions preceding flapped /t/ (such as in the words *writer* or *outer*). The phonetic raising pattern is characterized by raising before voiceless obstruents, but no raising before flapped /t/ (i.e., raising in *write* but not *writer* or raising in *out* but not *outer*). The phonological raising pattern is characterized by raising before both voiceless obstruents and flapped /t/ (i.e., raising in both *write* and *writer* or raising in both *out* and *outer*). These two patterns crucially differ in what level of following voicing triggers raising: A speaker who produces the phonetic pattern relies on the phonetic (i.e., surface) voicing of the following segment to condition raising, while a speaker who produces the phonological pattern relies on the phonological (i.e., underlying) voicing of the following segment to condition raising.

The phonological raising pattern has been well-documented for both /ai/ (Vance, 1987; Berkson et al., 2017; Fruehwald, 2017; Davis et al., 2020) and /aw/ (Chambers, 1973; Sadlier-Brown, 2012), although existing research on the phonologization of /aw/ has focused near exclusively on acoustic data from Canadian English varieties. In contrast, the phonetic pattern for both /ai/ and /aw/ has proven difficult to document; in fact, this stage of raising has even been theorized to occur too rapidly to observe *in vivo* (Weinreich, Labov, & Herzog, 1968; Janda & Joseph, 2003; Fruehwald, 2017). Recently, Berkson et al. (2017) published acoustic evidence for a phonetic /ai/ raising pattern among a few speakers from Fort Wayne, Indiana, while Bissell (2021) reported additional acoustic evidence for a phonetic /ai/ raising pattern among a few speakers in Columbus, Ohio. In contrast, Joos (1942) impressionistically observed the phonetic raising pattern for /aw/, which he termed 'Dialect B,' among Canadian schoolchildren more than seventy-five years ago; however, no acoustic evidence of this type of /aw/ raising pattern in any North American English variety has been published since that observation. The current study presents a detailed acoustic analysis of pre-voiceless /aw/ raising patterns among English speakers in Chalmette, Louisiana to investigate the stages of phonologization that are observable for pre-voiceless /aw/ raising.

1.2. Background and research questions

Varieties of English spoken in Greater New Orleans (GNO) have not been well described—especially phonetically—until relatively recently. GNO was historically inhabited by the Chitimacha, many of whom still reside in neighboring parishes (Dajko & Walton, 2019). French colonizers arrived in the late 1600s, establishing New Orleans in 1718 as a key outpost near the mouth of the Mississippi River. The territory of Louisiana would remain largely Francophone until the mid-1800s, despite changing hands between France and Spain and ultimately becoming a US state in intervening years. The iconic white, working class New Orleans accent, which has much in common with a New York City accent (Labov, 2007; Carmichael & Becker, 2018), developed in the late 1800s and early 1900s, spoken by a mix of Irish, Italian, and German immigrant groups who worked on the docks of the Mississippi River. Following school integration in the 1960s, many of these white, working class New Orleanians moved outside city limits to majority white suburban towns like Chalmette (US Census Bureau, 2000), thereby enacting de facto school segregation and creating an enclave of white, working class locals who retained traditional linguistic features longer than other areas of GNO. Indeed, Chalmette is now considered by many New Orleanians to be the center of this accent (Mucciaccio, 2009; Carmichael, 2014), which is characterized by variable non-rhoticity (Carmichael, 2017), a split short-a system (Carmichael, 2020a), and pre-voiceless /aw/ raising (Carmichael, 2020b). While non-rhoticity and the split short-a system have been documented as historically present in New Orleans (e.g., Reinecke, 1951; Labov, 2007), pre-voiceless /aw/ raising has not.

Based on an examination of F1 measurements at 25% duration in the /aw/ vowel class, Carmichael (2020b) demonstrated that pre-voiceless raising of /aw/ is a change in progress in the community of Chalmette and postulated that this change may be widespread throughout the greater New Orleans metropolitan area. In this study, we follow up on these insights in order to characterize the acoustic qualities of /aw/ raising more clearly, and to participate in conversations about phonetic versus phonological raising patterns that have become recently popular in the field (Fruehwald, 2016; Berkson et al., 2017; Fruehwald, 2017; Davis et al., 2020). Berkson et al. (2017) and Davis et al. (2020) both showed acoustic evidence of incipient /ai/ raising (i.e., phonetic raising patterns) among a few American English speakers in Fort Wayne, Indiana. The authors of these studies concluded that the existence of phonetic raisers in this community supported a late abstractness hypothesis of phonologization, in which a phonetic raising stage chronologically precedes a phonological raising stage: This claim contrasts with Fruehwald’s (2016) analysis of /ai/ raising in Philadelphia, in which he argued that phonologization occurred so rapidly that a purely phonetic stage of raising was not observable. In the present study, we aim to contribute to these conversations by examining phonologization as a diachronic change in Chalmette. We accomplish this via analysis of the entire F1 trajectory of the vowel to gain a fuller understanding of the phonetic dimensions of variation for speakers across different stages of this change in progress. We thus pose the following questions:

1) Has /aw/ raising been phonologized among speakers in Chalmette? What are the acoustic characteristics of the stages of this change over apparent time?
2) To what extent can examining full F1 trajectories shed light on the time course of this change among speakers in this community, and how can this methodology inform best practices for the acoustic examination of raising in the context of variationist research paradigms?

These are the questions to which we now turn.

2. Methods

2.1. Data collection and processing

Thirty-six white residents of Chalmette were interviewed by the second author in 2012. Participants are identified throughout by their self-selected pseudonyms. Interviews were recorded in .wav format on a Handy H4 zoom recorder with participants wearing a Shure SM10A headset microphone to capture fine acoustic detail and minimize the effect of background noise. Interviews lasted 1–3 hours, with the goal of eliciting free-flowing, narrative style speech. This was accomplished by using an oral history approach to the interview to collect stories about life in Greater New Orleans.

Thirty to forty-five minutes of the interview was selected for transcription and was force-aligned for analysis using the Montreal Forced Aligner (McAuliffe, Socolof, Mihuc, Wagner, & Sonderegger, 2017). For most participants, this portion of the interview consisted of their “Hurricane Katrina story”—a common local narrative in which individuals chronologically describe their preparation and expectations for the storm, whether/where they evacuated, and then how their life was affected afterwards. At the end of the interview, participants also completed a reading passage and word list that targeted linguistic variables of interest, including /aw/. Sociodemographic information about the participants is provided in the Appendix.

2.2. Acoustic measurements and speaker classification protocols

Pre-nasal tokens (e.g., *down, town*) were excluded from the dataset because of extreme raising and fronting in these environments (Carmichael, 2014; Carmichael, 2020a). Coda /aw/ tokens with following word boundary (e.g., *how, cow*) were also excluded to maximally control for following environment. F1 measurements from all eligible tokens of /aw/ were automatically extracted at nineteen equally-spaced time points (5% duration, 10% duration, …95% duration) using a script in Praat (Boersma & Weenink, 2021). After data processing, tokens preceding voiced flaps (e.g., *louder; crowded*) were excluded due to infrequency. Finally, speakers without pre-flapped /t/ tokens (n = 21) were excluded.

The resulting data (n = 28,886 acoustic estimates from 36 speakers) were coded for the following segment: voiced obstruent, voiceless obstruent, or flapped /t/. Outliers, which were defined as any F1 (Hz) measurement that was greater than three standard deviations away from a speaker’s mean F1 measurement (Hz) at a given time point, were hand-corrected. A total of 757 F1 estimates (2.6%) were corrected using this protocol. The final data set that was analyzed contained speech from three contexts: conversational interview (61.7%), reading passage (24.2%), and word list (14.1%).

Then, mean F1 trajectories for each talker were generated in R (R Core Team, 2021) for each following environment using generalized additive models (GAMs). This method was selected to gain insight into formant dynamics over the course of the /aw/ diphthong for each following environment of interest. Modeling vowel-inherent spectral change has long been utilized for understanding the details of formant dynamics within vowel productions (Nearey & Assmann, 1986; Morrison & Nearey, 2007). While several studies have operationalized GAMs to model vowel inherent spectral change across speakers and generations (Sóskuthy, Foulkes, Hughes, & Haddican, 2018; Sóskuthy, Hay, & Brand, 2019; Renwick & Stanley, 2020), in the present study we chose to use GAMs to capture variability in /aw/ productions by following environment *within* speakers (cf. Hualde, Barlaz, & Luchkina, 2021 on /ai/ raising in Chicago, Illinois). While diphthongs like /aw/ by definition undergo spectral change over the course of any given production due to having multiple acoustic targets, GAMs are capable of specifically modelling non-linear effects of both timepoint and following environment for each speaker.

We fit a separate GAM for each speaker's data. The dependent variable, F1 (Hz), was predicted by a smooth factor interaction involving timepoint and following environment: This structure allows for a separate smooth to be constructed for each level of following environment. While the visualizations that appear in the following section were generated using the GGPLOT2 package (Wickham, 2016) in R, the models themselves can also be generated using the MGCV package (Wood, 2011) in R.[1]

In our analysis, we knew that pre-flapped /t/ tokens would prove crucial for differentiating phonetic raising behaviors from phonological raising behaviors. Several scholars have used pre-flapped /t/ productions as indicators of phonetic versus phonological raising patterns (Joos, 1942; Chambers, 1973; Berkson et al., 2017; Fruehwald, 2017; Davis et al., 2020): Speakers who produce the phonetic pattern raise only before surface voiceless following environments. Speakers with this pattern would produce raised /aw/ nuclei in *out* but not *outer*. Speakers who produced the phonological pattern raise only before underlyingly voiceless following environments. Speakers with this pattern would produce raised /aw/ nuclei in both *out* and *outer*. These two kinds of raising patterns are distinguishable from one another only in a relatively small number of lexical items in the Chalmette corpus, especially given the relative infrequency of pre-flap /aw/ tokens in English more generally (and especially compared to those for /ai/). The Hoosier Mental Lexicon (Nusbaum, Pisoni, & Davis, 1984) lists twelve lemmas that consist of /aw/ preceding a coda /t/ that would be eligible for /t/ flapping, if suffixes like *-ing* or *-er* were to be added (de Jong, 2011).

The classification procedure for determining each speaker's type of raising behavior was quantitatively motivated. First, we categorized speakers as raisers or non-raisers. They were classified using Labov et al.'s (2006) 60 Hz acoustic diagnostic, which was the mean difference between unnormalized pre-voiced obstruent and pre-voiceless obstruent F1 nuclei measurements that they designated as constituting allophonic raising. This particular diagnostic has been widely adopted by phonetic and sociolinguistic researchers alike to quantify /ai/ and /aw/ raising in North American English varieties (Boberg, 2008; Nycz, 2018; Farris-Trimble & Tessier, 2019; Carmichael, 2020b). Labov et al. (2006, p. 38), among others (Moreton & Thomas, 2007; Risdal & Kohn, 2014), advocated for using F1 maximum as a nucleus height estimation for diphthongal nuclei, although several recent studies of American raising have adopted a static measurement point (typically 25%, 30%, or 33% of total vowel duration) for quantifying diphthongal nucleus height (Berkson et al., 2017; Carmichael, 2020b; Dodsworth et al., 2020).

Carmichael (2020b) previously used this 60 Hz cutoff as a classificatory mechanism for /aw/ productions in Chalmette with acoustic estimates that were uniformly measured at 25% segment duration. In contrast, the current study analyzed F1 measurements extracted at the F1 trajectory's global maximum, which was treated as the F1 nucleus value for separating raisers from non-raisers

[1] To implement a GAM model using the MGCV package in R for a speaker included in the data file in the appendix, use this general formula with the appropriate subset: bam(f1_long ~ s(timepoint, by = Wordclass, bs = "fs"), data = subset(frame, conditions)).

(cf. Labov et al., 2006; Moreton & Thomas, 2007); this extraction protocol allowed the F1 nucleus measurement to be motivated by the acoustic signal itself, such that F1 nucleus time points could vary both across and within speaker productions by following environment. These F1 nucleus values were extracted from the raw data with an R script that selected the peak F1 value from each speaker’s mean trajectory for each following environment. Each speaker’s mean F1 nucleus value in pre-voiceless environments was subtracted from their mean F1 nucleus value in pre-voiced environments, and then speakers were categorized as raisers if this difference exceeded 60 Hz and as non-raisers otherwise. Although we argue in this paper that raising can best be examined via consideration of the entire vowel trajectory, making use of the 60 Hz cutoff served two functions in this study: (1) it makes our work comparable with previous research on Canadian raising of /aw/ in terms of identifying the proportion of raisers in the speech community and (2) it provides a functional diagnostic of raising that allowed us to focus specifically on speakers in our sample likely to manifest phonetic and phonological raising patterns.

To distinguish phonetic raising behaviors from phonological raising behaviors within the broader category of raisers that had been established, we first calculated the global F1 maximum value for a speaker’s /aw/ trajectories in pre-voiced, pre-voiceless, and pre-flapped /t/ environments. Then, we numerically compared the differences between mean pre-voiced and mean pre-flapped /t/ F1 nuclei and between mean pre-voiceless and pre-flapped /t/ F1 nuclei to determine which following voicing category the pre-flapped /t/ tokens patterned with most closely (cf. Berkson et al., 2017).

Another acoustic factor of potential interest, F2 (Hz), has been omitted from the current analysis. While this factor has been implicated in /ai/ raising processes elsewhere in North America (Thomas, 2000; Moreton & Thomas, 2007; Onosson, 2018), its role in /aw/ raising processes is less clear. Especially given historical evidence of /aw/ nucleus fronting in the context of the Southern Vowel Shift (Thomas, 2003), F2 is likely a relevant factor for conceptualizing /aw/ raising in New Orleans in a very broad sense. F2 acoustics are outside of the immediate scope of this analysis primarily due to the centrality of Labov et al.’s (2006) 60 Hz metric in our raiser classification scheme, although the role of F2 in /aw/ raising processes is an area ripe for future study in this dataset.

3. Results and discussion

3.1. Speaker classification: Non-raisers, phonetic raisers, and phonological raisers

In order to examine /aw/ raising in this corpus, we first completed an assessment of which speakers were raisers, and amongst them, which speakers raised in phonologically voiceless environments (all underlyingly voiceless environments, including those preceding flapped /t/) and who raised in only phonetically voiceless environments (thus excluding pre-flapped /t/ environments). Non-raisers were characterized as having a mean difference between their pre-voiced and pre-voiceless /aw/ productions that did not clear the 60 Hz threshold. **Table 1** shows the distribution of non-raisers, phonetic raisers, and phonological raisers documented in this data set, demonstrating that our corpus of speakers contains all three stages of phonologization that have been frequently discussed in the raising literature (Joos, 1942; Berkson et al., 2017; Fruehwald, 2017; Davis et al., 2020).

Raiser type	Counts
Non-raiser	21
Phonetic raiser	4
Phonological raiser	11

Table 1: Distribution of raiser types among Chalmatian speakers (n = 36).

This table demonstrates that non-raisers were the most frequently observed and phonetic raisers were the least frequently observed. **Figure 1** shows F1 trajectories typical of the non-raiser pattern: the left panel shows F1 trajectories for Mary, a 76-year-old female speaker, and the right panel shows F1 trajectories for Super, a 62-year-old female speaker. Mary's mean F1 difference by voicing was 20 Hz, while Super's mean F1 difference by voicing was 7 Hz.

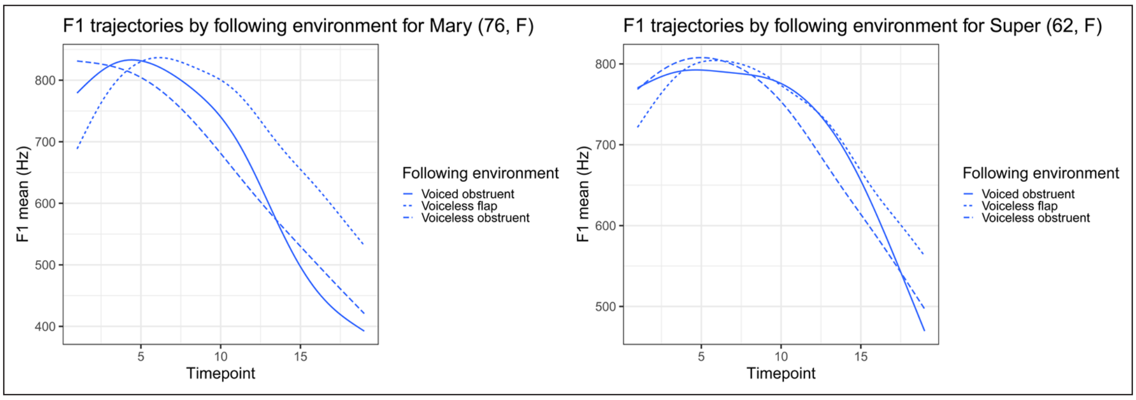

Figure 1: F1 trajectories by following voicing environment for Mary, a 76-year-old female non-raiser, and Super, a 62-year-old female non-raiser.

Both phonetic and phonological raisers by definition clear the 60 Hz difference threshold between F1 maxima preceding voiced and voiceless obstruents. **Figure 2** shows F1 trajectories typical of the phonetic raising pattern in this data set, in which pre-flapped /t/ environments pattern with pre-voiced obstruent environments, for Bella, a 46-year-old female speaker with a mean F1 difference by voicing of 60 Hz, and Margaret, a 59-year-old female speaker with a mean F1 difference by voicing of 69 Hz. Both of these speakers exemplify the phonetic raising pattern, which is evident because their pre-flapped /t/ productions are not raised (i.e., patterned with unraised pre-voiced obstruent tokens). That is, the *phonetic* or surface voicing of the following segment conditions raising.

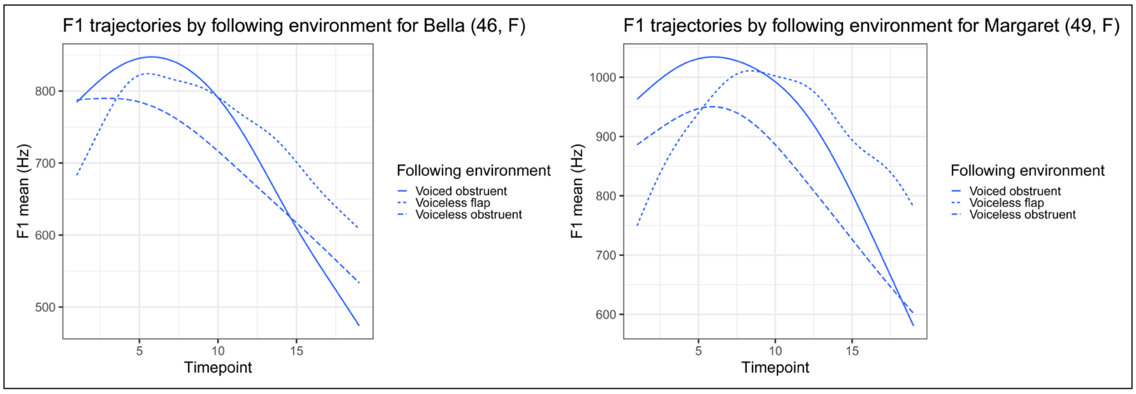

Figure 2: F1 trajectories by following voicing environment for Bella, a 46-year-old female phonetic raiser, and Margaret, a 49-year-old female phonetic raiser.[2]

Contrastively, phonological raisers show a raising pattern in which their pre-flapped /t/ productions were raised (i.e., pattern with raised pre-voiceless obstruent tokens)— indicating that the underlying voicing of the following segment, rather than its phonetic (surface) realization, triggers raising. **Figure 3** shows F1 trajectories for two speakers who typify this kind of pattern, in which we can see that pre-voiceless flap environments pattern with pre-voiceless obstruents for Dave, a 19-year-old male speaker with a mean F1 difference by voicing of 142 Hz, and Sara, a 31-year-old female speaker with a mean F1 difference by voicing of 125 Hz.

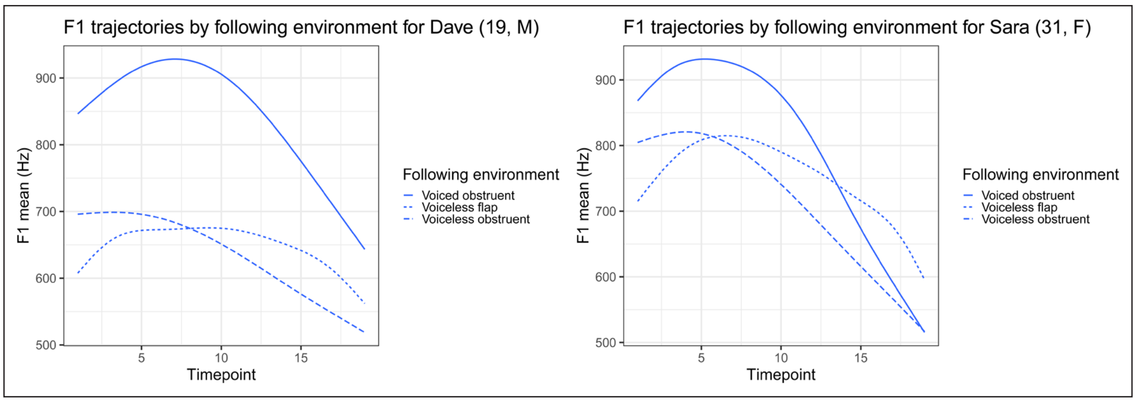

Figure 3: F1 trajectories by following voicing environment for Dave, a 19-year-old male phonological raiser, and Sara, a 31-year-old female phonological raiser.

[2] Differences in the *shape* of the pre-voiceless flap trajectory, such that it tends to have a later maximum and more centralized start/end points, persist throughout. While the precise factors driving this pattern warrant additional scrutiny, in the meantime we suspect that this pattern is at least partially the result of especially short durations in pre-voiceless flap environments (see Table 2). For example, it is possible that monophthongization driven by gestural timing constraints is motivating this pattern.

The existence of all three raising stages among Chalmatian speakers provides strong evidence that the phonologization of /aw/ raising is a change in progress occurring in this community. In particular, this analysis shows novel acoustic evidence for phonetic /aw/ raising in a North American English dialect, which to our knowledge has not been previously documented. Further, the current analysis also suggests similar processes of phonologization for pre-voiceless /aw/ raising and that of /ai/ raising noted in other communities, prompting additional questions about the presence of the latter within this dialect.

The evidence from this study also mirrors Berkson and her colleagues' (2017) findings when documenting phonetic raising patterns in Fort Wayne, Indiana: Phonetic raisers were rare relative to phonological raisers, which is to be expected due to the sheer speed of sound change (Weinreich et al., 1968; Janda & Joseph, 2003). Moreover, the observation of all three raising patterns (none, phonetic, and phonological) in the current analysis facilitates a detailed assessment of the acoustics of raising across these three stages of phonologization. Before turning to an exploration of apparent time acoustic evidence relating to the diachronic course of this phonologization process in Chalmette, we briefly detour to a discussion of how another acoustic factor, vowel duration, may play a role in the patterns that have been observed.

3.2. Duration effects

That duration plays a role in F1 dynamics in the context of pre-voiceless diphthong raising is generally accepted, regardless of whether the mechanism for this process has to do with nuclear undershoot (Joos, 1942; Pycha & Dahan, 2016) or differences in assimilation patterns across following voicing environments (Moreton & Thomas, 2007). Therefore, the extent to which durational differences across raising patterns and following environments contribute to the acoustic patterns described elsewhere in this section is worth probing. For example, it could be the case that raisers produce shorter pre-voiceless /aw/ tokens than non-raisers, suggesting that duration may be driving group-level acoustic differences.

A two-way ANOVA was conducted to examine the effects of following environment (voiced obstruent, voiceless flap, voiceless obstruent), raising pattern (none, phonetic, phonological), and their interaction on vowel duration. The test revealed only a significant effect of following environment on vowel duration ($f(2) = 350.39$, $p < 0.05$). **Table 2** shows group means by following environment and raising pattern. The lack of significant effect of either raising pattern or its interaction with following environment suggests relative uniformity in vowel duration by following environment regardless of raising pattern.

Three post-hoc Tukey tests of the following environment categories with Bonferroni correction showed that all three environments are significantly different from one another. As expected, pre-voiced obstruent tokens were longer than pre-voiceless obstruent tokens ($p < 0.05$). Pre-voiceless flap tokens were shorter than both pre-voiceless obstruent tokens ($p < 0.05$) and

	Voiced obstruent	Voiceless flap	Voiceless obstruent
None	328 ms	137 ms	166 ms
Phonetic	329 ms	140 ms	175 ms
Phonological	335 ms	133 ms	153 ms

Table 2: Mean values for vowel duration by following environment and raising pattern.

pre-voiced obstruent tokens ($p < 0.05$). The pre-voiceless flap tokens were likely shorter due to being produced in a disyllabic context, as was commented upon in Berkson et al.'s (2017) similar durational findings among speakers from Fort Wayne, Indiana. Taken together, these duration-related findings suggest that in the aggregate the three raising patterns are not distinguishable from one another by duration alone in any particular following voicing environment.

3.3. Nucleus timing variability

Since we were using the F1 maximum to estimate nucleus height, this value was collected at various points along the first 60% of the vowel duration. **Figure 4** shows variability in nucleus timing for all /aw/ productions that were analyzed. Many speakers' maxima occurred within the first 10% of the vowel, with another cluster of tokens around 25% and 35%, and a few closer to the halfway point in duration. But overall, there is just a lot of variability.

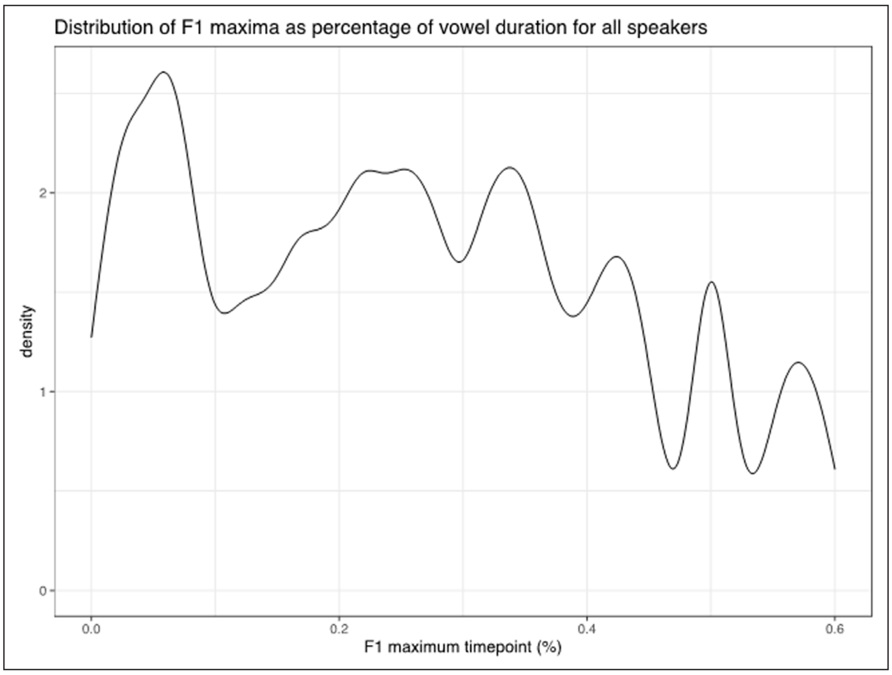

Figure 4: Density curve of the distribution of by-token F1 maxima as a proportion of total segment duration.

In examining F1 trajectories according to following environment (voiced obstruent, voiceless obstruent, and voiceless flap—phonetically voiced but underlyingly voiceless), it became clear that nucleus timing can also vary across these environments within a single speaker's productions—selecting a single time point to represent the nucleus across these environments may not accurately capture F1 maxima. **Figure 5**, for example, shows four speakers who produced variable nucleus timing by following environment, with several speakers demonstrating later peaks for pre-flap tokens than for other environments. While the source of this particular pattern is left for future research, the speakers shown in **Figure 5** demonstrate the large amount of variability in nucleus timing both within and across speakers in this corpus.

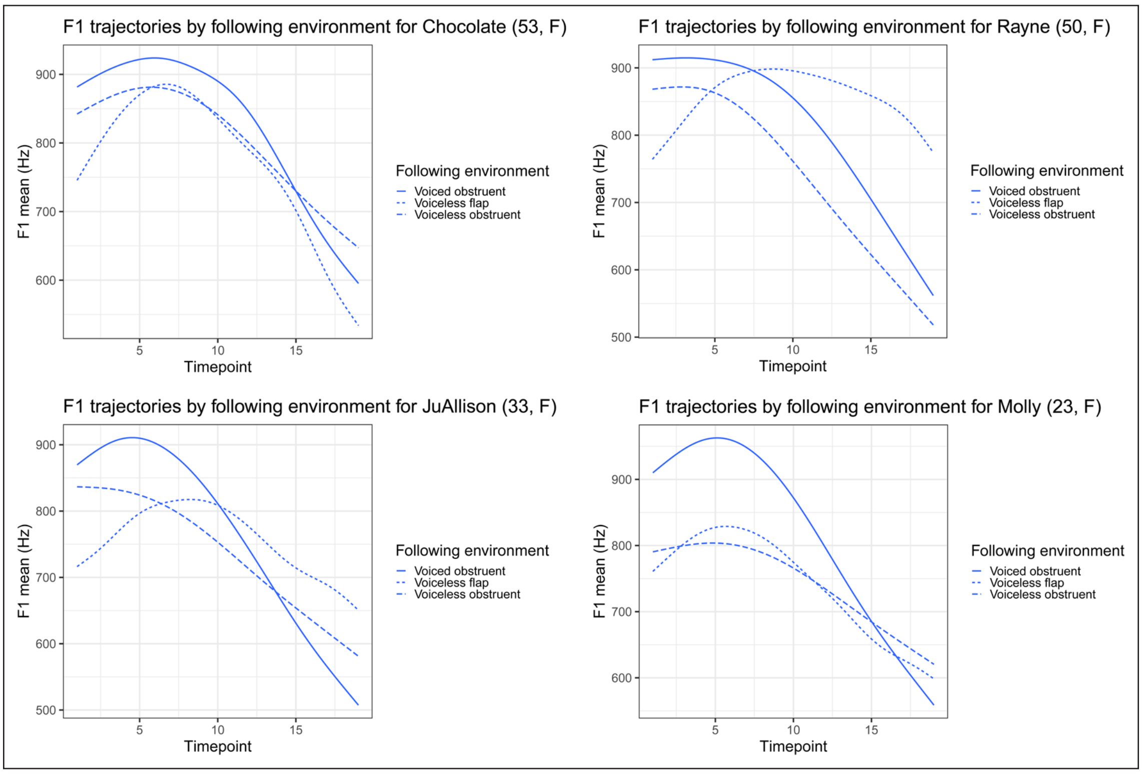

Figure 5: Mean F1 (Hz) trajectories for tokens produced by Chocolate, a 53-year-old female non-raiser; Rayne, a 50-year-old female phonetic raiser; JuAllison, a 33-year-old female phonological raiser; and Molly, a 23-year-old female phonological raiser.

In **Figure 5** we also see examples of all three raiser types—Chocolate is a non-raiser, with little difference between her tokens of /aw/ across the various environments; Rayne is a phonetic raiser, with the maximum F1 for pre-voiceless flap /aw/ patterning with that for pre-voiced obstruent /aw/; and JuAllison and Molly are phonological raisers, with pre-voiceless flap /aw/ patterning with pre-voiceless obstruent /aw/. Some speakers feature variably more monophthongal pre-flap tokens (e.g., Rayne, JuAllison) than others (e.g., Chocolate, Molly), which also affected at what point their maximum F1 measurement occurred for those tokens. Especially for these speakers, extracting formant values for the pre-flap tokens at a given timepoint and comparing to that same time point for other environments, rather than considering the full trajectory, might have altered the categorization of their raising patterns.

3.4. The acoustics of phonologization over apparent time

To assess how the acoustic qualities of raising developed over the course of phonologization, we analyzed the difference between pre-voiced and pre-voiceless F1 nuclei as a function of raising pattern. We conducted a Kruskal-Wallis rank sum test (the non-parametric equivalent of an unpaired, two sample t-test) to determine whether there were significant between-group differences in F1 according to following voicing environment for phonetic raisers and phonological raisers.[3] Non-raisers ($n = 21$) were excluded, as their production differences according to following voicing environments were by definition known to be uniformly less than 60 Hz ($M = 24$ Hz, $SD = 24$ Hz).

The results of the Kruskal-Wallis rank sum test revealed that there were significant differences between the individuals who produced phonetic and phonological raising patterns in terms of mean acoustic differences between pre-voiced and pre-voiceless /aw/ tokens ($X^2 = 7.89$, df = 1, $p = 0.005$). **Table 3** shows group means and standard errors, demonstrating that speakers with a phonological raising pattern, in general, produce more divergent allophones acoustically in terms of F1 than phonetic raisers do. That is, raising of /aw/ is more pronounced amongst speakers who have phonologized this pattern, indicating that phonetic enhancement has occurred for the phonologized pattern.

Raising pattern	Mean difference	Standard error
Phonetic	65 Hz	2 Hz
Phonological	110 Hz	9 Hz

Table 3: Mean values and standard errors for differences in F1 nucleus productions by following voicing environment.

This acoustic difference between phonetic and phonological raising patterns matches what has frequently been observed by researchers studying phonologization. The results presented in **Table 3** likely reflect phonetic enhancement of a phonologized effect, which was reported in detail by Fruehwald (2016, 2017) for the phonologization of /ai/ raising in Philadelphia, Pennsylvania. We argue that a similar effect is occurring in the Chalmette data, such that the acoustic production

[3] A non-parametric test was selected due to the two groups having very different variances: The phonological group’s variance is 1215.2, while the phonetic group’s variance is just 16.3. Because this large difference violates one of the fundamental assumptions of the parametric t-test, a non-parametric test was conducted instead.

of an allophonic effect that has been phonologized becomes more distinct as the diachronic process of phonologization progresses. Importantly, this analysis serves as a proof of concept for Hyman's (1976, 2008) notion that phonologization should be fundamentally characterized as exaggeration of a phonetic effect. Explicit comparison of phonetic and phonological raising patterns in this study allowed for direct testing of this theory that the phonologization of /aw/ raising would involve increasing amounts of acoustic divergence throughout the stages of the process.

Fruehwald (2017) observed that the phonologization of /ai/ raising among Philadelphians (and, more generally) was an atypical phonologization process, such that the distribution of the contexts in which the raised variant appeared once phonologized was actually *altered* from the distribution of the contexts in which the raised variant appeared in a preceding phonetic stage. Namely, pre-flapped /t/ tokens would not be raised for phonetic raisers but would become raised once the pattern was phonologized. What Fruehwald (2017) did not observe among his Philadelphia speakers was phonetic raising patterns, which made it difficult to assess whether phonologization itself was the root cause of the phonetic enhancement effects he reported: It is certainly possible to imagine a world in which phonetic enhancement (i.e., phonetic divergence of allophones) becomes quite advanced prior to the moment of phonologization itself. The current analysis provides evidence that phonetic and phonological raisers differ significantly from one another with respect to the F1 differences they produced based on the following voicing environment. Moreover, the data we presented here demonstrated that the phonologization of /aw/ raising indeed instantiated further acoustic divergence on a relatively large scale.

3.5. Exploratory analysis: Social factors

The apparent phonologization of /aw/ raising among Chalmatians is novel, especially given that prior studies have shown Chalmette speakers' tendencies towards being linguistically conservative, eschewing many non-traditional features that have become more common in New Orleans proper (Mucciaccio, 2009; Carmichael, 2017; Carmichael, 2020b). Therefore, the social factors involved in this change in progress are worth investigating in more depth.

Although Carmichael (2020b) established /aw/ raising in general as a change in progress in the speech of Chalmatians, her analysis did not differentiate between different types of raising patterns—phonetic versus phonological. To probe this question, we examined the mean age of speakers who produce different raising patterns. **Figure 6** shows means and standard errors for the ages of speakers who produced each type of pattern.

On average, phonological raisers were younger than both non-raisers and phonetic raisers. This age distribution across groups suggests that phonological raising patterns are newer in a relative sense than both non-raising and phonetic raising patterns. This sort of pattern is not unexpected, given what has been described as the chronology of phonologization generally by Hyman (1976, 2008) and more specifically for /ai/ raising by Berkson et al. (2017). This data provides further

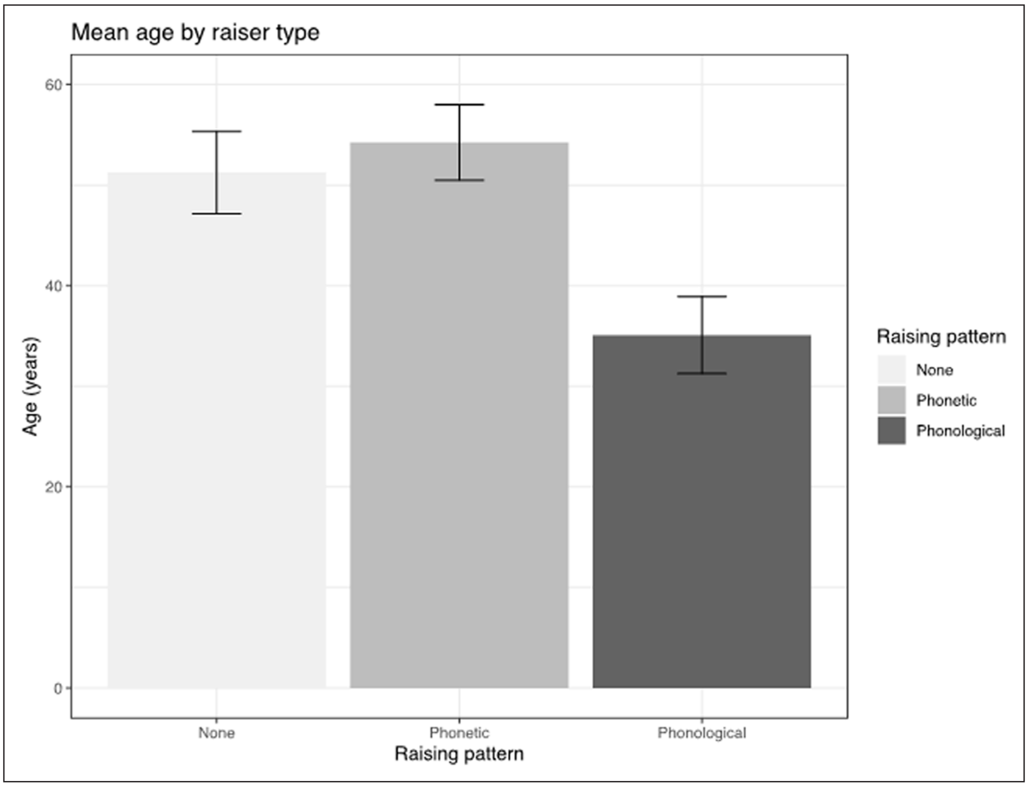

Figure 6: Mean values and standard errors for speaker age by raising pattern.

hints about the way phonologization of diphthong raising proceeds on the community level. The question arises, however, of who within the community is leading the change. To answer that question, we first examined gender trends by type of raising pattern, since gender is frequently implicated in sound changes in progress (Labov, 1994). **Table 4** shows information about the numbers of self-identified men and women who produce each raising pattern.

Raising pattern	Number of women	Number of men
None	13 (62%)	8 (38%)
Phonetic	4 (100%)	0 (0%)
Phonological	6 (55%)	5 (45%)

Table 4: Gender distribution of speakers by raising pattern.

Table 4 demonstrates similar overall rates of /aw/ raising for men and women, but it is notable that no men in our sample produced the phonetic raising pattern. Moreover, all of the phonological raisers were under age 40, in contrast with the phonetic raisers and non-raisers who averaged 50–60 years of age at time of recording. Taken together, **Tables 4** and **5** suggest that middle-aged women may have been the innovators of phonetic /aw/ raising patterns in Chalmette, although additional data is needed to confirm these trends, since so few phonetic raisers exist in this data set. In our analysis, we assume that phonetic raisers innovated this change in progress which crystalized as their raising system, rather than phonetic raising representing a stage within a single speaker on the way to phonological raising; that said, the status of phonetic and phonological raising as individual versus community-wide patterns is an open question that we hope others will take on for future research.

Carmichael (2020b) reported that pre-voiceless /aw/ raising as a change in progress did not appear to be led by men or women based on F1 acoustics, without accounting for phonetic versus phonological raising pattern differences across speakers. The current study provides an additional frame of reference for these findings. Because the stages of phonologization have been proposed to unfold over apparent time (Hyman, 1976; Hyman, 2008), they too are relevant for contextualizing this change in progress. The results from the current analysis show that, in its intermediate phonetic raising stage, this change in progress among Chalmatians appears to be led by women of a particular age group. In contrast, the end-state phonological raising stage appears to be both newer and more evenly distributed in terms of gender composition, obscuring the gender effects we report on here.

The four phonetic raisers in our sample do not share any clear uniting social factors aside from being women and middle-aged. In terms of their use of other previously studied socially meaningful linguistic features in the community, such as non-rhoticity and split short-a systems, both of which are on the retreat for younger speakers (Carmichael, 2017; Carmichael, 2020a), none of these speakers demonstrates a particularly innovative linguistic profile in terms of these changes in progress. That is to say—there is no obvious reason based on the identity of these speakers why they would be leading the change in progress towards raising in this community, and they are not the linguistic 'Avant Garde' (cf. Labov, 2018) of Chalmette in other ways. Thus, additional social factors motivating the development of pre-voiceless /aw/ raising will be important to consider in future work on this variable within Greater New Orleans.

3.6. The status of /aw/ raising as a sound change in Greater New Orleans

As we have shared evidence of the phonologization process of pre-voiceless /aw/ raising, we must also broach the question of why, how, and amongst whom this change is occurring, and what our analysis can contribute more broadly to our understanding of sound change. The data set we report upon comes from one of the most linguistically conservative areas of Greater New Orleans, a bastion of many traditional linguistic features in part due to the socially insular nature of this community (Carmichael, 2014, 2017, 2020a). Indeed, Carmichael (2020b) puts forth some evidence that Chalmatians may be laggards in terms of adopting /aw/ raising, a change in progress which may be further advanced in other parts of GNO. Because there is no evidence of the innovators of this change being from another dialect area featuring raising, Carmichael suggests that this feature is a change from below. But what we have captured in this data set is not likely to be from those innovators; rather, the speakers using this feature are adopting a trend that is ongoing in GNO—meaning that although this feature may have originally arisen spontaneously due to articulatory forces, within Chalmette its adoption is more likely a case of diffusion from other GNO users, rather than true innovation (see Labov, 2007).

Because Chalmette speakers are still in the process of acquiring this feature, it is possible to see the phonetic stage of the phonologization process. This is a benefit for this particular study but leaves us with little context about how phonologization is progressing more broadly in the region, and how long one might expect the phonetic raising patterns to coexist with phonological raising in a speech community. Thus, before satisfying answers can be proposed about the source of this sound change, it will be crucial to determine the status of this feature in other parts of GNO. Another key direction for future research is the examination of /ai/, in order to determine whether there is a shared phonetic motivation for diphthong raising before voiceless segments, as has been proposed by some (e.g., Moreton, 2004; Moreton & Thomas, 2007). If pre-voiceless /ai/ raising is observed to be concomitant with pre-voiceless /aw/ raising, then we have stronger evidence for an argument of articulatory motivation as the original impetus for this sound change taking hold in this community. If, in contrast, /ai/ raising is not observed to be concomitant, New Orleans would represent an intriguingly rare US dialect, eschewing so-called 'American' raising (of /ai/) but adopting so-called 'Canadian' raising (of /aw/), which would pose additional questions for the phonetic naturalness argument.

4. Conclusions

This study represents the first documentation, to our knowledge, of the phonetic raising pattern for /aw/ in North American English. Mirroring key findings for /ai/ (Berkson et al., 2017; Davis et al., 2020), we demonstrate not only the existence and observability of the phonetic stage in phonologization, but also the ways that the acoustic signal itself changes over the process of phonologization, with evidence of phonetic enhancement amongst the phonological raisers in our corpus. Additionally, we provide sociodemographic context to support our analysis of the diachronic course of phonologization in Chalmette. The phonetic raisers, a group entirely composed of middle-aged women in this corpus, may likely be innovators of this change in progress. Lending support to this interpretation is the fact that this finding matches existing accounts of women leading sound changes from above, both in Greater New Orleans specifically (Carmichael, 2017) and in general in Western contexts (Labov, 1990).

This paper also featured methodological improvements compared to previous research on /aw/ raising, both in Greater New Orleans and elsewhere, by using GAMs to examine the full formant dynamics of the diphthong. This allowed us to account for nucleus timing differences which vary considerably by following context for many speakers. We argue that when examining variation in diphthongs, it will be essential moving forward to adapt our methods from the use of static measurements to more dynamic modeling, in order to gain a more nuanced picture of the acoustic signal.

Additional files

The additional files for this article can be found as follows:

- **Appendix.** Participant sociodemographic information. DOI: https://doi.org/10.5334/labphon.6453.s1
- **File 1.** Raw data in CSV format. DOI: https://doi.org/10.5334/labphon.6453.s2
- **File 2.** R code for generating the figures in the paper. DOI: https://doi.org/10.5334/labphon.6453.s3

Acknowledgements

We would like to thank our editor, Lisa Davidson, as well as our reviewers, Joey Stanley and one anonymous reviewer, for their feedback and guidance that helped us to greatly improve this article. We would also like to thank audiences at Southeastern Conference on Linguistics (SECOL), New Ways of Analyzing Variation (NWAV), and Ohio State's Sociolinguistic Meaning discussion group for their suggestions and thoughts on earlier versions of this research. Finally, we would like to thank Morgan Primeaux for her behind-the-scenes work on formatting and citations.

We also thank the Linguistics in Open Access foundation (https://www.lingoa.eu/) for financial support of open access publication of *Laboratory Phonology*.

Competing interests

The authors have no competing interests to declare.

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