Acoustics of Regionally Accented Speech

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Sociocultural variation in pronunciation is a fast-developing, captivating area of acoustic research as regional accents continue to diversify American speech.

Introduction

Speech communication typically takes place in a social context. Naturally, spoken language transmits not only a message but also indexical variation cueing social attributes of the speakers, such as their age, sex, socioeconomic status, education, or occupation. Variation of this kind reflects social aspects of language use within conventions imposed by both the individual and society.

But language use is also sensitive to more general cultural factors such as beliefs, attitudes, behaviors, customs, and values of a given group that are transmitted from one generation to the next. Indeed, cultural history has played an important role in the development of regional variation in English spoken in North America. The geographic patterns of early immigration from England were largely shaped in the 18th and 19th centuries as settlers constructed transportation systems facilitating the spread of their original English dialects westward. Settlement patterns had important linguistic consequences for the formation of American cultural geography and regional variation in American English (AE) and, to some extent, still exert a persistent influence on modern speech.

Traditionally, the development of AE dialects in the United States has been studied within the field of sociolinguistics, a branch of linguistics concerned with how language use is influenced by society. More focused work on regional dialects has been carried out within the subfield of dialectology. In seeking to determine features of regional dialects and understand their sociocultural context, both sociolinguists and dialect geographers examine speech samples and classify markers of differences in the lexicon (vocabulary), grammar, usage, and phonology (pronunciation). Phonological variants are fairly salient markers and, typically, have been identified by means of auditory ("by ear") judgments and described qualitatively. For example, the salience of the r-less speech feature of eastern New England associated with the Bostonian accent has often been captured orthographically ("Pahk the cah in Hahvahd yahd" for "Park the car in Harvard yard") or transcribed using phonetic symbols. But traditional descriptions tend to fail when faced with modern speech recognition applications (listen how to Siri deals with the Bostonian accent at https://www.youtube.com/watch?v=1wBpSWxPo6o).

This is where acoustic analysis of regionally accented speech has emerged as a welcome area of scientific inquiry. With the technological advancement over the last two decades and development of new analytic tools and methodologies, regional variation has been explored with a great deal of scientific rigor, producing new evidence and advancing the field of speech communication.

Here, we present a few key concepts and selected highlights from this rapidly developing area in speech acoustics. We focus here on AE because most of the

acoustic studies have been conducted in North America. However, regional variation has become a fertile field not only in the remaining parts of the English-speaking world including the British Isles (Ferragne and Pellegrino, 2010), Canada (Boberg, 2005), Australia (Cox, 2006), and New Zealand (Watson et al., 2000) but is also emerging in languages and geographic regions worldwide. The growing interest is reflected in presentations at international conferences including the International Congress of Phonetic Sciences, INTERSPEECH, the Conference on Laboratory Phonology (LabPhon), and ASA meetings. Journal-length papers have also begun to document acoustics of regional variation in languages such as Dutch (Adank et al., 2007) and French (Schwab and Avanzi, 2015). The complexity of dialects in China, including subdialects of Mandarin, has been explored in MA theses and PhD dissertations around the globe, such as Li (2015) who used several acoustic metrics to examine rhythm patterns in 21 Chinese dialects.

The Concept of Speech Community

The central tenet of sociolinguistics is that the linguistic behavior of individual speakers cannot be understood without knowledge of the larger group, the speech community, to which they belong (Labov, 2001). Research in regional variation is thus concerned with the extent to which individuals conform to pronunciation patterns in their own speech community. There are different kinds of communities because each community is a group of people who uniquely share a specific pattern of language use that determines its size and location. For example, a speech community can be geographically defined and be relatively small (such as the island of Martha's Vineyard, Massachusetts) so that the pronunciation patterns may be viewed as a marker of local identity (Labov, 1963). A different kind of speech community has often been found in larger cities. Such communities consist of social networks or "ties" between individuals who speak a common variety to show their solidarity with one another and maintain group identity. For example, a study of Belfast English found that the local dialect features were preserved in individuals participating in dense networks (who shared the same social contacts) and interacted in multiple social contexts, whereas weak ties and loose networks stimulated the reduction of distinctive local accents, favoring standardization (Milroy, 1980).

In the United States, speech communities can be very large. The dominant pronunciation patterns in these major geographic regions spanning several states became the primary focus of acoustic analysis. The first and most comprehensive

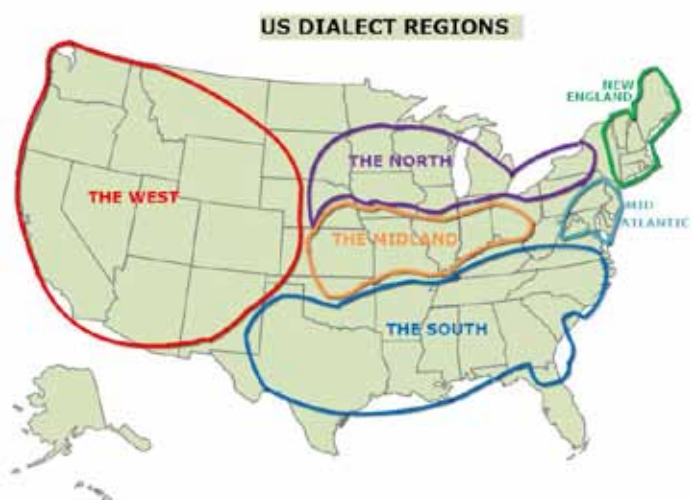

Figure 1. *Map of the six major dialect regions in the United States.*

overview of the major regional variants (or dialects) of English spoken in North America was provided in the *Atlas of North American English (ANAE)*, based on the acoustic analysis of 439 speakers recorded in the years 1992-1999 (Labov et al., 2006). Using a sociolinguistic sampling procedure by means of telephone interviews, the *ANAE* identified six broad dialect regions shown in **Figure 1**: North, Midland, South, West, New England, and Mid-Atlantic. Within these major varieties, there are also dialect regions identified on the basis of more specific variables such as vowel changes (known as shifts, mergers, and splits). In fact, the *ANAE* is predominantly a study of the pronunciation of vowels because it is primarily the vowels that differentiate regional variants in AE.

A particularly striking vowel pronunciation pattern has been found in large metropolitan areas around the Great Lakes in the North, extending from southeastern Wisconsin (Madison, Milwaukee, Kenosha) to northern Illinois (Chicago, Peoria), northern Ohio (Cleveland, Toledo), Michigan (Detroit, Grant Rapids), and New York State (Syracuse, Rochester, Buffalo). This large region with a population of about 34 million people constitutes a relatively uniform speech community known as the Inland North. The core feature of the dialect of the Inland North is a series of vowel pronunciation changes termed the northern cities shift (NCS; listen to Wisconsin speech, **Demonstrations 1** and **3**, at http://goo.gl/bOFDWw).

In sharp opposition to the Inland North is the Inland South, a much smaller community in the South whose regional accent has a particularly high concentration of core Southern features. The Inland South is a mountainous Appalachian region that includes parts of Tennessee, North Carolina, Georgia, and Alabama, whose homogeneity originates in its settlement history dating back to the 18th century. The region was populated primarily by Scotch-Irish migrants

whose cultural identity has favored isolation and small-town values. The vowel system in the Inland South is affected by the Southern Shift, a distinct set of changes whose traces can be found across the whole American South. However, the features of Southern Shift are particularly robust in the Inland South and even more so in the speech of older speakers (listen to North Carolina speech, **Demonstrations 1** and **3**, at http://goo.gl/bOFDWw). These two contrasting speech communities, the large metropolitan Inland North and the smaller and relatively detached Inland South, provide two examples of adherence to different regional cultural patterns that underlie both the divergence of AE dialects in today's society and the survival of regional accents in the face of population mobility, television, and multicultural influences.

Sound Change

The divergent trends in AE dialects are in part due to the operation of distinct chain shifts in regional vowel systems (such as the NCS or the Southern Shift) that have stimulated audible changes in pronunciation patterns across generations of speakers and, to a large extent, predict further development of regional dialects. In the English language, sound changes of this kind have been known for centuries and documented by historical phonologists in descriptive terms. The most famous example of such diachronic sound change is the English Great Vowel Shift, which was a radical sound change affecting the English vowel system during the 15th to 18th centuries (Stockwell, 1978). Although the primary evidence for the diachronic change comes from historical scripts, it is the state-of-the-art of the acoustic analysis that enables progress in documenting sound change. The precision of acoustic measurements prevents misinterpretations and inaccurate assumptions. Also, knowledge of typical acoustic variation is essential to execute more systematic control in selecting speech materials for recordings and analysis, which has significant implications for a better understanding of sound change.

Ideally, sound change in a speech community ought to be studied in "real time," that is, longitudinally over a number of years, but there is an obvious difficulty in obtaining speech data from the same individuals repeatedly over several decades. A notable exception is an analysis of the annual Christmas broadcasts of Queen Elizabeth II over a 50-year period (Harrington, 2006). These broadcasts contain the Queen's annual addresses to Britain and the Commonwealth read in a similar style. A careful acoustic analysis revealed changes in the pronunciation of some of the Queen's vowels. Possibly, these changes reflect the Queen's adoption of certain features of a mainstream pronunciation and certainly are not associated with any specific geographic region. The acoustic exploration of the Queen's pronunciation patterns over time has a unique value and is an excellent example of a real-time study, even if it does not provide insights into sound change in a particular speech community. Admittedly, the eminent Queen's accent (also known as the Queen's English) represents upper-crust received pronunciation of British English (Wells, 1982), a nonlocalized variety spoken by a relatively small number of individuals belonging to the highest social class. The speeches can be found on the official website of the British Monarchy. The first televised broadcast was delivered in 1957 (https://www.youtube.com/watch?v=mBRP-o6Q85s) and the latest in 2015 (https://www.youtube.com/watch?v=8Mzor6Hf1tY).

To overcome the difficulties in obtaining longitudinal data, acoustic analyses of sound changes have been carried out in "apparent time," that is, cross-sectional. In those studies, the pronunciations of younger and older speakers were compared and any changes were interpreted as sound change in the community over the period corresponding to the age difference between the two generations. Such cross-generational comparisons provide sufficient evidence of sound change if the speakers have resided in their communities for most of their lives (Labov, 1994; Sankoff, 2005). A more recent example of an apparent-time study is a large-scale investigation of sound change in three distinct AE speech communities in southeastern Wisconsin, central Ohio, and western North Carolina (Jacewicz et al., 2011a). Using a common experimental protocol, speech samples were obtained from three generations: grandparents (66-91 years old), parents (35-51 years old), and children (8-12 years old). Acoustic analysis revealed robust changes in the pronunciation of vowels across the generations, providing new evidence and improved understanding of the most current sound changes that each speech community is undergoing (listen to **Demonstration 1** at http://goo.gl/bOFDWw).

Acoustic Measurements in Characterizing Regional Vowel Systems

A more systematic use of acoustic analysis for studying vowel production in sociolinguistic context was introduced in early 1970s when sociolinguist William Labov and his team at the University of Pennsylvania first utilized vowel formant measurements to characterize regional vowel variation (Labov et al., 1972). However, over the next three decades,

the progress in this area has been relatively slow, hampered by time-consuming early-measurement techniques on one hand and by a general lack of theoretical or practical interest in studying language variation by speech scientists on the other.

A brief look at four important studies, all published in *The Journal of the Acoustical Society of America*, can help us appreciate how the attitude toward regional variation has gradually changed over the years. The first seminal acoustic study of vowel production by Peterson and Barney (1952) did not even consider that the variable regional background of the speakers could obscure the overall pattern of AE. A modern replication of the study by Hillenbrand et al. (1995) acknowledged and addressed this limitation by controlling for the dialect so that the majority of the speakers were selected from southern Michigan. Numerous differences between the two studies were found that may stem from the fact that the participants in Hillenbrand et al. (1995) spoke the regional variant of the Inland North affected by the NCS.

As research interest in socially motivated indexical variation in pronunciation intensified in the early 2000s (which was to some extent driven by advances in speech technology applications), acoustic explorations of regional vowel systems received a more serious consideration. To that end, Clopper et al. (2005) provided a comprehensive description of the acoustic differences among vowels in the six major dialect regions (see **Figure 1**). Further progress was stimulated by the discovery that regional accents utilize important acoustic details in the dynamic vowel structure that contribute to audible differences among dialects (Fox and Jacewicz, 2009).

Exploration of Acoustic Details in Regional Vowel Systems

Formant frequency analysis has been the primary approach to study the acoustic characteristics of vowels and has also been applied to regional variation. Traditionally, the frequencies of the first two formants, F1 and F2 (representing the two most prominent maxima in the vowel spectrum), have been measured at a vowel's center or "steady state" under the assumption that these measurements represent its canonical target values. This classic approach is shown in the left panels of **Figures 2** and **3**. The data points in these plots indicate mean F1 and F2 values for the vowels in the selected words. The dispersion of these data points tells us how the vowels are distributed in the F1 by F2 plane (or vowel "space") and how their configuration differs as a function of

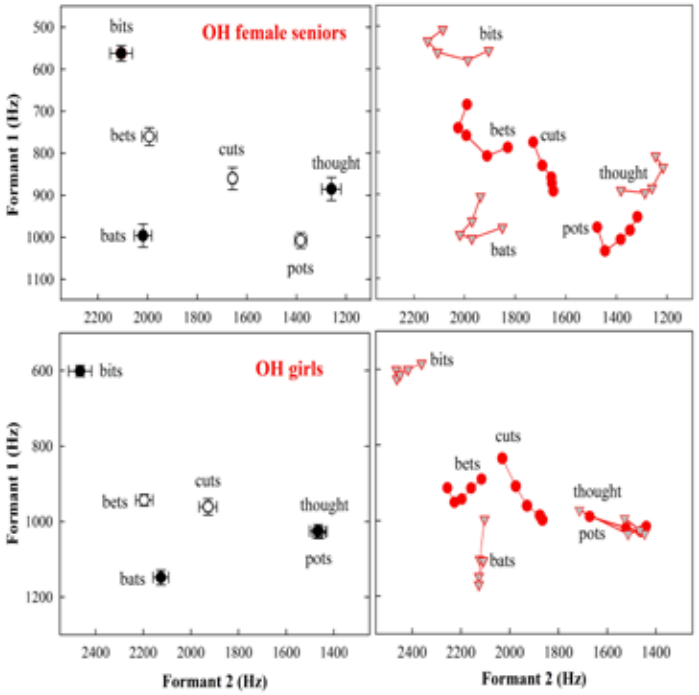

Figure 2. *Example of a formant plot showing a configuration of vowels measured in the selected words. Using speech analysis software, frequencies of the first two formants, F1 and F2 (representing the two most prominent maxima in the vowel spectrum) are measured and the plotted values reflect dialect-specific articulation patterns. Left: Each data point is the mean ± SE of several instances of the vowel in each word spoken by seven women in their 70s and 80s (top) and ten girls 8-10 years old (bottom) from central Ohio (OH). The relative positions of several vowels have changed in children's speech, reflecting cross-generational sound change in this speech community. For example, the vowels in "pots" and "thought" have merged in children, and this merger indicates that they cannot tell the difference between words such as "cot" and "caught." Right: The corresponding panels provide more details about time-varying spectral change in a vowel. The frequencies were sampled five times in equidistant time intervals to approximate formant trajectory shape. The acoustic proximity of the five points is interpreted as a degree of diphthongization. For example, the vowels in "bits" and "bats" have lost much of the formant movement in children relative to adults, becoming more monophthongal.*

dialect and speaker generation. This is how acoustic measurements inform us about regional variation. In particular, researchers examine and interpret changes in the relative positions of the vowels in the acoustic space, which may signal mergers (manifested as an acoustic overlap) or shifts (movement in a particular direction). But this approach assumes that vowels are purely monophthongal (such as when saying "iiiiiiiiiiiiii"). In reality, research has shown that even nominal monophthongs (and not only diphthongs such as in "my-cow-boy") display reliable amounts of spectral change (Nearey and Assmann, 1986).

Consider now the plots in the right panels of **Figures 2** and

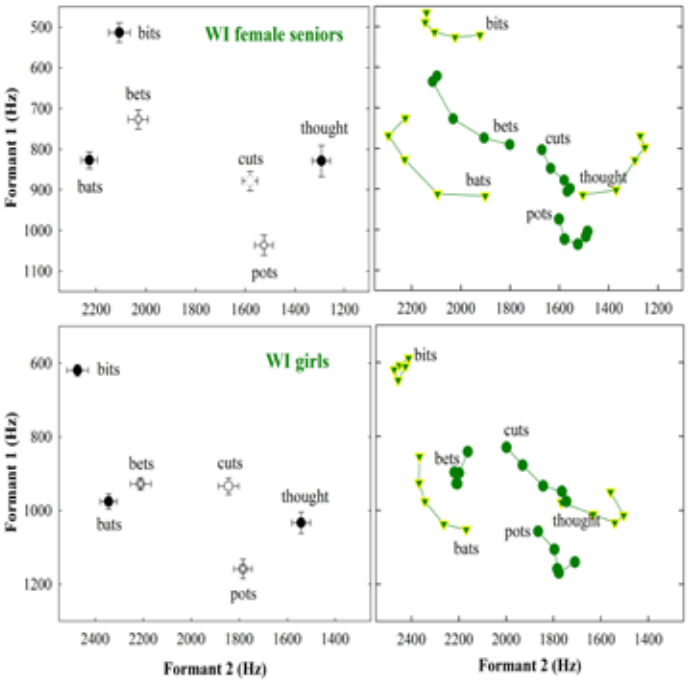

Figure 3. *Configuration of vowels spoken by eight women in their 70s and 80s (top left) and ten girls 8-10 years old (bottom left) from southeastern Wisconsin (WI). Each data point is the mean ± SE of several instances of the vowel in each word. The dialectal differences between WI and OH (see* ***Figure 2****) are in part due to the operation of the northern cities shift in WI. Right: The corresponding panels provide more details about time-varying spectral change in a vowel. Compare the relative positions of "cuts" and "pots," the lack of the "pots/thought" merger in WI children, and the elevated position of "bats" relative to "bets." The dialectal differences are also reflected in the nature of formant dynamics.*

3. The points indicate mean F1 and F2 values sampled multiple times over the course of each vowel's duration. These multiple measurements allow us to observe the spectral change and estimate formant movement patterns for each vowel. Our lab has recently tested this approach with about 360 speakers from 3 distinct dialects spoken in southeastern Wisconsin (the Inland North), central Ohio (the Midland), and western North Carolina (the Inland South). We found that such detailed acoustic variations indicate dialect-specific use of dynamic information in vowels to enhance cultural differences and cross-generational sound change (Jacewicz et al., 2011a,b,c; Jacewicz and Fox, 2013).

A good example of the dialect-specific use of dynamic information is the differential pronunciation of the vowel in *bad* in Wisconsin and North Carolina as illustrated in **Figure 4**. The two variants may have similar midpoint frequencies but neither has a true "steady state." In fact, thinking of these two variants in terms of static vowel positions in the acoustic space is misleading. As shown in the right panel of **Figure 4**, it is the dynamic nature, direction, and extent of formant movement that is shaped by regional variation, and these acoustic attributes become markers of a regional accent (see **Demonstration 2**, at http://goo.gl/bOFDWw).

Modeling the Acoustic Variation

Over the past two decades, much work has been devoted to modeling variation in formant dynamics. Although descriptive approaches are informative in their own rights, statistical evidence is needed to increase the understanding of dialect-specific influences on the dynamic formant pattern. Although not necessarily common, curve-fitting parameterization has been generally accepted in modeling changes in formant trajectories. For example, in discrete cosine transform (DCT) modeling, the first coefficient represents a straight line whose slope value is proportional to the mean frequency of the original formant trajectory, a measure of basic vowel position; the second coefficient is a measure of tilt, and the third is a measure of curvature. In general, a 2-DCT model performed well in a number of studies (Zahorian and Jagharghi, 1993; Watson and Harrington, 1999), but these studies did not examine dialect-related variations. In our lab, we fitted several models to the North Carolina data (DCT and polynomials) and found a 3-DCT significantly outperforming a 2-DCT model. Although the effectiveness of this type of modeling still needs to be evaluated in the broader context of regional variation, it is clear that more sophisticated approaches need to be developed to separate the pure effects of regional accents from other sources of variation in formant movement coming from consonant environments, prosody, or speech tempo. A useful overview of the current work in this area, including modeling efforts, can be found in a volume from Springer's *Modern Acoustics and Signal Processing* series (Morrison and Assmann, 2013).

Consonants, Prosody, Tempo, and Perceptual Categorization of Dialects

Besides vowels, acoustic studies of regional variation in other aspects of AE have been far less systematic. Little is known about consonant variation (but see Purnell et al., 2005; Jacewicz et al., 2009) or about the use of prosody across dialects. Prosodic differences were found in the rising pitch accents between Minnesotan and southern Californian speakers (Arvaniti and Garding, 2007) and in pitch movement differences between midwestern and southern speakers (Clopper and Smiljanic, 2011) but far more work remains to be done. One area that has received considerable attention is temporal variation such as how speech tempo and tempo-

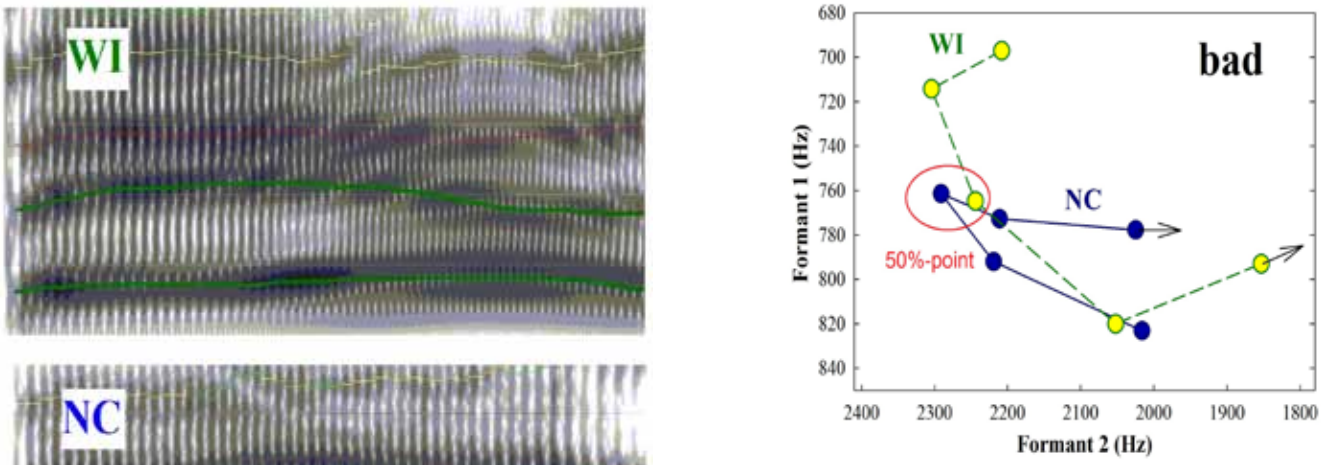

Figure 4. *Acoustic details cueing regional dialect. Left: Spectrograms of the vowel in "bad" with formant tracks spoken by a female speaker from southeastern WIi (top) and western North Carolina (NC; bottom). The first two formants, F1 and F2, are emphasized in green for WI and in blue for NC. Right: Plot is mean F1 and F2 (from multiple repetitions) sampled at 20, 35, 50, -65, and-80% time points. Arrows are at the 80% point and depict the differential direction of formant movement in each dialect.*

ral patterns are shaped by regional variation. For example, Jacewicz et al. (2010) found that southern speakers have a significantly slower articulation rate than the northerners and that this difference is maintained across the life span. An important question is whether durations of individual segments (vowels and consonants) are globally reduced in the North because of the faster speech tempo and globally lengthened in the South given that the southerners speak slower. The mounting evidence suggests that the correspondence between segmental timing and speech tempo is not as straightforward and that temporal relationships are more complex. For example, the temporal distinction between long and short vowels (such as in "dad" and "kid," respectively) is manifested differently in different dialects irrespective of dialect-specific speech tempo (Fridland et al., 2014; Clopper and Smiljanic, 2015). A complicating factor is a dialect-specific use of pauses so that the temporal properties of the pauses, such as their frequency and duration and the resulting prosodic phrasing, may have a differential effect on the duration of vowels and consonants across dialects. Much more research needs to be done to better understand how complex temporal relationships are shaped by regional variation.

Naturally, acoustics of regional accents extends to their reception. Sociolinguists have studied dialect identification and intelligibility of individual dialects at least since the 1950s (Dickens and Sawyer, 1952), but it is the modern work in the perception of regional variation, notably by Clopper and Pisoni (2004), that introduced experimental rigor and methodological advancement. This work has examined the salience of acoustic information and listeners' strategies in perceptual categorization of dialects. For example, it was shown that untrained listeners have an explicit awareness of distinctive features of AE dialects and that "army brats" who lived in several dialect regions categorize talker dialect more accurately than "homebodies" who lived in only one place (Clopper and Pisoni, 2004). Also, intelligibility of regional dialects under difficult listening conditions such as in a background noise can vary as a function of dialect and talker gender, although General American, the more "standard" midwestern variety, seems to be more intelligible than other dialects (Clopper and Bradlow, 2008).

The Changing Demographics in the United States and Their Influence on Regional Variation

Media reports and folk perception have increasingly suggested that long-standing regional distinctions and many regional variants have been receding among younger people in favor of more General American forms. Thus, what is the

future of regional dialects and how will the changing demographics in today's multicultural society affect the pronunciation patterns across the country? Researchers can only speculate at present and predict new developments on the basis of knowledge of both principles of sound change and sociolinguistic perspectives on human behavior, but the current evidence gives us reasons to believe that regional variation will not be erased in the next 20 years and that local pronunciation features will continue to diversify AE speech.

Earlier in this article, we emphasized the importance of the speech community in cross-generational transmission of regional features, suggesting that the survival of dialects is associated with the acquisition of cultural values. That is, dialect divergence is likely to persist if children are both able and willing to perceive, reproduce, and employ the patterns representing the target of language learning in their community. Some of those patterns can still be traced to the settlement history of the mid-19th century. Consider, for example, the strength of the cultural and linguistic boundary between the North and the Midland (Labov, 2010). The northern settlement stream came from New English Yankee communities, whereas the Midland was settled by the Quakers from Philadelphia and southern settlement spreading from Appalachia. Today, there is no shortage of communication between the northern cities such as Chicago and the Midland cities such as Columbus, Ohio, yet the vowel systems of children on either side of the boundary continue to diverge. Accounting for this divergence, Labov (2010) points out that it is the cultural clash between the Yankees and Midland settlers that established the differences in lifestyle and community norms. For example, Yankees built towns and cities and maintained a strong emphasis on literacy, whereas the Quakers formed farm communities rather than towns. The two regional dialects are thus associated with two different value systems and will be maintained as long as each successive generation acquires the knowledge of these cultural configurations and will be willing to follow the established sociocultural path.

An interesting current trend has been noted along the dialect boundary between East and West New England (Stanford et al., 2012). Namely, dialect features play a role in New Hampshire (East) and Vermont (West) state identities to the point that in a local shop near the state border one can buy a "New Hampsha" sandwich (spelling reflecting the r-less pronunciation) or a "Vermonter" sandwich (pronounced with a final "r"). The sharp distinction between the eastern and western New England speech is well documented (Kurath, 1939) and can be traced back to the social patterns of the founding settlers. Eastern New England developed the r-less pronunciation following the patterns of early settlers from southeast England, whereas a mixture of Yankee and Scotch-Irish families settled the r-pronouncing western New England. Although the Vermont-New Hampshire boundary is rooted in historical contrasts, modern lifestyle and increased contacts between younger residents have reduced the sharp dialectal differences in these populations. Younger eastern speakers do not want to sound old-fashioned and try to avoid r-less pronunciation in favor of the r-ful variant. Yet, a closer acoustic analysis shows that their speech has still retained less noticeable eastern features that, together with the r-ful variant, have constructed a more modern model of regional eastern New England identity. This example shows that, even if the most salient dialect features can be receding in young people, the regional varieties may not be fully merging into the General American, which lacks regional features.

Conclusions

Sociocultural variation in AE pronunciation patterns has become a new fascinating area of acoustic research. As American society becomes increasingly multicultural, much work needs to be done to understand the current and future changes in speech across the country and, increasingly, in the context of immigration. New questions arise. For example, will non-native speakers of English be able to acquire community patterns, and can such regional patterns be transmitted through non-native-accented English? Can they perceive subtle regional variations? If so, are such variations meaningful to them? Knowledge of regional variations can enhance work in related areas of acoustic research in speech communication, forensic science, signal processing and, perhaps, room acoustics and noise. But regardless of the background and area of scientific interest, we encourage readers of this article to test their implicit knowledge of regional accents the next time they go shopping, walk a dog, or stop at a pub. It can be a rewarding experience.

Biosketches

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