ABSTRACT

FOX, MICHAEL JOSEPH. Accounting for the role of homophily in the participation in sound change. (Under the direction of Dr. Steve McDonald).

The social mechanisms that influence the direction of language change operate along the networks of communication (Bloomfield 1933; Labov 2001; Lippi-Green 1989; Milroy and Milroy 1985), however, these mechanisms are underspecified in sociolinguistic work and could thus benefit from the advances made in sociological network theory and analysis. The most prevalent social network mechanism is homophily wherein similar others tend to associate with each other (Lazarsfeld and Merton 1954; McPherson, Smith-Lovin, and Cook 2001). This mechanism operates along dimensions of social distance (Blau 1977a, 1977b) that are relevant in the localized contexts of human activity (Feld 1981, 1982, 1984) such as schools which have their own social ecology defined by the local distribution of social characteristics and moderates the operation of homophily (McFarland et al. 2014). Net of the local context, homophily is predicted to operate on the networks of communication so as to influence the direction language change takes in social space.

This study uses acoustic vowel measurement data from 132 speakers in three geographically contiguous cities (Eau Claire, Chippewa Falls, and Altoona) located in northwestern Wisconsin to investigate the role of homophily in structuring the reversal of the Northern Cities Shift – a complex movement of multiple vowels in concert – in this region (Fox 2016). Applying a relational framework wherein all participants are compared to all others along linguistic and social dimensions (McPherson 2004) allows for the testing of whether homophily is operating within and across these communities to structure this reversal.

Modeling results predict (1) similar socio-geographic contexts lead to linguistic similarity; (2) dissimilarity in social ecology leads to greater linguistic dissimilarity as dyads become further apart in age, especially within Chippewa Falls; (3) net of local socio-geographic context and social ecology, similarity in sex and age leads to linguistic similarity and dissimilarity in these dimensions leads to linguistic dissimilarity. These patterns indicate that homophily is operating within local social ecologies in order to structure the form of linguistic change within and between groups.

Accounting for the role of homophily in the participation in sound change

by
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DEDICATION

To Alyssa,

Thank you.

BIOGRAPHY

Michael Joseph Fox was born and raised in Altoona Wisconsin, and moved to North Carolina for Graduate School in 2011. After getting a masters in Sociolinguistics at North Carolina State University, he got a second masters in Sociology from the same university. He lives and works in the Raleigh-Durham area, and enjoys the location because it’s an easy drive to either the beach or the mountains.

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INTRODUCTION

Bloomfield's (1933) classic statement about the emergence of dialect (dis)similarity contends that "[e]very speaker is constantly adapting his (sic) speech-habits to those of his (sic) interlocutors" (326) and that "[t]he inhabitants of a settlement, village, or town, ... talk much more to each other than to persons who live elsewhere. When any innovation in the way of speaking spreads over a district, the limit of this spread is sure to be along some line of weakness in the network of oral communication" (328). Even within relatively small geographic regions there exists socially differentiated variation in the use of linguistic forms (Labov 1968, 2001; Wolfram and Fasold 1974 inter alia), which begs the question of what factors structure the networks of oral communication such that language change, which originates in interaction (Eckert 2008) and spreads through networks (Milroy and Llamas 2013), is influenced by mechanisms of social tie formation.

In a tri-city area (Eau Claire, Chippewa Falls, and Altoona) in northwestern Wisconsin, the Northern Cities Shift (NCS) – a complex and concerted shifting of multiple vowel pronunciations leading to a complete reconfiguration of a region's accent – was found (Bauer and Parker 2008; Purnell 2008) and has been reversing away in recent years (Benson, Fox, and Balkman 2011; Fox 2016). This set of vowel class movements has been found in other regions to be used more by adolescent "Burnout" girls than other groups (Eckert 1988, 2000) implicating social networks in influencing the degree of participation in the change.

While this local group level variation in linguistic behavior is borne out for other changes in subsequent literature (e.g. Bucholtz 1999; Mendoza-Denton 2008), there has been minimal examination of what social network mechanism bridges the gap from the group and interactional level to the aggregate (e.g. Milroy and Milroy 1985, 1985, 1992). The most prevalent network mechanism is homophily, which states that people have a strong tendency to form ties and continue to associate with others who are similar to them socio-demographically (Brashears 2008; Kalmijn 1998; Lazarsfeld and Merton 1954; McPherson et al. 2001; Verbrugge 1977). Homophily is subject to the opportunities for contact as a function of an individual's participation in "foci", which are focused activities such as their occupation, schools, sports teams, and families wherein individuals spend a majority of their time interacting with others (Feld 1981, 1982, 1984). Within foci individuals choose associates based on how on how socio-demographically (race, sex/gender, education, income) similar they are (Blau 1977b, 1977a). Homophily operates within socio-demographic space (henceforth Blau-space) in two ways: (1) through contact opportunity via geographic proximity, known as induced homophily, and (2) choice of associates made on socio-demographic dimensions, known as choice homophily.

This thesis examines how choice homophily operates – net of induced homophily from a network of attendance at different schools located in three geographically contiguous communities in northwestern Wisconsin (Eau Claire, Chippewa Falls, and Altoona) – to structure the lines of communication necessary for both linguistic variation and change as well as its conformity. This will be accomplished by relating the extant literature on sociolinguistic variation and change to how homophily operates within Blau-space as a relational theoretical framework and applying this framework to the Northern Cities Shift.

BACKGROUND

Sociolinguistic Variation and Language Change

The acquisition of one's dialect is mainly completed during adolescence under conditions of dynamic change operating within a community (Labov 2007; Roberts 1997), and, depending on the linguistic variable (Bowie 2005), changes little over the course of one's subsequent life-span (Sankoff and Blondeau 2007). However, when individuals do change across their life-spans there are two crucial distinctions that moderate it. First, adult language change varies according to the ease of acquisition hierarchy going from easy to hard as a function of the part of language it affects. The order goes from easy to hard such that changed in vocabulary are easier than changes in phonology: vocabulary > syntax > morphology > phonology (Kerswill 1996). In the case of the NCS, a phonological change, this means greater stability across the life-span. Second, language change varies according to the social evaluation of a change – i.e. whether it is socially salient as a marker of group membership in a particular community (Sankoff and Blondeau 2007; Wagner 2012).

When the change is not socially salient, as individuals age they tend to use more forms that are more advanced along the trajectory of change (Boberg 2004; De Decker 2006; Wagner 2008). When the change is socially salient individuals in the upper and upper middle class tend to use more conservative forms as they age (Wagner and Sankoff 2011). This variation is ostensibly due to the higher premium placed on the conservative forms of socially salient changes (Wagner 2008) within certain linguistic market places (Bourdieu 1984, 1991). However, even though there is resistance in some social dimensions, this does not stem the tide of any particular change in the long run, but rather is one mechanism that contributes to socially differentiated variation (Wagner 2012).

Each successive generation acquires their linguistic structures in an environment with both stable variation and ongoing changes that are differentiated by social group membership (Labov 2001, 2007, 2011; Weinreich, Labov, and Herzog 1968; Wolfram 1991; Wolfram and Fasold 1974). Linguistic changes have been abundantly observed spreading from one social stratum to another (a la Labov 1968) with women leading innovations and men maintaining conservative vernaculars (Eckert 1989b; Labov 1990, 2001) as well as stark racial differences in dialect features (Wolfram 1969, 1974b, 1974a; Wolfram and Thomas 2002). As such, each age cohort is exposed to a slightly changed version of the language, thereby allowing researchers to compare generational differences in order to observe language change across "apparent-time", i.e. the time-span observed by comparing age cohorts (Labov 1975; Labov, Yaeger, and Steiner 1972:272–74).

The apparent-time construct allows for the study of the effects of social variables on the differentiated progression of linguistic change because an individual's dialect more or less stabilizes during their adolescence and early adulthood. These effects are assessed in the aggregate and causal relationships are hypothesized between social category membership and linguistic variation. Indeed, as with many other social phenomena (e.g. Blau, Duncan, and Tyree 1994; Massey 2007), language variation and change is structured along socio-demographic categories, such as race/ethnicity, sex/gender, socioeconomic status, and age (see Labov 2001 for a comprehensive review and formulation). While sustained contact between groups of people is necessary for linguistic features to spread (Bloomfield 1933; Labov 2001; Labov, Ash, and Boberg 2006), the exact social mechanisms that structure the lines of communication between socio-demographic groups are under-specified, especially when it comes to the crucial stage of adolescence.

Sociolinguistic work on networks of communication has shown that densely connected networks promote the use of local dialect variants (Edwards 1992; Lippi-Green 1989; Milroy and Margrain 1980) and that cross-group ties (i.e. bridges) promote the diffusion of linguistic variants (Ash and Myhill 1986; Cheshire et al. 2008; Milroy and Milroy 1985). Moreover, Stanford and Kenny (2013) show, via agent-based modeling, that simple density and intensity of contact between two populations can give rise to typical S-shaped adoption curves; however, this is not predicted to result in new dialect formation (Baxter et al. 2009). Language is a key part of how people perform interactional identity work to reflect group membership such as nerdiness (Bucholtz 1999, 2001), urban orientation, age-cohorts, social class (Eckert 1988, 1997, 2000, 2003), and gang-membership (Mendoza-Denton 2008). As such the social mechanisms that influence the paths of language change are those which bring people into these types of groupings.

Sound change and Chain Shifting

Changes in pronunciations of words are highly structured along both internal linguistic dimensions as well as social dimensions (Labov 1994, 2001). One of the most studied sound changes in American English is the Northern Cities Shift (NCS). The NCS is a type of sound change more widely attested in the historical record, known as a Chain Shift

(Hock and Joseph 2009:133–37; Labov 1994:113–271). Chain Shifting is the systematic movement of a set of vowel classes (all words containing a particular vowel sound) within the vowel spaces of individuals living within a geographic region. Vowel position and movement is measured via the first two acoustic formants (henceforth, F_1 and F_2) which are correlated with the height and frontness/backness of the tongue.

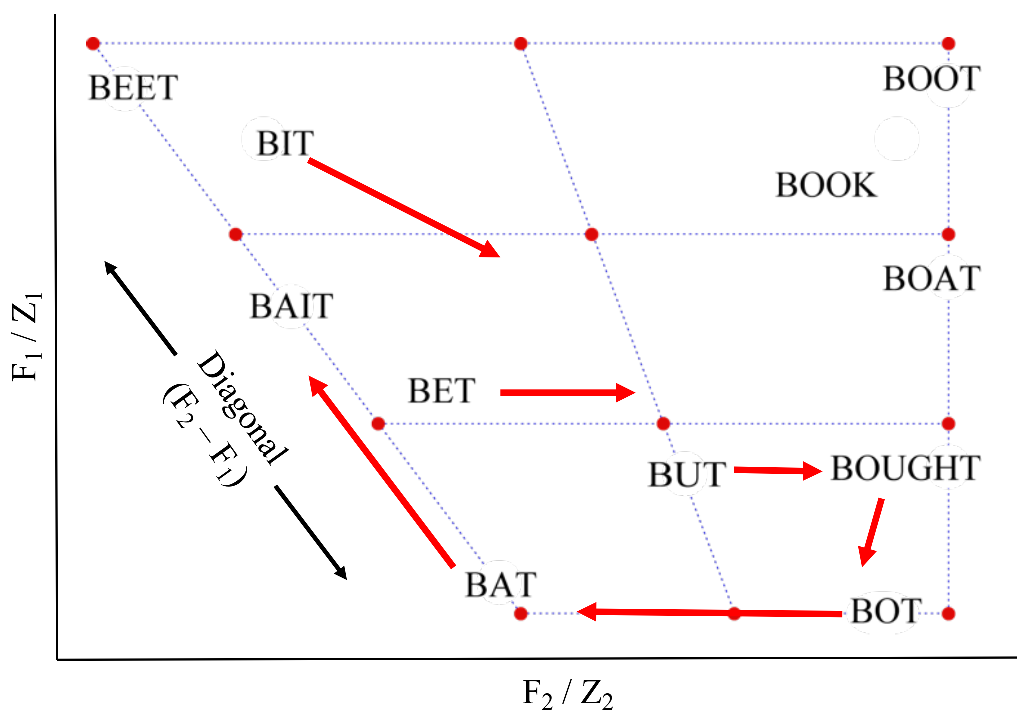

Figure 1: Canonical American English Vowel Space (Front = Left, Back = Right) with NCS movement illustrated by red arrowed lines.

A chain shift is said to be actively in progress when there is evidence of pronunciation differences across apparent-time. A sound change is typically labeled a chain shift when the movement of vowel **A** into the space of vowel **B** is believed to have triggered a chain reaction of vowel **B** moving in order to maintain contrast with vowel **A** (i.e. avoid confusion in pronunciation due to overlap in the cognitive mapping). This cascades to vowel **B** causing vowel **C** to move and so on and so forth (Labov 1994:113–271). The red arrows in figure 1 depict this situation for the vowel classes involved in the NCS. Arrows that move from bottom to top represent "raising", where downward movement represents "lowering". Likewise, right to left movement is "fronting" and left to right is "backing".

The NCS is a complex coordinated change in the pronunciation of multiple vowels that is found in large cities around the Great Lakes region (Dinkin 2013; Eckert 1988; Fasold 1969; Gordon 2001; Labov 2011; Labov et al. 2006, 1972). The direction of movement of each vowel class is represented in figure 1 by the red arrows. The acoustic dimensions that movement occurs on are marked on the axis' (F_1/Z_1 and F_2/Z_2) and along the diagonal of the front of the vowel space ($F_2 - F_1$). The stages[i] of the chain shift are believed to be triggered by: (1) the raising and fronting of BAT followed in sequence by, (2) the fronting of BOT, (3) the lowering and fronting of BOUGHT, (4) the backing of BUT, (5) the backing of BET, and finally (6) the backing and lowering of BIT. The order of stages (1) and (2), however, is a matter of debate (Gordon 2001; Labov 1994).

Important to the progression of the NCS within any particular region is the set of linguistic conditioning factors that affect the internal structure of the change itself. The NCS is generally believed to be initiated by the raising and fronting of BAT towards BAIT, but this change affects one part of the lexicon before the other: cases of BAT before /d, t/ (henceforth BAD-raising) start to move before all other contexts (Gordon 2001; Labov 1994). Since there is the possibility of geographically adjacent or overlapping linguistic changes to have similar internal structure, this leads to the potential for changes that are internally similar (same vowel class but different conditioning environments), but not necessarily historically related (one was present before the other), to co-occur and interact within a particular dialect.

Since BAD-raising is considered the initiating event, it's important to consider all other cases of the consonantal conditioned raising of this vowel. In this case, the NCS in Northwestern Wisconsin (Labov et al. 2006) overlaps with a similar change of the BAT vowel class wherein it raises and fronts in words where it occurs before a /g/, but not /k/, henceforth BAG-raising (Bauer and Parker 2008; Benson et al. 2011; Purnell 2008; Zeller 1997) as well as before the nasal consonants /n, m/, henceforth BAN-raising (Labov et al. 2006). While these two changes are found in other geographic regions – the former across the northwestern United States out to the Pacific Northwest (Wassink 2015) and the corresponding adjacent regions of Canada (Labov et al. 2006) and the latter across the majority of the northern United States (Labov et al. 2006) – their co-occurrence with the NCS in this region brings up the potential for some changes (e.g. BAG-raising) to be following one trajectory while another (e.g. NCS style raising of BAT) follows a different one in the same city.

The NCS is believed to have originated historically in the northeastern United States and then spread west, hopping from one large city along the great lakes region to another, reaching as far as southeastern Wisconsin (Labov et al. 2006). The internal structural cohesion of this change across historical time is questionable given recent real-time comparisons showing reversal and reorganization in two core NCS dialect regions: Syracuse, New York (Driscoll and Lape 2015) and Lansing, Michigan (Wagner et al. 2016). Thus we expect that some vowel classes could be progressing while some retract along the predicted patterns of change depicted by the red arrows in figure 1.

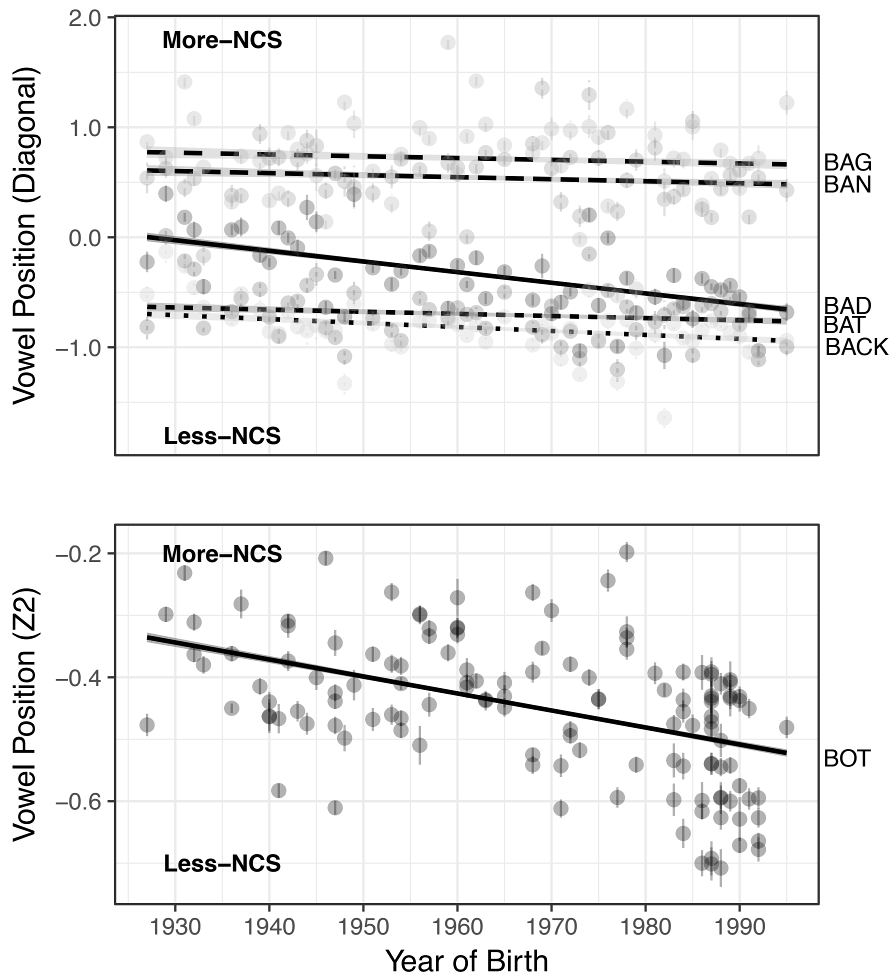

Figure 2: Position BAT (top) and BOT (bottom) vowel classes across YOB. Dots are mean and standard deviation by speaker. Lines are linear models fit by vowel class subset.

Indeed, previous analyses of a smaller version of the current dataset found the NCS in the greater Eau Claire-Chippewa county region (Benson et al. 2011). However, recent, more expanded analyses reveal that across apparent-time this region of Wisconsin is undergoing reversal of BAD and BOT but not the other NCS stages (Fox 2016). Figure 2 shows these apparent-time trends in terms of absolute vowel position. The trend lines are simple subset regressions for each vowel class and the dots are mean/standard deviations for each speaker. In the aggregate, it appears that prior generations BAD (top panel solid line) and BOT (bottom panel) were more NCS-like, but have been steadily retracting (downward movement of the solid lines) across apparent-time. Moreover, BAG-raising (medium dashed line) with its concomitant lack of raising in BACK (dotted line), and BAN-raising (large dashed line) are both present across the age cohorts with little change apparent at this level of analysis.

The patterns of change for NCS, wherein BAD and BOT are retracting but not the other stages, and stability for BAN, BAG, and BACK, point to a more nuanced picture of these phenomena in this region. Indeed, the fact that retraction is happening, and out of sequence, points directly to a social cause rather than a linguistic one (Labov 2001).

Dialect Formation and School Social Ecology

The crucial period for dialect formation is adolescence (Chambers 1992; Kerswill 1996; Kohn 2014; Nycz 2011; Roberts 1997, 2013; Roberts and Labov 1995; Thomas 1996) with family, caretakers, and peers being the main source of influence on the form of the dialect acquired (Roberts and Labov 1995). Because the transition to high school is strongly correlated with increasing vernacularity (Kohn 2014; Van Hofwegen and Wolfram 2010), examination of the foci that are most important during this period is warranted. Adolescents spend the majority of their day attending school and therefore the range of variation in their environment is circumscribed by which schools they attend.

The "adolescent peak," wherein use of a vernacular feature undergoing change in apparent-time is much higher for adolescents (Kirkham and Moore 2013:279–80; Labov 2001:454), is attributed to a motivation for differentiation from the speech of adults (e.g. Labov 2001:415–17), and is found in morphology, phonology, and syntax (Ash 1982; Cedergren 1988; Tagliamonte and D'Arcy 2009). Indeed, before high school when children are transitioning to adolescence, group membership becomes the most salient (Eckert 1997), thus making differentiation from both adults and other peers a very important project for maturing children.

Eckert's (1988, 1989, 2000) ethnographic work at Belten High has shown that the adolescent life stage is a time at which membership in groups is central to the contextually variable way in which identities are negotiated and expressed via linguistic behavior such that distinctions are made both between and within age cohorts (Eckert 2003, 2008). The fact that some adolescent groups choose one dialect variant over another, even showing group-internal differentiation, illustrates that adolescent involvement in language change is not a mechanistic process of gradual incrementation (Labov 2007), but rather, is differentiated along locally meaningful dimensions. The lives of adolescents are organized by the education system into grades, class periods, lunch hours, and extra-curricular activities, thereby creating a sociolinguistic ecology wherein the range of others within it is highly structured and constrained. Moreover, high school life is intimately connected to the (re)creation of category boundaries and hierarchy among students along class, race, and gender lines (Bettie 2003; Eckert 1989a; MacLeod 2009; Morris 2012).

While Eckert's work has shown us how language change plays out within schools, that of Dodsworth (Forthcoming, 2014, 2016) and Dodsworth and Benton (2017) has shown that attendance at certain schools has structured the retreat from the Southern Vowel Shift resulting in a more a-regional sounding dialect within the Raleigh, North Carolina area (Dodsworth and Kohn 2012). This change started along its path with the influx of migrants from different northern dialect regions during the tech-boom of the 1960s, resulting in what is now known as the Research Triangle (Raleigh-Durham-Chapel Hill). These migrants brought with them their dialects and their children, who either attended the established K-12 schools or the ones that were built to accommodate the increasing population.

Each child has their own trajectory through the school system defined by their attendance at a particular kindergarten (if available), elementary school, middle school, and high school. While school districting determines the majority of who attends which high school, in this region the elementary and middle school attendance is determined more by neighborhood of residence, thereby creating variation in prior sociolinguistic ecologies. Each child can be more or less similar to others in their record of attendance; however, the further apart in age two individuals are, the less similar their school ecologies would be expected to be even if they had attended the exact same schools. Indeed, given the way students are divided into grades, it is unlikely that any two individuals separated by more than 4-5 years would have been exposed to a social ecology similar to one another.

Adolescence is the crucial part of the life-span that plants the seeds of one's dialect for the rest of one's life. Understanding how it is that social group membership affects linguistic variation requires investigation of mechanisms that structure the flow of social influence between people. The strongest and most prevalent social mechanism that has repeatedly been shown to structure social relations is homophily: the tendency for people to form and sustain connections with others who are similar to them along relevant social dimensions such as race, gender, class, education, income, religious and political ideology, etc. (Lazarsfeld and Merton 1954; McPherson et al. 2001; Verbrugge 1977). Homophily operates along the social dimensions that are locally present for individuals within their social environments, indicating that the relations between people are more meaningful than category membership. Indeed, social divisions based on race, social class, education, etc. are structured by homophilous tie formation both historically (Marsden 1987, 1988) and contemporaneously (DiPrete et al. 2011).

Blau-Space and Homophily

The social environment in which people act is first demarcated by the physical makeup of their region, state, community, and neighborhood. However, modern society has added and continues to add myriad dimensions along which social differentiation can take place (McPherson 2004). One way of studying this expansive landscape is to shift from conceptualizing individuals as a conglomeration of social characteristics grouped for comparison, to considering the distribution of all possible relations in a *k*-dimensional social space (Blau 1977a, 1977b), termed Blau-space (McPherson 2004). Important to this approach is that relations are both locally specific (McPherson and Ranger-Moore 1991; McPherson and Rotolo 1996) and embedded within larger social structures. That is, the distribution of possible relations (e.g. cross-racial ties or cross class-ties), and thus probability of contact, is determined by the locally specific distribution of characteristics: the local social ecology.

The social ecological makeup of the space that people inhabit is defined by the physical characteristics of the environment, the distribution of socio-demographic characteristics, the structure of opportunities for meeting one's needs for education, occupation, and recreation, and is constantly changing due to the dialectic relationship between the environment and the people who inhabit it. Moreover, the activities that people engage in throughout the course of their daily lives are organized around what Feld (1981) calls "foci" (i.e. occupations, voluntary associations, schools, family), which are embedded within and structure the network relations among individuals (McFarland et al. 2014; McPherson 1983; McPherson and Smith-Lovin 1987). Indeed, since people need to meet in order to form relationships, the majority of relationships are made within the context of one or more foci (Feld 1981, 1982; Kalmijn 1998; McPherson et al. 2001) making foci a meso-level site of (re)production of the social cleavages along race, gender, and class lines (DiPrete et al. 2011; Marsden 1987; McPherson and Smith-Lovin 1987; Popielarz 1999), and a unit of organization that moderates tie formation processes such as homophily.

Within this framework an individual's social existence is located in the space between people; that is, their "social position" is defined by their position relative to all others along the *k*-dimensions of Blau-space (McPherson 2004). Moving the focus from the individual to the relations between individuals creates three advantageous circumstances: (1) the measurement of key concepts is more in-line with theory surrounding the social construction of meaning in interaction (Bourdieu 1984, 1991; Eckert 2008; Silverstein 2003) because positions are relative rather than absolute; (2) Blau-space is an conceptualization of the likely influence of induced homophily; and (3) since all actors are compared to all others the number of observations increases as a factorial of the number of individuals.

The dynamics of relationship formation are subject to the ecological makeup of the space, in that homophilous network tie formation can only operate along socio-demographic dimensions that are present within the community (McPherson 1983, 2004; McPherson and Smith-Lovin 1987). The closer individuals are to each other within Blau-space the higher the likelihood of their interacting given physical proximity. However, since an individual's time is limited, the number and configuration of foci will be limited to those readily available and those that do not compete for an individual's time, i.e. baseball and basketball have non-overlapping seasons (Popielarz and McPherson 1995). Thus, any choice that an individual makes about who to associate with is constrained by the context in which this choice occurs.

If network ties are non-randomly skewed toward formation with similar others, then the structure of influence among adolescents' networks is expected to tend towards homophilous cliques, located within one or more foci; thus, knowing which foci an individual is a member of and for how long tells us how induced homophily operates. In the case of language change, ostensibly the most important foci are schools. Indeed, even within a single school dramatic variation in the degree of participation in the NCS has been found as a function of social clique membership (Eckert 2000) and such network formations are moderated by the school's social ecology (McFarland et al. 2014). Within each school it then becomes important to consider how each actor relates to each other in Blau-space to determine whether choice homophily is operating along any social dimensions within the local ecologies.

Within a Blau-space framework we can estimate homophily in a latent form (i.e. its' potential) via measures of geographic proximity and social ecological similarity for induced homophily, and socio-demographic similarity for choice homophily. In this case, schools demarcate who comes into contact with who and therefore which dialect features are present within the local context for adolescents to choose from. That is, the lines of communication are structured by their network of attendance at the multitude of schools, and the more similar these networks are the more likely they are to have similar options for tie formation and dialect exposure.

Hypotheses

Given what we know about induced and choice homophily we can formulate two hypotheses about how they would affect language variation and change.

H1) People who occupy similar institutional and geographic space should display greater linguistic similarity and trajectories of change relative to those who are more distant institutionally and geographically.

The geographic diffusion of the NCS has followed the path of hopping from one large urban area to another (Dinkin 2013; Labov et al. 2006). Ostensibly this is due to greater contact flowing from a large city to a smaller one (e.g. Chicago or Madison to Eau Claire), with the cities surrounding the target being eclipsed by the local urban area (Trudgill 1974). The three cities studied herein are predicted to have been influenced by the NCS in the order of Eau Claire > Chippewa Falls > Altoona. Thus, each town should have different trajectories of change toward or away from the NCS.

The reversal of the NCS-like vowel system would be expected to behave in this way because movement towards or away from a particular dialectal configuration is capable of indexing local and extra-local distinctions between groups (or geographically contiguous towns). That is, degree of participation in the NCS – i.e. use of some vowel pronunciations more than others (a la Eckert 1988) – would be expected to vary as a function of community. Whether or not this works in tandem with BAG- and BAN-raising or if they have opposite trajectories of change would shed light on their relationship if any.

H2) People with greater socio-demographic similarity should display greater linguistic similarity and similar trajectories of change, even net of occupying similar social and geographic space.

The three communities under investigation are a great place to evaluate these hypotheses for two reasons. First, each city has been found to participate in the NCS and are now retreating from it. Second, the combination of these cities offers a useful comparison of urban, rural, and suburban contexts. Testing whether homophily structures the retreat of the NCS in this region should lead to insights into how language changes in general.

METHODS

Subjects

Semi-structured interviews were conducted in the summers of 2008, 2011, and 2013-2016 with one hundred and thirty-two speakers (77 females, 55 males), whose year of birth ranged from 1927 to 1995, from Eau Claire, Chippewa Falls, and Altoona, Wisconsin. Thirty-one speakers in the current corpus were partially analyzed by Benson et al. (2011). All respondents are native English speakers born and raised in the greater Eau Claire-Chippewa county area with little to no time spent outside of the area. Speakers were recruited through personal friendships (*n* = 27), family relationships (*n* =9), friend-of-a-friend networks (*n* = 29), snowball sampling (*n* = 37), and an advertisement in a local cultural magazine (*n* = 30).

Data gathering techniques[ii] included a standard sociolinguistic interview (Tagliamonte 2006) followed by reading of a wordlist, a story, and a sentence list, this study includes only tokens from the story and sentence tasks. While the first thirty-one speakers read the materials once over, the other one hundred and one read each of them twice.

Variable Coding

The dependent and independent variables in this study are listed in table 1 with the attribute and relational values that they take and the procedure for how they were measured, coded, or derived. The vowels were measured acoustically, the sociodemographics were coded from answers to a questionnaire, and the schools-to-individual networks were constructed from actors' reported schools attended.

Two units of analysis are used: (1) multiple vowel measurements from each speaker and (2) relations between actors *i-j* for all possible speaker dyads. Vowel measurements for each speaker are attribute based data and provide us with a picture of absolute vowel position. Dyadic data are relational units transformed from the attribute data into format as detailed below. Each type of data shows one aspect of the phenomena under investigation.

Vowel Measurement

Recordings were force aligned to the reading transcripts (i.e. automatically segmented into phonological units) using P2FA (Yuan and Liberman 2008). A semi-automatic measurement routine was used for the first ninety-six speakers thereby allowing for token-by-token segment boundary adjustments, resulting in 9,354 hand corrected measurements[iii]. The remaining 10,947 measurements were obtained fully-automatically from the force aligned TextGrid via a script that set the LPC filter order and maximum frequency range by comparing measurements taken with different combinations of settings with a hand measured model and minimizing the Mahalanobis distance between new tokens and the model values. That is, a range of potential measurements were compared to a model value for that segment and conditioning factor, and the option that was closest to a realistic vowel like candidate was chosen. F_1 and F_2 measurements were taken at the 0%, 25%, 50%, 75%, and 100% points of the vowel's duration. All analyses were performed on the 50% time-point measurement because this is the point at which the influence of preceding and following consonant would be expected to be equal: any further in the vowel and the preceding consonant will have less influence and the following will have more, and vice versa. Every vowel class represented in figure 1 was measured extensively, and included all of the consonantal conditioning environments of the NCS and BAG-/BAN-raising, resulting in a total of 8 vowel classes.

Tokens were normalized using the formula from Lobanov (1971) to eliminate the sex-based larynx differences between men and women since measurements from the rest of the vowel system (n = 89,541) were available (Adank, Smits, and van Hout 2004; Clopper 2009), and cross-sex comparisons are made. To account for the inequality in token count between vowel classes across speakers (i.e. speakers have different number of tokens for each vowel), Lobanov's formula was modified by using the grand mean of the vowel classes, and the standard deviation of all the means of each vowel class i.e., the mean and standard deviation of each vowel within speaker. This procedure safeguards against bias being introduced as an artifact due to one or more vowel classes having a larger token count and skewing the normalization. Henceforth F_1/F_2 will be called Z_1/Z_2.

Relational Measures

The relational dependent variables in this study are operationalized as the Mean Vowel Class Difference of each vowel category for each pairing of actors (henceforth MVCD). That is, since we are explicitly looking at how each actor *i* relates to actor *j,* we have to compute this as a difference between the two actor's mean for each vowel class. Since the vowel classes involved in the NCS have different directions of movement and can move along separate axes (i.e. Z_1 and Z_2), three sets of models were constructed for each hypothesis (below). One set each for BOT and BUT which move forwards and backwards along Z_2 and another set for vowels (BAT, BAD, BAN, BAG, BACK, BAC) that move along the front diagonal, D. The front diagonal is defined as simply $Z_2 – Z_1$ and is commonly used for these vowel classes (e.g. Labov, Rosenfelder, and Fruehwald 2013). The BAC vowel class is a residual category that includes all other instances of BAT that end in other consonants such as *bash, jazz,* and *bath*. The relational versions of D and Z_2 are MVCD_{Z2} and MVCD_D the calculations of which are detailed in table 1. However, due to the fact that these are relational measures it's not possible to tell from the estimates which of the *i-j* pair is more or less NCS-like, but just that they are more or less similar to each other on that linguistic dimension.

Table 1: Variable Operationalization.

	Variables	Attributes	Relations	Coding Procedure
DV	Z_2	Normalized(F_2)	$\text{MVCD}_{Z2} = \lvert Z_{2i} – Z_{2j}\rvert$	Measured from acoustic signal
	DIAGONAL	$Z_2 – Z_1$	$\text{MVCD}_D = \lvert D_i – D_j\rvert$	Measured from acoustic signal
IV	SEX	Male Female	1 = Same Sex 0 = Diff. Sex	Self-identified gender category
	YEAR OF BIRTH (YOB)	1927-1995	$\lvert YOB_i – YOB_j\rvert$	Self-reported Year of Birth
	OCCUPATION	Blue Collar White Collar (No degree) White Collar (Degree)	1 = Same Ocu. 0 = Diff. Ocu.	Self-reported occupation coded for collar via reference to SOC groups on O*NET.
	TOWN	Eau Claire Chippewa Falls Altoona	1 = Same Town 0 = Diff. Town	The school district that an individual graduated high school from.
	HAMMING DISTANCE (HD)		0+	Hamming distance as a measure of positional similarity computed on the bipartite network.

While SEX was coded as Male / Female and YOB as simply a number, OCCUPATION was coded via reference to O*NET's use of Standard Occupational Codes (SOC) (National Center for O*NET Development n.d.)[iv]. An individual's self-reported occupation was coded as Blue Collar if the work activities listed for it involved manual labor (e.g. construction worker or a short order cook). They were coded as White Collar (No degree) if their job did not involve manual labor but also did not require a degree (e.g. receptionists and administrative assistants). Lastly, they were coded as White Collar (Degree) if their job usually required a bachelors or higher (e.g. K-12 teacher, paralegal, or pharmacist).[v] If they were retired, then their most recent occupation was used. No participant was unemployed at the time of interview.

Adult occupation was used for two reasons. First, measures of parental SES from childhood were unavailable in the current dataset. And second, myriad sociolinguistic studies have found that adult occupation is a highly influential factor in the direction and rate of linguistic change (e.g. Labov 1968; Milroy and Milroy 1992, 1993; Wolfram and Fasold 1974), and has productively been used as a measure of SES in studies of language variation and change (for a review see Dodsworth 2009). While adult occupation does not directly reflect the SES of a child during adolescence, eventual occupational attainment is influenced by their parental SES (Blau, Duncan, and Tyree 1978; Blau et al. 1994; Sewell, Haller, and Ohlendorf 1970; Sewell, Haller, and Portes 1969). With this in mind it is reasonable to use adult occupational attainment as a proxy measure for SES during adolescence. However, this fact also introduces a temporal ordering problem that precludes any causal inferences being made about this particular variable.

In this region there are three school districts that cover the majority of the two county urban-suburban-rural continuum: Eau Claire (urban), Altoona (suburban), and Chippewa Falls (urban and rural). Individuals were coded as from one of these towns if the high school that they attended and graduated from was within said district. This is a coarse grained measure of which city they grew up in rather than the full K-12 trajectory. Both Eau Claire and Chippewa Falls have multiple high schools and corresponding feeder schools and each district covers the city and its surrounding hinterland while Altoona has one K-12 system that until recently (2016) was located all in one building.

Within the Blau-space framework the unit of analysis becomes the difference or distances between actors *i-j* along the dimensions measured. This requires that the dependent and independent variables be transformed into a round-robin dyadic structure wherein every actor is compared to every other actor (Kenny, Kashy, and Cook 2006). That is, rather than examining the effect of sex or gender on the dependent variable, the sex or gender difference between *i-j* is coded as SEX_{ij}. This conversion is illustrated in figure 3, where the values of Male / Female become Same / Different, i.e. they go from individualistic to relational measures. The same recoding was performed for OCCUPATION_{ij}. In the case of Year of Birth, YOB_{ij} simply becomes the absolute value of the numerical difference between the years of birth of *i-j*.

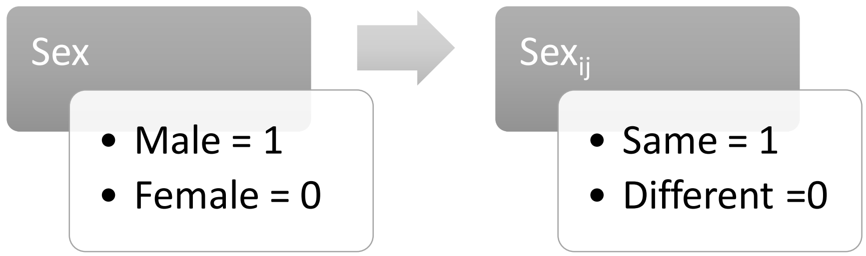

Figure 3: Dyadic Coding Procedure

The hamming distance method was used to create the social ecological distance matrix $\mathbf{D}_{HD}$ from the bipartite matrix **A** of actors and schools, with relations defined by whether or not an actor *i* attended school *j,* henceforth HD. The variables TOWN and HD are closely related since school districts are usually located within the town itself. However, in larger towns there are many different trajectories through a K-12 school system, especially when there are multiple high schools (both public and parochial). Indeed, in Eau Claire there were three public high schools (Central Hi before 1962, Memorial, and North which opened in 1962), and approximately thirty-two elementary and twenty-one middle schools. Attendance at any of these schools is determined by many factors such as neighborhood of residence, moving housing within or across towns, school choice options, socioeconomic resources of the parents, and so on. Thus, while living in one city typically does circumscribe the options for school attendance, it does not completely determine them.

Hamming Distance

Homophily (McPherson et al. 2001) is such a prominent process that measuring foci participation and socio-demographic information can work as an estimate of latent induced homophily and latent choice homophily. That is, if two actors *i-j* attended the same school or were members of the same clubs at the same time, then it is reasonable to assume that they were exposed to similar social ecologies and thus similar dialect forms. After the similarity in social ecology has been estimated, then the effect of latent choice homophily can be estimated by determining how actors *i-j* relate to each other socio-demographically.

Taking school attendance records and constructing a bipartite network of schools-to-individuals allows for the quantification of each individual's ecological similarity to all others. Bipartite network data with participants and the schools they attended as the nodes will yield an incidence matrix **A** where $\mathbf{A}_{nm} = 1$ if participant *n* attended school *m* during their time in the K-12 grades.

An idealized bipartite network of co-attendance at schools (figure 4) shows that some individuals share more similar social ecologies than others. Given a set of actors **N** = {A, G, E, F, I, H} represented by circles and the set of schools **M** = {B, C, D} represented by triangles, then it becomes clear in a simple graph who attended the same schools: color represents idealized ecological similarity with blue being its absence. In the bipartite network presented in figure 4, because actor A attended schools {D, C, B} they are less ecologically similar to actors {H, I} or {F, E} then either of those two pairings are to each other. That is, since the latter two pairings both attended the same schools – {H, I} attended school D and {F, E} attended school B – they would have been exposed to similar social ecologies.

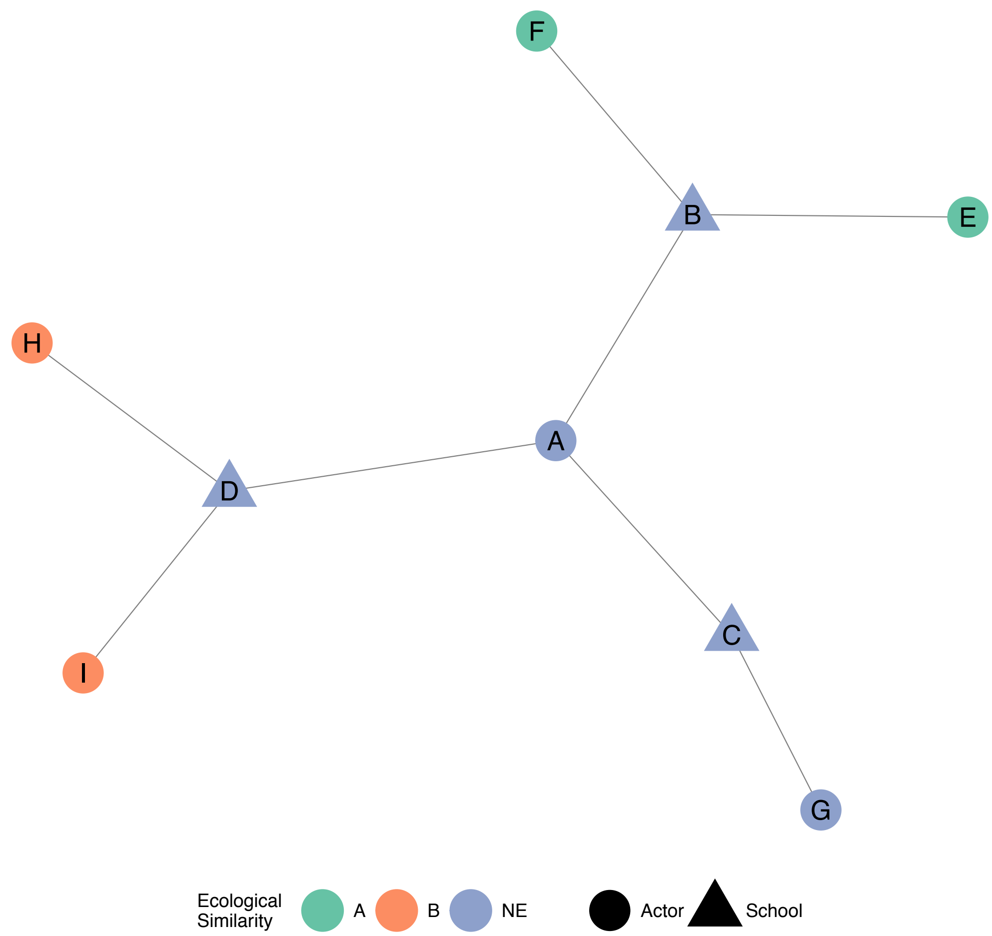

Figure 4: Ecological Similarity in a Bipartite Network

Within this bipartite network, measuring ecological similarity between actors *i-j* is easily accomplished via Hamming Distance (Batagelj, Ferligoj, and Doreian 1992; Hamming 1950). Hamming Distance (HD) provides a distance matrix $\mathbf{D}_{HD}$ were D_{ij} is the ecological similarity between actors (or schools) *i-j*. In the case of actor-school relations, HD is the closest to a direct measure of induced homophily because it is simply the sum of similar connections between actors *i-j*, and is therefore an estimation of the similarity in social ecological exposure during adolescence.

Recent work on bipartite networks has shown that co-affiliation with an organization or institutional setting provides sufficient data for modeling the diffusion of behaviors due to the effects that foci have on tie formation (Fujimoto 2012; Fujimoto, Chou, and Valente 2011; Fujimoto, Unger, and Valente 2012; Fujimoto, Wang, and Valente 2013). More specifically, since school ecologies have been found to moderate homophilous tie formation (McFarland et al. 2014), school affiliation data can therefore be used to model the role of local ecology at the city and school levels in language change. Measuring co-attendance of schools can serve as an approximation of lower level processes such as homophily without requiring longitudinal data on each person.

Statistical Modeling

This paper uses an Information Theoretic approach to model building, selection, and inference, as laid out by Burnham & Anderson (2002). The focus of such an approach is on constructing a set of models that correspond to the hypotheses in question, fitting the models, and making inferences from the group of models. Central to this process is the Akaike Information Criterion (AIC), an entropy-based statistic originating from a rich tradition in Information Theory, which explicitly rejects the notion that there is a true model, but rather asserts that all models are just approximations of 'reality' (Burnham and Anderson 2004).

Models ranked via AIC are considered comparatively better than the other when the AIC value is smaller (though this does not mean that 0 is 'the best' value), thus the focus of comparison is on $\Delta AIC = AIC_i - AIC_{min}$ (i.e. the difference between model *i* and the model with the lowest value). Starting with the first, each model is nested within the next model, and as such, is designed to answer whether or not the model with the added variable or interaction is better given the data, which in turn provides evidence for or against the proposition that the variable is a component of the underlying processes. To answer this type of question, Burnham and Anderson (2002:70–71) give the recommendation that ΔAIC values between 0 and 2 indicate no difference between the models, values between 4 and 7 indicate considerable differences, and values > 10 indicate complete difference.

The use of ΔAIC for ranking each model is the first step in determining the best estimated model. The second step is to examine the likelihood of a model given the data, or what Burnham and Anderson (2002: 74-75) term Akaike Weights, or w_i. This calculation quantifies the strength of evidence for each model given the set of models and the assumption that one of them must be the best estimate.

Table 2 contains the structure of each set of models developed for the two hypotheses. Since the trajectories of linguistic (dis)similarity are of interest, each IV is interacted with YOB_{ij}. A check mark denotes that a term was included in the model. The main effects and each lower order interaction, can be assumed to be present. Each panel represents each hypothesis with each model labeled within the hypothesis (henceforth, H1M1 = hypothesis 1, model 1). For BAT, vowel class (VC) is included as an independent variable with values for BAT, BAD, BAG, BACK, BAN, and BAC, but for BOT and BUT it is not included because separate models were run for each.

Table 2: Model Structure for both Hypotheses

Hypothesis One	Null	H1M1	H1M2	H1M3	H1M4	H1M5	H1M6	H1M7	
INTERCEPT	✓	✓	✓	✓	✓	✓	✓	✓	
VOWEL CLASS (VC)		✓	✓	✓	✓	✓	✓	✓	
YOB$_{ij}$		✓	✓	✓	✓	✓	✓	✓	
TOWN$_{ij}$			✓	✓	✓	✓	✓	✓	
HD$_{ij}$				✓	✓	✓	✓	✓	
VC*YOB$_{ij}$*HD$_{ij}$					✓		✓	✓	
VC*YOB$_{ij}$*TOWN$_{ij}$						✓	✓	✓	
VC*YOB$_{ij}$* TOWN$_{ij}$*HD$_{ij}$								✓	
Hypothesis Two	Null	H2M1	H2M2	H2M3	H2M4	H2M5	H2M6	H2M7	H2M8
INTERCEPT	✓	✓	✓	✓	✓	✓	✓	✓	✓
VOWEL CLASS (VC)		✓	✓	✓	✓	✓	✓	✓	✓
TOWN$_{ij}$		✓	✓	✓	✓	✓	✓	✓	✓
HD$_{ij}$		✓	✓	✓	✓	✓	✓	✓	✓
YOB$_{ij}$			✓	✓	✓	✓	✓	✓	✓
OCCUPATION$_{ij}$				✓	✓	✓	✓	✓	✓
SEX$_{ij}$					✓	✓	✓	✓	✓
VC*YOB$_{ij}$*OCCUPATION$_{ij}$						✓		✓	✓
VC*YOB$_{ij}$*SEX$_{ij}$							✓	✓	✓
VC*YOB$_{ij}$*OCCUPATION$_{ij}$* SEX$_{ij}$									✓

RESULTS

The bipartite network of actor-to-school connections is given in figure 5, with triangles marking schools and circles the actors. The colors mark which city those schools are located in, and each high school is labeled by name. Three patterns seem immediately apparent: (1) Altoona is clustered around three schools (the elementary, middle, and high schools for this city are all one building); (2) Chippewa Falls has a central cluster, but also more rural branches; and (3) Eau Claire is much more diverse in terms of clusters and cross-cluster connections. Previous analysis has shown that only some vowel classes show movement across apparent-time (Fox 2016), and therefore results are presented only for vowel classes that showed apparent-time change: BAT, BAD, BAG, BACK, BAN, BOT, and BUT.

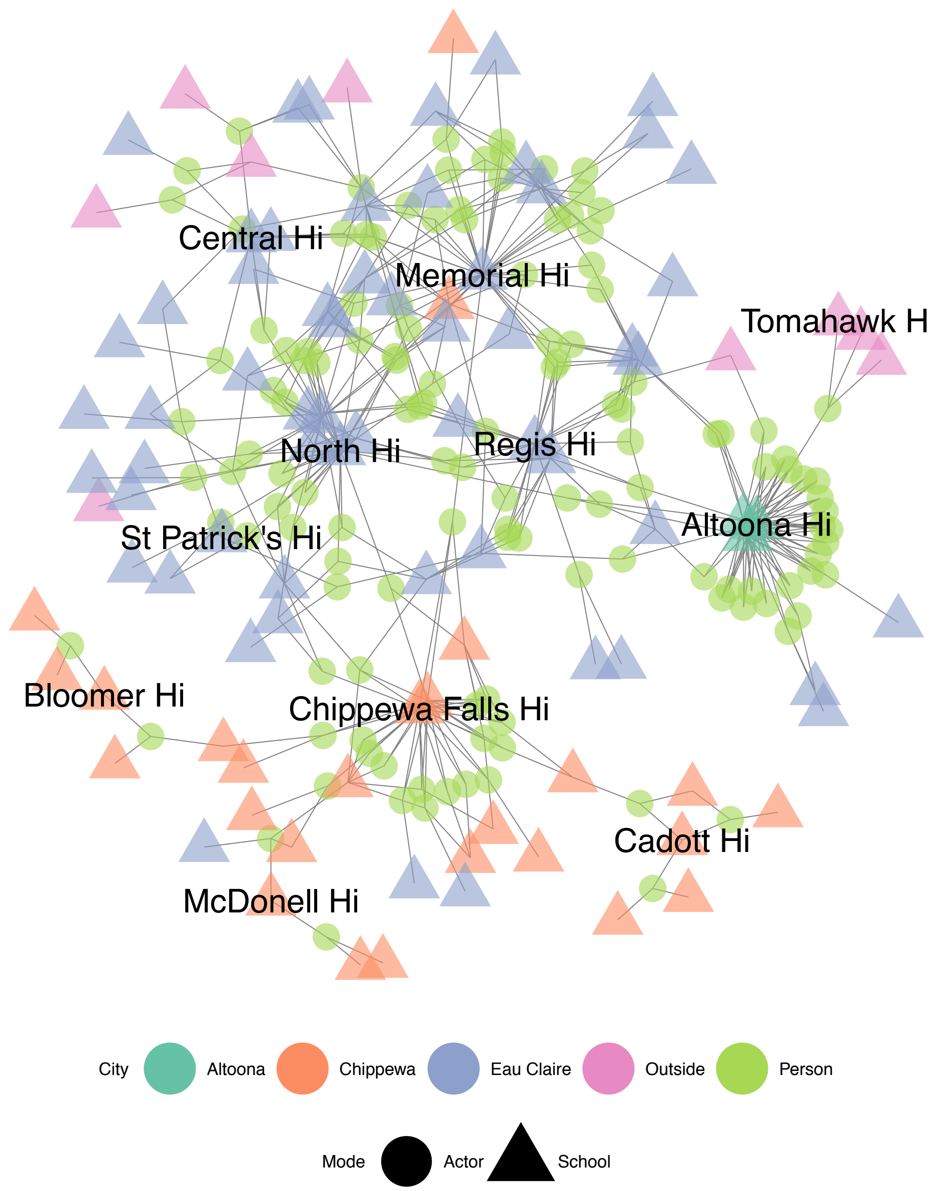

Figure 5: Actor-to-School Bipartite Network (Color = City, Shape = Mode)

First, looking at the position of all speaker's position in vowel spaces for each vowel class across apparent-time and as a function of TOWN will elucidate what trajectories the NCS has taken there: i.e., which vowel classes if any are progressing and which are retracting. Figure 6 plots each individual's mean position (front diagonal of the vowel space) for all classes of BAT across YOB and TOWN. The shape of the symbol and line type represents town. The point symbols are by-speaker means with 1.5 standard deviations around the mean marked by the vertical lines. Each line is a simple least square's regression fit for each subset of data by the *ggplot2* package in R. Higher values equal more NCS like and vice versa.

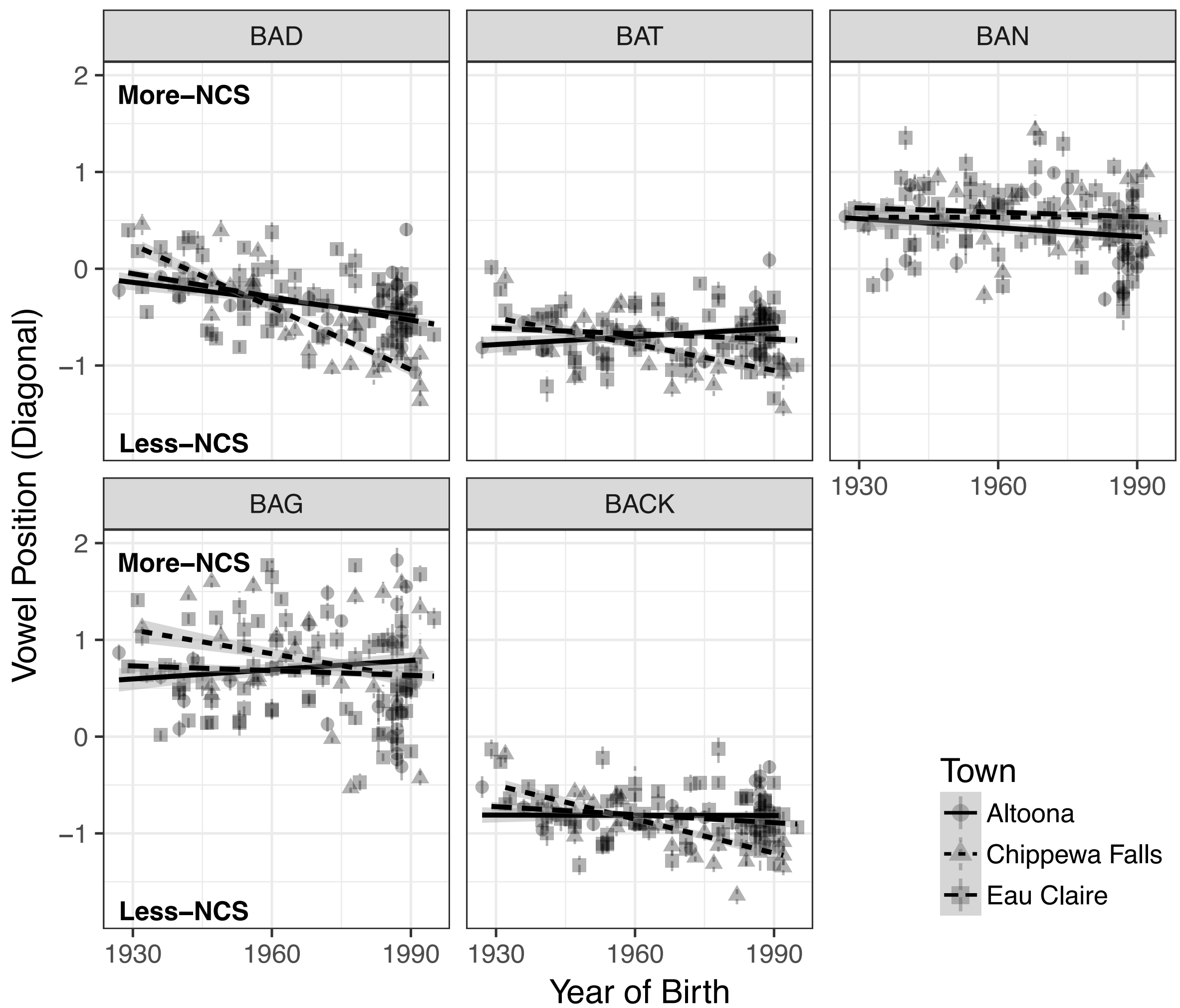

Figure 6: Diagonal of all BAT vowel classes across YOB, SEX, and TOWN. Dots are mean and standard deviation by speaker. Lines are linear models fit by subset.

Figure 6 shows that not only are BAD and BAT retracting away from an NCS-like system – i.e. they are moving down the front diagonal – but that Chippewa Falls is moving the most and fastest of the three, ending up much more retracted. Moreover, BAG and BACK show the expected split with the former much higher and fronter and the latter lower and backer. While there is some retraction happening with BAG, this gap is still there. Indeed, the fact that BAG is raised above BAD and BACK is much below BAD indicates that BAG-raising is a separate phenomenon from NCS-raising. Lastly, BAN appears to be high and fronted near BAG, but not changing in any town, indicating a functional distinction from the NCS.

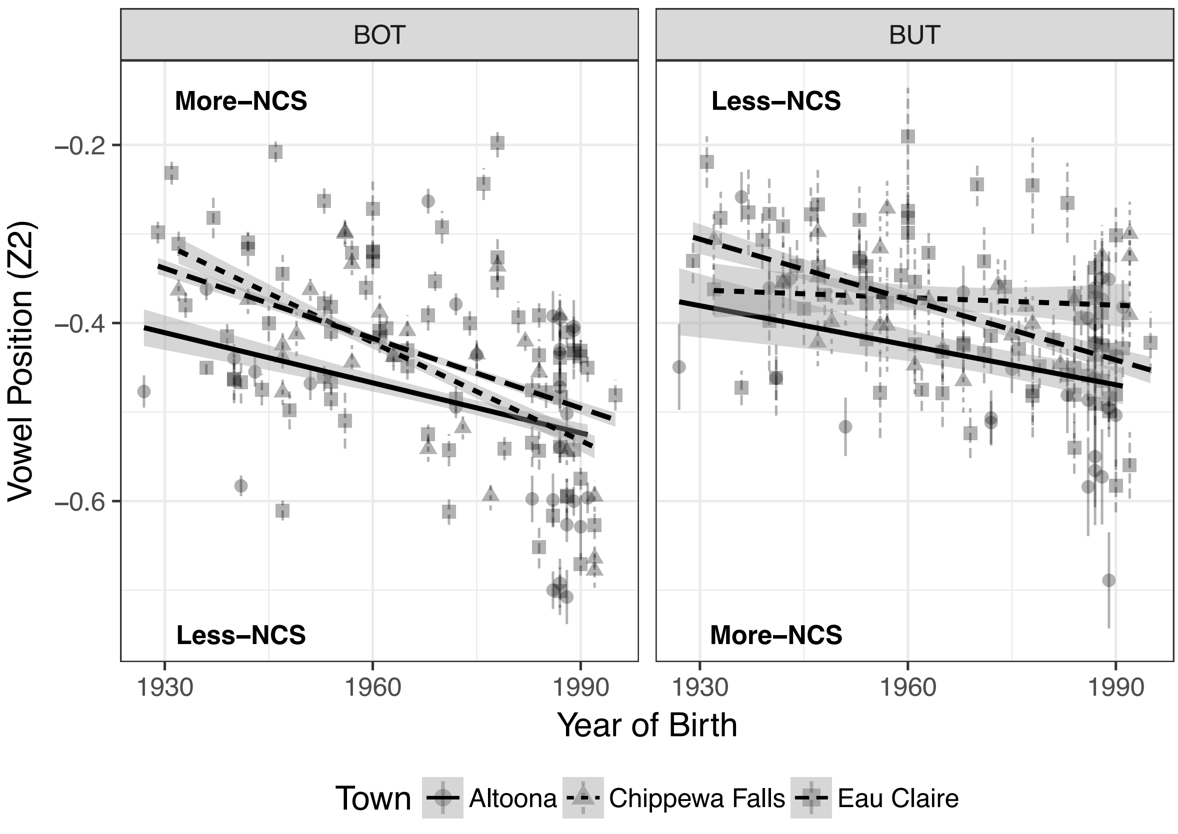

Figure 7: Z_2 of BOT and BUT across YEAR OF BIRTH, SEX, and TOWN. Dots are mean and standard deviation by speaker. Lines are linear models fit by subset generated by *ggplot2*.

Figure 7, in the same way as figure 6, shows the trajectory of change in vowel position (Z_2) for BOT and BUT across apparent-time. It appears to be the case that while BOT started out more NCS-like in some cities than others, all three have started to retract across apparent-time, ending up back in a much less NCS-like position. However, the BUT vowel class is also backing to become more NCS-like despite it being predicted to change as the fourth vowel to move in the chain shifting sequence. That is, while the first (BAT) and second (BOT) stages are retracting and the third (BOUGHT) is not showing any effects, the fourth (BUT) is moving towards an NCS-like position.

This out of sequence movement, combined with the fact that Chippewa Falls shows more and faster retraction away from the NCS indicates the presence of social mechanisms operating within and across these communities that structure these differences. As figure 5 shows, there are various demarcations of social ecological environments that have the potential to structure how homophily operates therein. That is, there are multiple trajectories through the K-12 school systems in each of these towns, and the social ecologies of these spaces are embedded within the historical moments that individuals lived through.

Hypothesis One

The first hypothesis asks generally whether or not geographic proximity, measured by having grown up in the same town or not, and/or latent induced homophily, as measured by hamming distance (HD_{ij}) within an actor-to-school bipartite network, affects the linguistic (dis)similarity of actors *i-j* for the vowel classes involved in the NCS. Specifically, it asks (1) whether simple geographic proximity is sufficient for producing linguistic similarity and (2) whether latent induced homophily is moderated by being from the same town. Answering these questions requires that we move to using Mean Vowel Class Difference between all actor dyads, henceforth MVCD, a relational measure of linguistic (dis)similarity. The models herein are hierarchical linear regressions with a random intercept for each *i-j* pair; their fixed effects structure is given in the top of table 2.

Table 3 is the AIC comparison of the set of $MVCD_D$ models for BAT derived from the diagonal measure of the vowel space. Table 4 and table 5 are the same for the set of models for $MVCD_{Z2}$ derived from Z_2 for BOT and BUT run separately. These dependent variables were derived separately because in the NCS BAT moves in a diagonal direction at the front of the vowel space while BOT and BUT move forwards and backwards in vowel space (figure 1).

Table 3: Hypothesis One Model Comparison via AIC for BAT for $MVCD_D$ (Diagonal)

Model	*K*	AIC	ΔAIC	$ΔAIC_{each}$	w_i	*LL*
$H1M7_D$	50	20119.59	0	60.96	1	-10009.74
$H1M6_D$	38	20180.55	60.96	18.11	0	-10052.25
$H1M5_D$	26	20198.65	79.07	9.9	0	-10073.31
$H1M2_D$	15	20208.56	88.97	1.44	0	-10089.28
$H1M3_D$	16	20210	90.41	27.65	0	-10088.99
$H1M4_D$	26	20237.65	118.06	16.21	0	-10092.81
$H1M1_D$	14	20253.86	134.27	7343.95	0	-10112.92
$H1_{NULL}$	3	27597.81	7478.22	0	0	-13795.9

Included in each table are *K* (the number of parameters in the model), raw AIC, ΔAIC (the difference between each model and the one with the lowest AIC), $ΔAIC_{each}$ (the difference between each consecutively ranked model), w_i (Akaike weights, which give the strength of evidence for a model being the best candidate model) and *LL* (the model Log Likelihood which AIC is a transformation of). Based on both the ΔAIC, w_i, and $ΔAIC_{each}$ given in table 3 for the BAT models, $H1M7_D$ is the best approximating model to the underlying generating process. The case of BOT and BUT are similar in that the best approximating models for both are $H1M7_{Z2}$.

The best approximating models being the same for BAT, BOT, and BUT indicates a similarity in how social ecology across time affects the trajectories of change for each. Specifically, that the $YOB_{ij}*TOWN_{ij}*HD_{ij}$ term is present in the case for all three models, indicating a moderation effect. This is a piece of evidence that supports hypothesis one if the coefficients are significant. The $YOB_{ij}*HD_{ij}*TOWN_{ij}$ coefficient for BOT is marginally significant with $t = 1.909$ and BUT is significant with $t = 4.031$ (Appendix B), but in the case of the BAT model (Appendix A) only BAN vs. BAC (reference level) comes out as a significant effect with $t = -3.243$. However, this says nothing about the significance of the contrasts between the other categories of BAT, for lower level interactions. To clearly interpret high dimensional interaction terms like this, the conditional slopes must be plotted and confidence interval overlap compared.

Table 4: Hypothesis One Model Comparison via AIC for BOT for $MVCD_{Z2}$

Model	*K*	AIC	ΔAIC	ΔAIC_{each}	w_i	*LL*
$H1M7_{Z2}$	9	-16285.89	0	14.08	1	8151.96
$H1M6_{Z2}$	7	-16271.81	14.09	1.61	0	8142.91
$H1M3_{Z2}$	5	-16270.2	15.7	4.71	0	8140.1
$H1M4_{Z2}$	5	-16265.49	20.4	22.51	0	8137.75
$H1M5_{Z2}$	5	-16242.98	42.91	0.05	0	8126.5
$H1M2_{Z2}$	4	-16242.93	42.96	0.12	0	8125.47
$H1M1_{Z2}$	3	-16242.81	43.08	186.85	0	8124.41
$H1_{NULL}$	2	-16055.96	229.94	0	0	8029.98

Table 5: Hypothesis One Model Comparison via AIC for BUT for MVCD_{Z2}

Model	*K*	AIC	ΔAIC	ΔAIC_{each}	w_i	*LL*
H1M7_{Z2}	9	-20943.05	0	16.91	1	10480.54
H1M6_{Z2}	7	-20926.14	16.91	2.68	0	10470.08
H1M3_{Z2}	5	-20923.46	19.6	14.06	0	10466.73
H1M4_{Z2}	5	-20909.4	33.65	13.94	0	10459.71
H1M5_{Z2}	5	-20895.46	47.6	0.1	0	10452.73
H1M2_{Z2}	4	-20895.36	47.69	2.71	0	10451.68
H1M1_{Z2}	3	-20892.65	50.41	162.39	0	10449.32
H1_{NULL}	2	-20730.26	212.79	0	0	10367.13

The top graph in figure 8 suggests that, among people living in the same town, there's virtually no change across cohorts in way that the BAN vowel class is pronounced (denoted by the flat trajectory) and also little difference in BAN by Hamming distance (denoted by lack of confidence interval separation). However, among people from different towns, Hamming distance has become highly consequential for the way that BAN is pronounced across apparent-time. Indeed, among people from different towns and from different social ecologies ($\text{HD}_{ij} = 14$), BAN is predicted to be changing across time (increasing large dashed line), but when they are from different towns and similar social ecologies ($\text{HD}_{ij} = 0$), younger people are becoming more similar to older people (decreasing solid line). In this latter case these dyads include one member who grew up and lived in one town but attended schools in another either for a short period or a full switch.

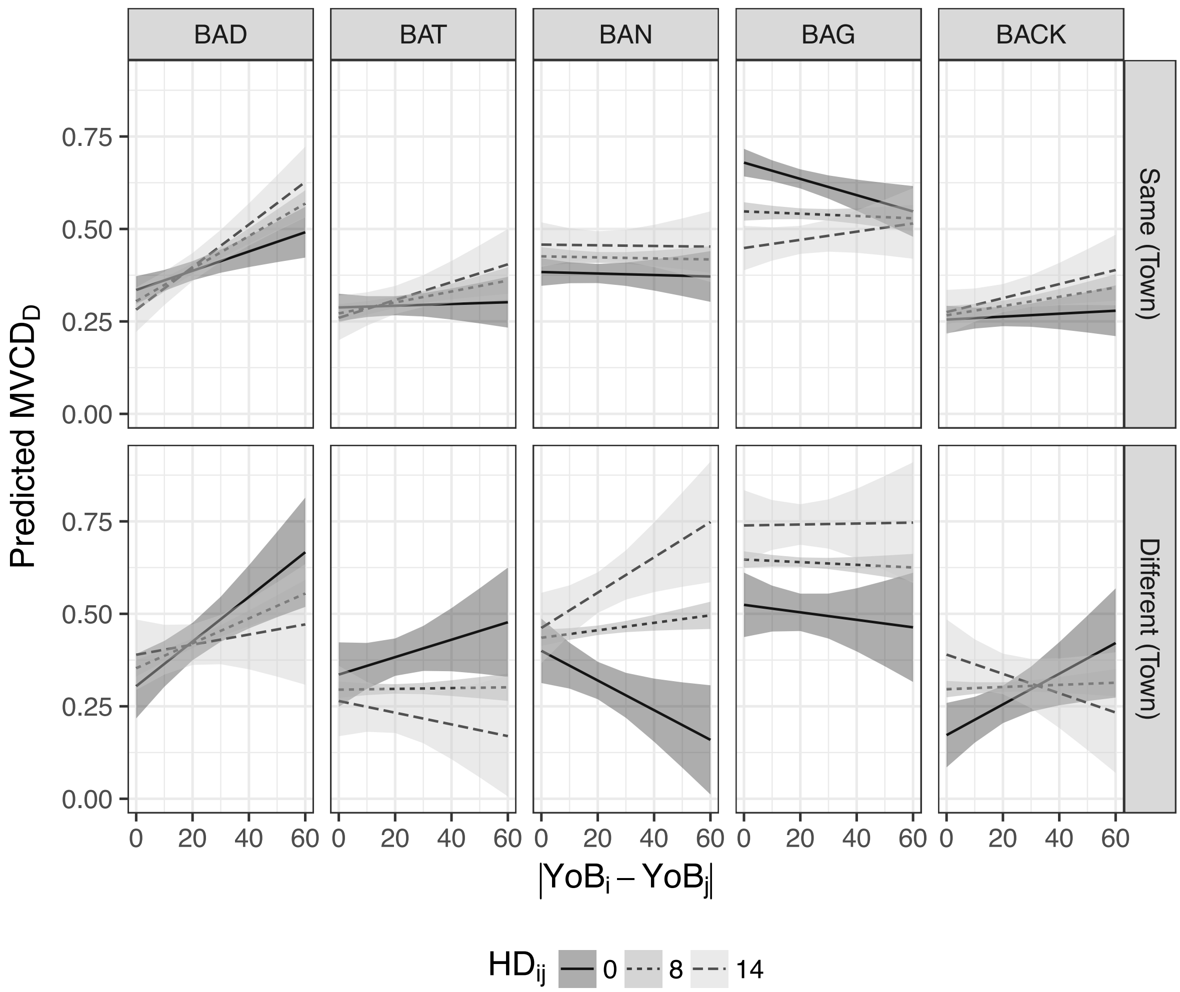

Figure 8: Conditional Slopes for $H1M7_D$ for BAT Vowel Classes. (High $MVCD_D$ = linguistic dissimilarity, low $MVCD_D$ = linguistic similarity).

The conditional slopes for the $VC*YOB_{ij}*TOWN_{ij}*HD_{ij}$ interaction from $H1M7_D$ tells us whether actors *i-j* are predicted by the model to be more linguistically different (higher $MVCD_D$ values) or similar (lower $MVCD_D$ values). Figure 8 shows: (1) when *i-j* are from different towns (bottom row) they are predicted to be consistently more linguistically different from each other than when they are from the same town (top row) as evidenced by less confidence interval overlap; (2) looking at how the solid line for $HD_{ij} = 0$ is lower (BAD, BAT, BAN, and BACK when $TOWN_{ij}$ = Same; BAN and BAG when $TOWN_{ij}$ = Different) than the other lines we can see that in the majority of cases *i-j* are predicted to be more linguistically similar when HD_{ij} is lower, i.e. closer in ecological space; (3) when $TOWN_{ij}$ = Different, having an HD_{ij} of 0 (min) is predicted to sometimes lead to more dissimilarity as YOB_{ij} increases (BAD, BAT, BACK) and sometimes similarity (BAN, BAG). The opposite is predicted when HD_{ij} is 14.

These points indicate that the effect of HD_{ij} on the linguistic similarity of *i-j* is different as a function of VC and $TOWN_{ij}$; that is, HD_{ij} is moderated by $TOWN_{ij}$ as predicted by hypothesis one. Indeed, the fact that $YOB_{ij}*HD_{ij}*TOWN_{ij}$ is significant ($t = 2.078$) while HD_{ij} is not ($t = -1.295$) indicates that HD_{ij} does not operate on its own, but is localized within each town. As per the prediction of hypothesis one, latent induced homophily appears to operate within localized regions/communities.

When *i-j* are from the same town the effects of HD_{ij} are much subtler. Generally, when HD_{ij} is 0 individuals are more linguistically similar across the YOB_{ij} continuum (lower solid line), although this is not a robust effect due to low confidence interval separation. However, in the case of BAG the lower HD_{ij} is the more dissimilar *i-j* are predicted to be, a strong effect shown by the confidence interval separation at the lower end of the YOB_{ij} scale. Indeed, as YOB_{ij} increases these trajectories converge to be overlapping. The shape of this effect is due to the fact that over the course of this time span for this vowel it went from low front, to high front, and is now moving back again. As such, there is more variation in the lower ranges of YOB_{ij} with some becoming more like the older people than their peers. Together the predictions for hypothesis one appear to hold for the BAT vowel classes. While not all contrasts are significant, the fact that being from different towns as well as different social ecologies affects linguistic (dis)similarity is evidence in favor of hypothesis one.

The greater confidence interval separation predicted for BAT vowel classes when *i-j* are from different towns than when they are from the same town, raises the question of which town might be driving this difference. Indeed, if this is the case then whether or not HD_{ij} has an effect within each city is also of interest. Figure 9 shows the patterning HD_{ij} (binned with a width of 2) for dyads where each member was from the same city. Two dimensional density estimations are plotted as contours to avoid over plotting and subset regression lines show directional trends. Only BAD, BAT, and BACK are shown because the patterning in figure 8 indicates that these vowel classes are undergoing change over apparent-time.

Figure 9 shows that for these three vowels, only those dyads that are both from Chippewa Falls appear to be diverging as they get further apart in age. Moreover, this effect is stronger for dyads that are more ecologically dissimilar. However, for BAD, even they are ecologically similar (solid dark line: 0-2), they are diverging across time. This within TOWN_{ij} patterning indicates that the fact that Chippewa Falls is changing more and faster (a la figure 6) is driving the cross-town difference comparison seen in figure 8. Lastly, the effect of HD_{ij} appears within Chippewa Falls more prominently than the other two towns indicating that social ecology matters for these vowel class changes in this town more than it does in the other two. This effect is possibly due to the fact that Chippewa Falls has school ecologies that span the suburban-rural continuum and is thusly reflected in the effect of HD_{ij} on linguistic similarity.

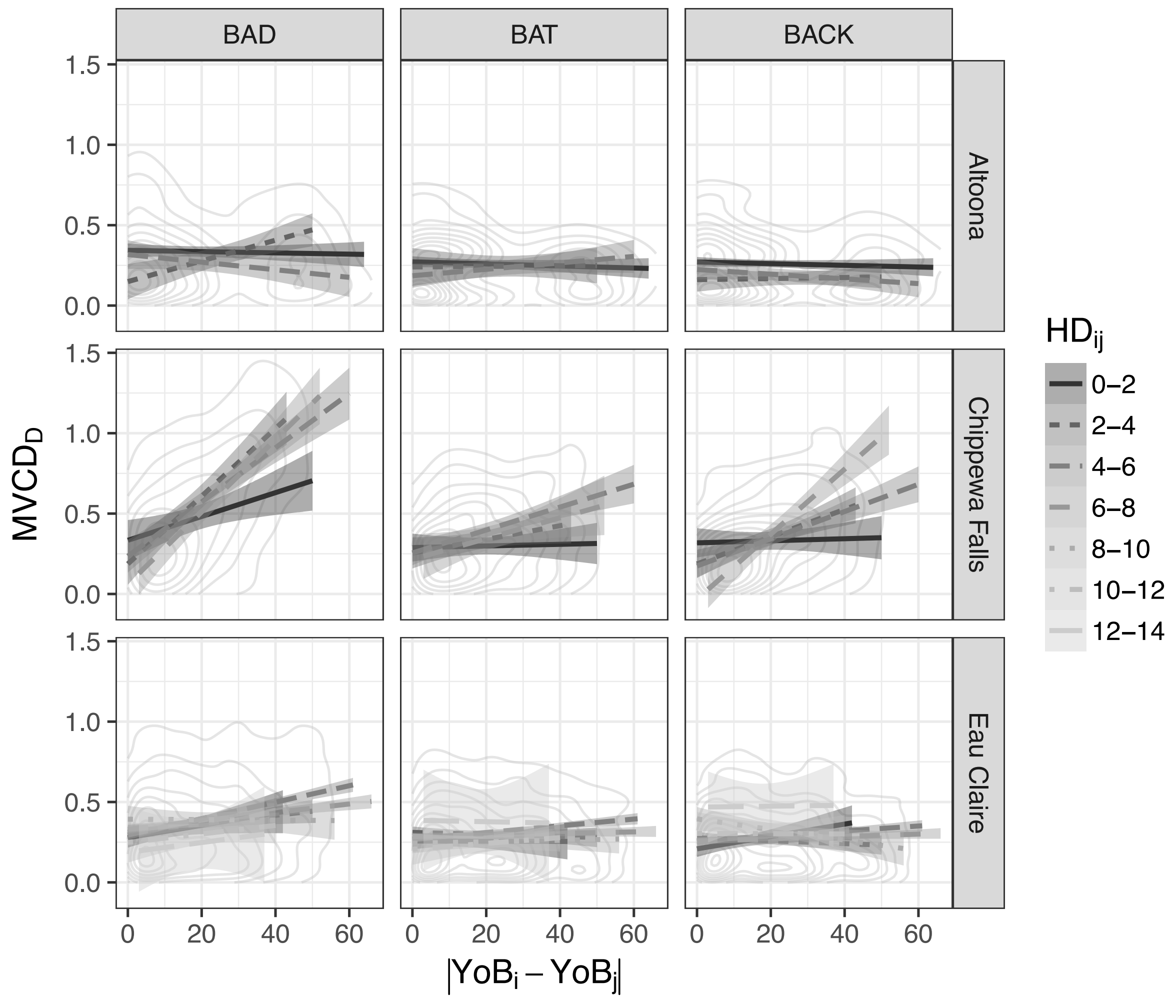

Figure 9: Within TOWN_{ij} Comparisons of BAD, BAT, and BACK. Contours are 2d density estimates and lines are simple subset regressions.

The results from H1M7_{Z2} for BOT and BUT are given in Appendix B and show robust results across the board. The conditional slopes from each of these models are shown in figure 10. When TOWN_{ij} = Different, *i-j* are more dissimilar than when TOWN_{ij} = Same, and this effect is greater when HD_{ij} is lower: i.e. $TOWN_{ij}$ moderates the effect of HD_{ij}. This is a strong effect due to large confidence interval separation between $HD_{ij} = 0$ and the other two. In the case of BOT this effect increases for all levels of HD_{ij} as YOB_{ij} gets higher, but for BUT this is only true for the lowest level, and the opposite is true for higher values of HD_{ij}. Lastly, when $TOWN_{ij}$ = Same the effect of HD_{ij} is the same for both BOT and BUT: at a HD_{ij} value of 0 there is little to no change in dissimilarity as YOB_{ij} increases, but at a HD_{ij} value of 8 or 14, *i-j* become more dissimilar as YOB_{ij} increases, indicating that local ecology matters within each town for these vowel classes. The fact that when *i-j* are from different towns (bottom row), but similar ecologies (solid line), and further apart in age, the more linguistically dissimilar they are shows the presence of cross-town distinctions because this is a situation in which one of the dyad moved to another town during adolescence or commuted to a school one town over.

Taken together the models for BAT, BOT, and BUT show substantial evidence for a moderating effect of $TOWN_{ij}$ on HD_{ij}. The evidence for the operation of latent induced homophily stands as: (1) being from a different town is predicted to increase linguistic dissimilarity for some vowel classes (BAD, BAT, BACK, BOT and BUT) and (2) being from the same town and being ecologically distant in terms of HD_{ij} is predicted to lead to more linguistic dissimilarity as YOB_{ij} increases (upward sloping lines for $HD_{ij} = 14$) for every vowel class but BAN. The fact that these effects vary as a function of the vowel class involved is commensurate with similar findings of low level variation in degree of use of the NCS (Eckert 1988). Whether or not social variables also have an effect when $TOWN_{ij}$ and HD_{ij} are controlled will tell us if latent choice homophily is a mechanism affecting linguistic variation and change.

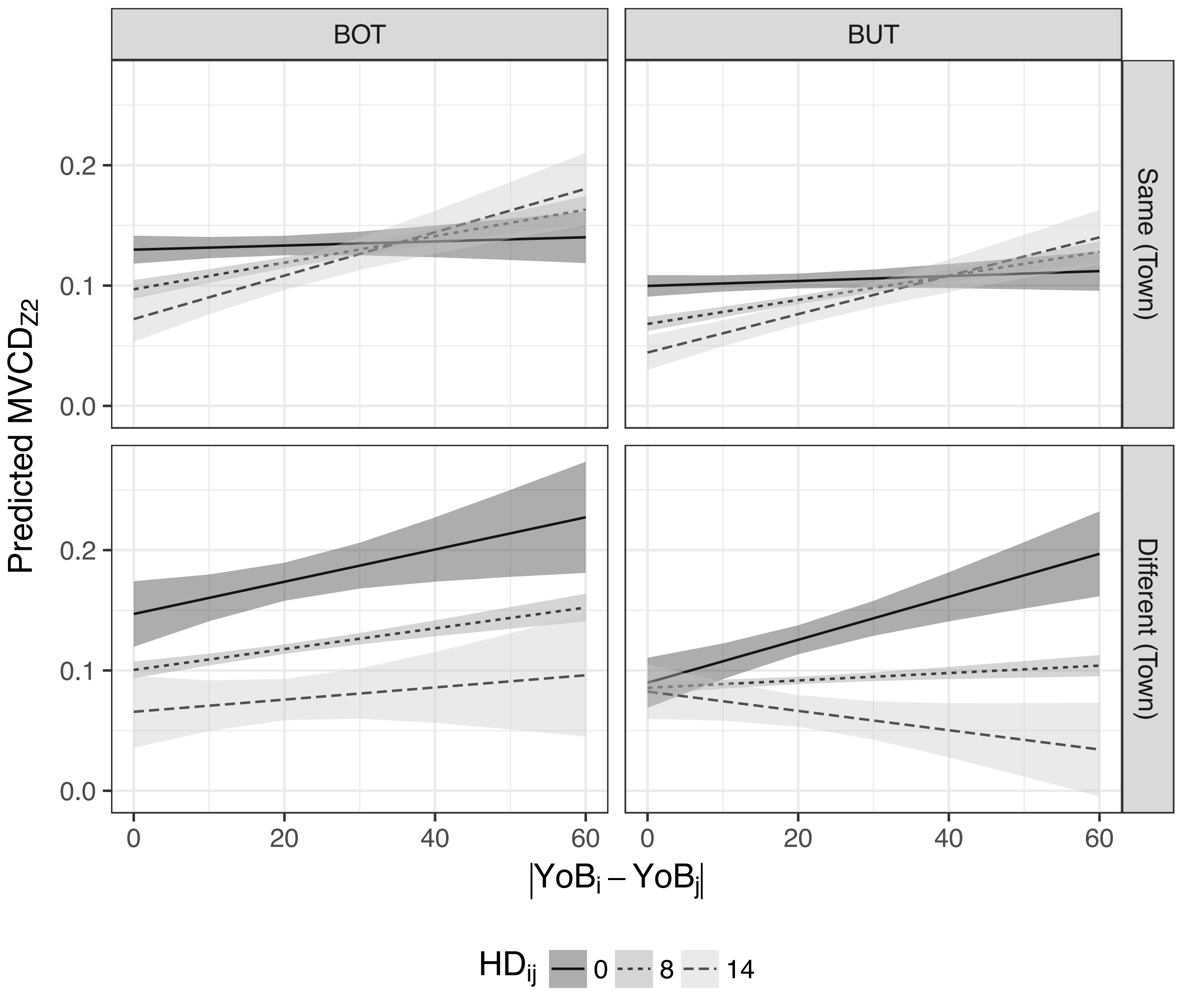

Figure 10: Conditional Slopes for H1M7$_{Z2}$ for BOT and BUT. (High MVCD$_D$ = dissimilarity, low MVCD$_D$ = similarity).

Hypothesis Two

The second hypothesis predicts that latent choice homophily, as measured by similarity in SEX and OCCUPATION, will affect the linguistic (dis)similarity of actors *i-j* for the vowel classes involved in the NCS, net of the effects of latent induced homophily.

Specifically, whether SEX_{ij} and OCCUPATION_{ij} have a main effect on linguistic similarity, as expected from sociolinguistic theory, or if they moderate the effect of YOB_{ij}, net of TOWN_{ij} and HD_{ij} as predicted by Blau-space theory. Again, these models used MVCD as the dependent variable and are hierarchical linear regressions models with dyad as a random intercept.

Table 6: Hypothesis Two Model Comparison via AIC for BAT MVCD_{D} (Diagonal)

Model	*K*	AIC	ΔAIC	ΔAIC_{each}	w_i	*LL*
H2M8_{D}	52	19890.02	0	66.24	1	-9892.96
H2M7_{D}	40	19956.26	66.24	5.06	0	-9938.1
H2M6_{D}	34	19961.33	71.3	139.16	0	-9946.64
H2M5_{D}	34	20100.49	210.46	11.36	0	-10016.22
H2M4_{D}	28	20111.84	221.82	88.95	0	-10027.9
H2M3_{D}	22	20200.79	310.77	9.21	0	-10078.39
H2M2_{D}	16	20210	319.98	7341.27	0	-10088.99
H2M1_{D}	5	27551.27	7661.25	46.54	0	-13770.63
H2_{NULL}	3	27597.81	7707.79	0	0	-13795.9

The model comparisons via ΔAIC for BAT, BOT, and BUT are given in table 6, table 7, and table 8 respectively. In the case of BAT and BUT, the top model is the H2M8. However, for BOT, the ΔAIC comparison is inconclusive due to the fact that models 3, 4, 6, 2, 5, and 7 are all less than 2 ΔAIC from the top model. As per the guidelines laid out earlier, this means that these models do not approximate the underlying process any better than the others. However, the w_i score, which gives the weight of evidence for that model being the best approximating model, shows that H2M3_{Z2} and H2M4_{Z2} have the most support. These models include only main effects for latent induced and latent choice homophily, indicating that for BOT the most meaningful dimensions are TOWN_{ij} and HD_{ij} as shown in the previous section. Moreover, this is an indication that BOT has not reached a level of social awareness to be recognized or used as a group marker; it is simply spreading through proximity.

Table 7: Hypothesis Two Model Comparison via AIC for BOT $MVCD_{Z2}$

Model	*K*	AIC	ΔAIC	ΔAIC_{each}	w_i	*LL*
$H2M3_{Z2}$	6	-16271.21	0	0.07	0.25	8141.61
$H2M4_{Z2}$	7	-16271.14	0.07	0.74	0.24	8142.57
$H2M6_{Z2}$	8	-16270.4	0.81	0.2	0.17	8143.21
$H2M2_{Z2}$	5	-16270.2	1.01	0.89	0.15	8140.1
$H2M5_{Z2}$	8	-16269.32	1.9	0.66	0.10	8142.67
$H2M7_{Z2}$	9	-16268.65	2.56	2.03	0.07	8143.34
$H2M8_{Z2}$	11	-16266.62	4.59	194.29	0.03	8144.33
$H2M1_{Z2}$	4	-16072.33	198.88	16.37	0.00	8040.17
$H2_{NULL}$	2	-16055.96	215.25	0	0.00	8029.98

The best approximating models for BAT and BUT are those which include the interaction: YOB_{ij}*SEX_{ij}*$OCCUPATION_{ij}$ while holding $TOWN_{ij}$ and HD_{ij} constant (i.e. consistent with hypothesis two). Since this indicates that this interactive moderation is part of the underlying generating process, this is a piece of evidence that latent choice homophily, net of latent induced homophily, affects how language varies and changes for these vowels.

Table 8: Hypothesis Two Model Comparison via AIC for BUT $MVCD_{Z2}$

Model	*K*	AIC	ΔAIC	ΔAIC_{each}	w_i	*LL*
$H2M8_{Z2}$	11	-21007.4	0	19.46	1	10514.71
$H2M6_{Z2}$	8	-20987.94	19.46	1.91	0	10501.98
$H2M7_{Z2}$	9	-20986.03	21.37	2.51	0	10502.03
$H2M4_{Z2}$	7	-20983.52	23.88	1.77	0	10498.76
$H2M5_{Z2}$	8	-20981.75	25.65	58.29	0	10498.88
$H2M2_{Z2}$	5	-20923.46	83.94	2	0	10466.73
$H2M3_{Z2}$	6	-20921.46	85.94	170.77	0	10466.73
$H2M1_{Z2}$	4	-20750.69	256.71	20.43	0	10379.35
$H2_{NULL}$	2	-20730.26	277.14	0	0	10367.13

The best approximating model ($H2M8_D$) for the BAT vowel classes is given in Appendix C and the conditional slopes are given in figure 11. First, in $H2M8_D$ there is a main effect for TOWN$_{ij}$ (t = -6.234), but not HD$_{ij}$ (t = 0.76). Since the TOWN$_{ij}$ moderates HD$_{ij}$ the fact that the effect is absent in this model is unsurprising. There are also interaction effects for YOB$_{ij}$*SEX$_{ij}$*OCU.$_{ij}$ for the BAG (t = -2.143), BAN (t = 2.565), and BAT (t = -2.288) vowel classes, indicating that choice homophily is operating on the trajectories of variation and change for these vowel classes. However, these are just in reference to BAC, and the predicted effects in comparison to everything can be examined via the conditional slopes (figure 11).

The conditional slopes (figure 11) predict that in most cases (BAD, BAT, BACK), as YOB$_{ij}$ increases linguistic similarity decreases when OCU.$_{ij}$ and SEX$_{ij}$ are either the "Same" or "Different" but this effect is stronger (i.e. steeper positive slopes) when SEX$_{ij}$ = Same. This differentiation across the age span, where linguistic dissimilarity increases as *i-j* get further apart in age indicates a change in apparent-time. In addition, the steeper slopes for SEX$_{ij}$ = Same and OCU.$_{ij}$ = Same (top row) indicates that there is more sex internal differentiation than cross-sex differentiation, and that over all, SEX is a more meaningful axis for latent choice homophily's effect on linguistic behavior than OCCUPATION. That is, as *i-j* become further apart in age but are from the same town and of the same sex, they are more linguistically dissimilar.

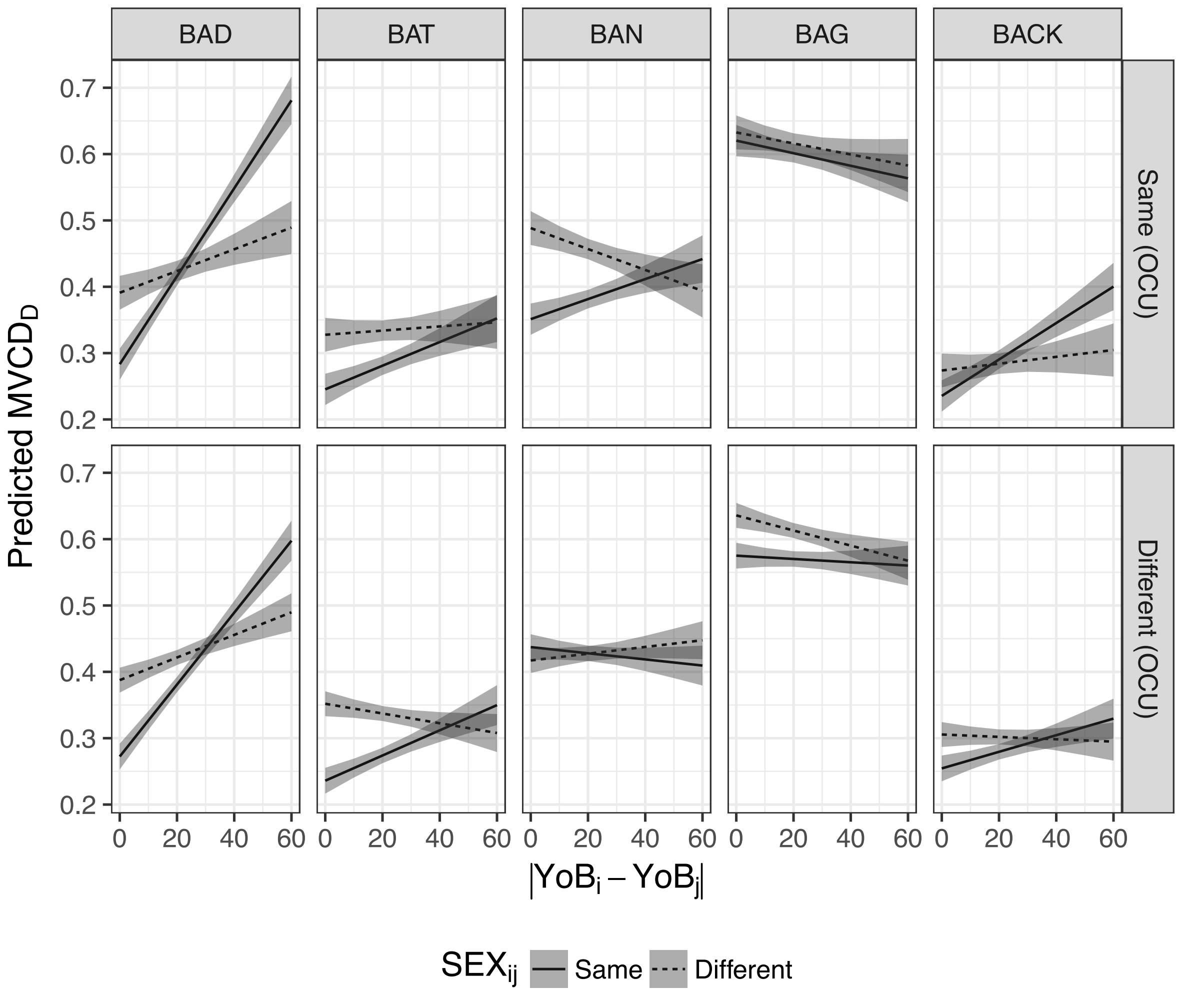

Figure 11: Conditional Slopes for H2M8$_D$ for BAT. (High MVCD$_D$ = dissimilarity, low MVCD$_D$ = similarity).

Examination of the attribute level patterns of BAD and BAT (figure 12) shows that females (top panel solid line) are retracting more than males (top panel dashed line) as evidenced by the steeper decreasing line for the former. In the aggregate there is not such a dramatic difference between occupation levels (bottom panels). For BAD the aforementioned retraction appears to be present in all levels of occupation as evidenced by the lack of a dramatic difference between the regression lines. However, this may also be due to the crudeness of the occupational measure, i.e. it only has three levels. The patterning of more sex internal differentiation found in figure 11, appears to be due to females retracting more and faster than males for both BAD and BAT. Moreover, the lack of occupational differentiation in figure 12 accounts for the fact that the vowel classes appear to pattern the same regardless of having the same or different occupation in figure 11. This result is commensurate with sociolinguistic work showing females leading change (Eckert 1989b; Labov 1990, 2001), indicating that one mechanisms leading to such an aggregate level pattern is sex based homophily.

The predictions for BAD are consistent with previous analyses (Fox 2016) reviewed above showing its retraction towards less NCS-like position, and those for BAN and BAG are in line with the fact that both of these have been found to be retracting for younger people, i.e., they are becoming more like the older generation (Fox and Mielke 2016). For BAD (far right column) the steeper positive slopes for SEX_{ij} = Same indicates that latent choice homophily is structuring its retraction. For BAN this is shown in the top BAN panel, by greater linguistic dissimilarity when *i-j* are similar in YOB and OCCUPATION, but different in SEX, which decreases as YOB_{ij} increases and lower dissimilarity when all else is the same except SEX_{ij} = Same, and linguistic dissimilarity is increasing as YOB_{ij} increases. This pattern appears to be due to the fact that BAN was raised and fronted (more NCS-like) well before this time window (1927-1995), and is now beginning to change. For BAG this is shown by greater linguistic dissimilarity when *i-j* are closer in age than further apart for all levels of SEX_{ij} and OCU._{ij} with no confidence interval separation for OCU._{ij} = Same, but only slight separation for

OCU.$_{ij}$ = Different. This is the same as the aforementioned effect for BAG in hypothesis one that is due to the historical change of raising and fronting followed by reversal among the younger speakers happening within the time window examined.

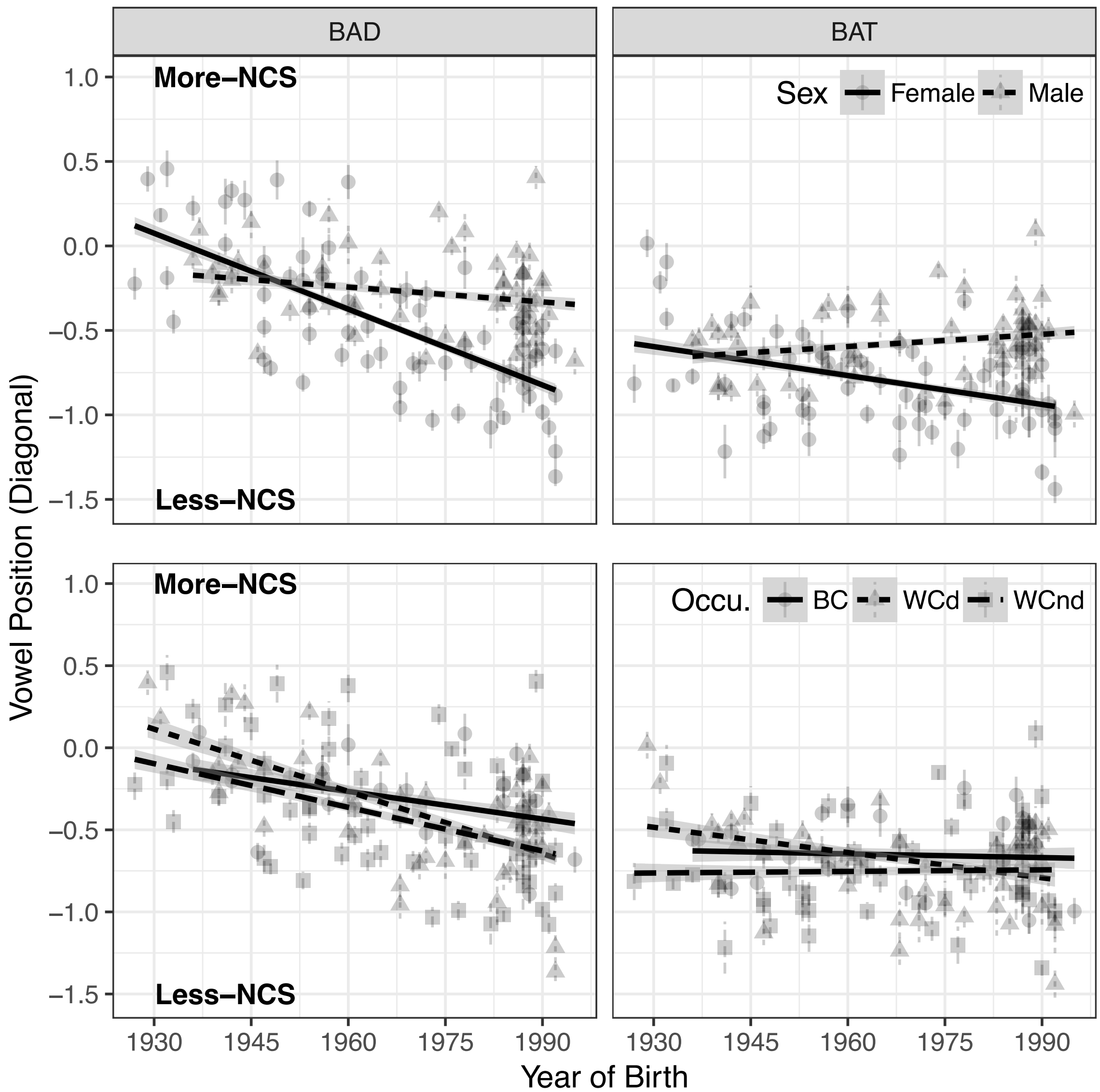

Figure 12: Position BAT for SEX (top) and OCCUPATION (bottom) vowel classes across YOB. Dots are mean and standard deviation by speaker. Lines are linear models fit by vowel class.

The BAT vowel classes show evidence for an interactive effect of SEX_{ij}*$OCCUPATION_{ij}$ on YOB_{ij} while controlling for $TOWN_{ij}$ and HD_{ij} which is strong evidence for hypothesis two. Indeed, the fact that there is more sex-internal differentiation across the age span than cross-sex differentiation is very strong evidence for the operation of latent choice homophily, because ostensibly the most salient social dimension for adolescents is perceived gender.

The occupation one achieves in later life, while correlated with family SES (Blau et al. 1978, 1994), is not a direct measure of the dimension along which latent choice homophily is expected to operate and this could be the reason we see a weaker effect. Indeed, adult occupational status could potentially be used as an indicator for either induced or choice homophily since to a large extent once an individual establishes themselves in a career trajectory, their occupational status would then determine the social ecology they exist in as an adult. However, since an adolescent's parental SES determines the degree to which they are able to display symbols of wealth or opportunities to acquire social and symbolic capital (Bettie 2003; Eckert 1989a; Lareau 2011; MacLeod 2009), this would be expected to be the measure most useful for quantifying the effect of choice homophily.

The results for BOT and BUT are given in Appendix D: $H2M3_{Z2}$ for the former and $H2M8_{Z2}$ for the latter. However, in both models there appears to be a lack of an interaction effect for YOB_{ij}*SEX_{ij}*$OCCUPATION_{ij}$, for BOT because it wasn't in the best model, and for BUT because it does not show an effect in the best model. As such, neither of these models is presented in depth. In both cases this lack of an effect suggests that latent choice homophily does not affect the linguistic similarity between actors within similar social ecologies for these vowel classes. Rather it appears that variation and change in these two vowel classes operates more along the $\text{TOWN}_{ij}*\text{HD}_{ij}$ axis as per hypothesis one.

In sum, both hypothesis one and two are supported in that latent induced homophily was found to affect the linguistic similarity for some vowel classes (BAN and BAG) and dissimilarity for others (BAD, BAT, BACK, BOT, BUT) and latent choice homophily was found to affect all BAT vowel classes but not BOT or BUT. Given the fact that the social factors which have been found to affect vowel changes are expected to be locally specific and embedded within the greater social context, the variability in how homophily operates on each vowel class is in line with both sociolinguistic and Blau-space theory. Indeed, the fact that not every vowel class behaves in the same way speaks to the multidimensionality of language in that not all social phenomena are overtly marked as indicating group membership, but rather can fly under the social consciousness radar and spread through the community through simple geographic proximity and social ecological exposure.

Discussion

The two hypotheses tested whether (1) latent induced homophily (i.e. similarity in the town *i-j* grew up in and their attendance at the same schools) affected linguistic similarity, and (2) latent choice homophily (i.e. *i-j*'s social similarity in terms of SEX and OCCUPATION) had its own effect on linguistic (dis)similarity, net of latent induced homophily. Each of these hypotheses was tested via a set of increasingly complex models with the most complex one coming out as the best model in all cases except BOT in hypothesis two. The evidence presented above shows that for the BAT and BUT vowel classes both latent induced and latent choice homophily affect linguistic similarity, but for BOT only latent induced homophily affects it.

In the case of an adolescents' acquisition of a dialect this means that the towns they grow up in, and the network of schools that they attend (latent induced homophily) are key factors in what linguistic features and changes they are exposed to. The range of others that they are able to choose to associate with is constrained by who is in their social ecology, and the range of linguistic features they are exposed to is constrained by their choice of associates. Thus, dialect features become localized within particular Blau-space locations first through the operation of homophily, and then through the operation of other social mechanisms.

Moving to the Blau-space framework allows for the explicit testing of the social structural mechanism of homophily by examining the ways in which people relate to each other rather than their aggregated characteristics. This relational framework is more in line with how sociological (Bourdieu 1984, 1991) and sociolinguistic (Eckert 2008; Silverstein 2003) theory conceptualizes the location of the (re)construction of social meaning(s). Individuals do not exist within a vacuum, but rather their behaviors are constantly being evaluated by others in context. The reactions – positive and negative – have ramifications for the continuation of any social behavior. While receiving positive feedback would be expected to promote the continuation of a behavior, if it receives negative sanctions an individual has two options: (1) stop the behavior, or (2) find another group of individuals to associate with who do not negatively sanction the behavior. Given this information, individuals are more likely to associate with people like themselves because there is a greater likelihood that if two actors are alike in some dimension – i.e. sociodemographics – they will be alike in other dimensions – i.e. tastes and behaviors (Lewis et al. 2008; Lizardo 2006; Mark 1998, 2003) – due to the fact that social entities localize in networks (McPherson 1983, 2004; McPherson and Ranger-Moore 1991; McPherson and Smith-Lovin 1987; Popielarz and McPherson 1995). Given the above analyses appears to be evidence that such processes affect how language change is socially structured.

Since schools are organized into grades and multiple grades are present in one school, the further apart adolescents are from each other in age is a key factor in how language change is incremented. That is, if one's dialect is mainly ossified during adolescence (Kerswill 1996; Sankoff and Blondeau 2007; Wagner 2008, 2012), and a high degree of social influence is necessary for linguistic conformity between actors *i-j*, then the fact that students move through the school systems in lock step with others their age means they would have less than the necessary exposure to individuals four or more years older than them. That is, older individuals have less social influence on the newer students because they are either institutionally separated by their movement through the K-12 school system or because of their transition from one life stage (adolescence) to another (early adulthood after graduation and beyond). However, in the case where these students have older siblings, there would be influence within the home that needs to be accounted for as another foci of interaction.

Implications for Sociology

The above analysis shows that a Blau-space framework is able to explain the role of homophily as a network mechanism in how dyads relate to each other in linguistic (dis)similarity. Indeed, McPherson (2004) argues that because social phenomena are localized in geographic space and networks of association, these factors must be accounted for before any causal mechanisms surrounding categories such as sex/gender or race/ethnicity can be examined. Without first accounting for simple socio-geographic proximity one cannot tell if an effect of “race” is due to a “race” based process, or if it’s simply proximity. Using bipartite networks is a new approach to teasing these effects apart and should lead to a much more nuanced picture of social processes.

Using foci as a mode in a bipartite network allows for the estimation of latent homophily. While schools are the primary foci that structure the lives of adolescents, there are others which deserve attention such as extra-curricular activities located either within the school (e.g. band, sports, clubs) or outside of it (e.g. boy-/girl-scout, 4H club, summer camps, youth groups). Indeed, McPherson and colleagues' (1991, 1996, 1987, 1995) focuses on these types of voluntary organizations in the lives of adults, specifically how these organizations compete for the time of their members across localized niches in Blau-space. Other productive avenues for study could involve construction of bipartite networks from employment histories and inclusions of university and graduate school attendance in school networks. These could be used in tandem to examine the localization of social phenomena in multiple non-overlapping social ecologies. Moreover, adding length of attendance as a network connection weight would allow for a closer examination of each foci's contribution to the overall effect.

Using more diverse foci in a bipartite network would allow for the examination of a wider range of social phenomena. Using workplace as a mode could help us better understand how and why people move between jobs by including social ecological characteristics of each workplace such as size and socio-demographic diversity. For example, if an individual's current workplace is or becomes ecologically different from themselves then they would be predicted to move to another workplace that is more ecologically similar. This is due to the fact that voluntary organizations recruit others that are similar to those already present (McPherson and Ranger-Moore 1991; McPherson and Rotolo 1996; Popielarz and McPherson 1995). Furthermore, using a bipartite network of workplaces could help tease apart language change effects that occur during adulthood, but this would require longitudinal data.

Lastly, school attendance networks which included university and beyond could be used in tandem with linguistic similarity to examine languages effect on social mobility. That is, since language is a form of cultural capital (Bourdieu 1991), how linguistically similar two people are would be expected to affect each of their conceptions of the other: positively if they are similar and negatively if they are different. However, this would also be expected to be moderated by whether or not one or both of them spoke a stigmatized dialect.

Implications for Sociolinguistics

Research in sociolinguistics has taken one of two tracts: (1) studying the aggregate effects of race, class, and sex/gender on social differentiation of dialect features across age cohorts (i.e. apparent-time) and inferring social processes from those patterns (a la Labov 2001), and (2) examination of the interactional (re)construction of sociolinguistic behavior within what Eckert (2000) calls Communities of Practice (CoP), which are simply groups that form for the purpose of completing or engaging in a particular activity (i.e. similar to foci). The latter posits CoPs as a meso-level mechanism that bridges the gap between the interactional group and the aggregate patterns. While studies that employ this framework (Eckert and McConnell-Ginet 1992; Eckert and Wenger 2005; Mendoza-Denton 2008) do a thorough job of showing how people use language in everyday interactions to do identity work, take stances, and other linguistic behavior, they focus on a particular time and thus cannot say much about historical change. Understanding how daily interactions lead to aggregate patterns and subsequently how these patterns feedback into daily interactions to produce language change requires that we continue to build this theoretical bridge and test its supports with the right kind of data.

Sociolinguistic studies typically utilize an apparent-time framework because of the convenience and utility of age-cohort data sets for studying language across historical time. However, the older an informant is at the time of interview the less reliable their recall about who they associated with during their adolescence is going to be. As such, the accuracy of a reconstructed actor-to-actor network from recall data is dubious at best. Using historical attendance data for the purposes of reconstructing networks of actors-to-schools – and potentially many other types of significant foci – can serve as a useful proxy for network processes that structure the social variation of language. This approach can thus be taken with existing datasets and further tested in other social ecologies.

While previous sociolinguistic network research has shown that bridging ties facilitate diffusion (Ash and Myhill 1986; Cheshire et al. 2008; Milroy and Milroy 1985) and densely connected networks promote the use of local dialect variants (Edwards 1992; Lippi-Green 1989; Milroy and Margrain 1980), how these ties are formed is an important aspect of these mechanisms that is usually underspecified. Indeed, since these studies have used self-reports to construct actor-to-actor networks during their subjects' adult life-stages, the nature of network mechanisms becomes murky due to the questionable correspondence of these networks to the ones important during dialect acquisition. However, the results herein add to our knowledge of social networks' influence on language change by showing how homophily operates to structure language change across apparent-time.

Examining the social ecology in which individuals acquire their dialect does not require research subjects to be followed throughout their life to acquire network data. The use of school attendance records as an estimation of induced homophily alleviates this need while also sidestepping any issues of recall error for older individuals who may not remember the details of who they associated with, but would almost certainly remember which schools they attended. Indeed, since actor-to-actor networks are very dynamic across time and especially during adolescence (Moody, McFarland, and Bender-deMoll 2005), using institutional co-attendance records affords us a view from above the canopy. Moreover, this allows for the easy collection of data on the contexts in which people acquired their dialects, and a social mechanism that supports the building of a bridge interaction and social differentiation. However, future research in this vein needs to pay particular attention to the temporal ordering of variables (a la occupation in this study) so that inferences about the dimensions along which choice homophily is operating are empirically sound.

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APPENDICES

Appendix A: H1M7$_{D}$, the best Approximating Model for the BAT (reference = BAC)

Variable	Estimate	*t*	CI Upper	CI Lower
INTERCEPT	0.26395	5.93854*	0.35107	0.17683
BACK	-0.09191	-1.60416	0.02039	-0.20421
BAD	0.04041	0.70521	0.15271	-0.07189
BAG	0.26038	4.54437*	0.37268	0.14807
BAN	0.13609	2.37520*	0.24839	0.02379
BAT	0.07181	1.25323	0.18411	-0.04050
YOB$_{ij}$	0.00454	2.54776*	0.00804	0.00105
TOWN$_{ij}$	0.02294	0.47463	0.11769	-0.07180
HD$_{ij}$	0.00437	0.66607	0.01723	-0.00849
BACK:YOB$_{ij}$	-0.00039	-0.17042	0.00411	-0.00490
BAD:YOB$_{ij}$	0.00149	0.65019	0.00600	-0.00301
BAG:YOB$_{ij}$	-0.00556	-2.41733*	-0.00105	-0.01006
BAN:YOB$_{ij}$	-0.00856	-3.72239*	-0.00405	-0.01306
BAT:YOB$_{ij}$	-0.00219	-0.95061	0.00232	-0.00669
BACK:TOWN$_{ij}$	0.06001	0.96293	0.18215	-0.06213
BAD:TOWN$_{ij}$	0.00759	0.12175	0.12973	-0.11455
BAG:TOWN$_{ij}$	0.13209	2.11966*	0.25423	0.00995
BAN:TOWN$_{ij}$	-0.03943	-0.63266	0.08271	-0.16156
BAT:TOWN$_{ij}$	-0.07097	-1.13887	0.05117	-0.19311
YOB$_{ij}$:TOWN$_{ij}$	-0.00382	-1.96770*	-0.00002	-0.00763
BACK:HD$_{ij}$	0.01118	1.32166	0.02776	-0.00540
BAD:HD$_{ij}$	0.00170	0.20083	0.01828	-0.01488
BAG:HD$_{ij}$	0.01096	1.29548	0.02754	-0.00562
BAN:HD$_{ij}$	0.00004	0.00454	0.01662	-0.01654
BAT:HD$_{ij}$	-0.00947	-1.11983	0.00711	-0.02606
YOB$_{ij}$:HD$_{ij}$	-0.00041	-1.55565	0.00011	-0.00093
TOWN:HD$_{ij}$	-0.00869	-1.18060	0.00574	-0.02312
BACK:YOB$_{ij}$:TOWN$_{ij}$	0.00007	0.02754	0.00498	-0.00484
BAD:YOB$_{ij}$:TOWN$_{ij}$	0.00039	0.15541	0.00530	-0.00452
BAG:YOB$_{ij}$:TOWN$_{ij}$	0.00264	1.05310	0.00755	-0.00227
BAN:YOB$_{ij}$:TOWN$_{ij}$	0.00763	3.04871*	0.01254	0.00273
BAT:YOB$_{ij}$:TOWN$_{ij}$	0.00170	0.67895	0.00661	-0.00321
BACK:YOB$_{ij}$:HD$_{ij}$	-0.00007	-0.20559	0.00060	-0.00074
BAD:YOB$_{ij}$:HD$_{ij}$	0.00008	0.23127	0.00075	-0.00059
BAG:YOB$_{ij}$:HD$_{ij}$	0.00049	1.44530	0.00116	-0.00018
BAN:YOB$_{ij}$:HD$_{ij}$	0.00104	3.04292*	0.00171	0.00037
BAT:YOB$_{ij}$:HD$_{ij}$	0.00013	0.38363	0.00080	-0.00054
BACK:TOWN$_{ij}$:HD$_{ij}$	-0.00542	-0.57154	0.01318	-0.02402
BAD:TOWN$_{ij}$:HD$_{ij}$	-0.00117	-0.12317	0.01743	-0.01977
BAG:TOWN$_{ij}$:HD$_{ij}$	-0.02313	-2.43780*	-0.00453	-0.04173
BAN:TOWN$_{ij}$:HD$_{ij}$	0.00958	1.00936	0.02818	-0.00902
BAT:TOWN$_{ij}$:HD$_{ij}$	0.01178	1.24178	0.03038	-0.00682
YOB$_{ij}$:TOWN$_{ij}$:HD$_{ij}$	0.00061	2.07783*	0.00119	0.00003
BACK:YOB$_{ij}$:TOWN$_{ij}$:HD$_{ij}$	-0.00002	-0.05979	0.00072	-0.00077
BAD:YOB$_{ij}$:TOWN$_{ij}$:HD$_{ij}$	-0.00005	-0.14266	0.00069	-0.00080
BAG:YOB$_{ij}$:TOWN$_{ij}$:HD$_{ij}$	-0.00046	-1.20513	0.00029	-0.00120
BAN:YOB$_{ij}$:TOWN$_{ij}$:HD$_{ij}$	-0.00123	-3.24317*	-0.00049	-0.00198
BAT:YOB$_{IJ}$:TOWN$_{ij}$:HD$_{ij}$	-0.00018	-0.46202	0.00057	-0.00092

Appendix B: $H1M7_{Z2}$, the best Approximating Model for BOT (top) and BUT (bottom)

BOT	Estimate	SE	*t*-value	CI Upper	CI Lower
INTERCEPT	0.146900	0.013910	10.560*	0.174164	0.119636
YOB_{ij}	0.001340	0.000558	2.401*	0.002434	0.000246
HD_{ij}	-0.005805	0.002054	-2.826*	-0.001779	-0.009831
$TOWN_{ij}$ (Same)	-0.017070	0.015130	-1.128†	0.012585	-0.046725
$YOB_{ij}*HD_{ij}$	-0.000060	0.000083	-0.717	0.000103	-0.000222
$YOB_{ij}*TOWN_{ij}$	-0.001168	0.000608	-1.921*	0.000024	-0.002360
$HD_{ij}*TOWN_{ij}$	0.001685	0.002304	0.731	0.006201	-0.002831
$YOB_{ij}*HD_{ij}*TOWN_{ij}$	0.000176	0.000092	1.909†	0.000357	-0.000005
BUT	Estimate	SE	*t*-value	CI Upper	CI Lower
INTERCEPT	0.089750	0.010630	8.444*	0.110585	0.068915
YOB_{ij}	0.001786	0.000426	4.189*	0.002622	0.000950
HD_{ij}	-0.000522	0.001569	-0.333	0.002553	-0.003598
$TOWN_{ij}$ (Same)	0.009969	0.011560	0.862	0.032627	-0.012689
$YOB_{ij}*HD_{ij}$	-0.000185	0.000063	-2.915*	-0.000061	-0.000309
$YOB_{ij}*TOWN_{ij}$	-0.001581	0.000465	-3.404*	-0.000671	-0.002491
$HD_{ij}*TOWN_{ij}$	-0.003431	0.001760	-1.949†	0.000019	-0.006881
$YOB_{ij}*HD_{ij}*TOWN_{ij}$	0.000284	0.000071	4.031*	0.000422	0.000146

Appendix C: H2M8$_D$, the best Approximating Model for the BAT (reference = BAC)

Variable	Estimate	SE	*t*-value	CI Upper	CI Lower
(Intercept)	0.34036	0.01184	28.742*	0.36357	0.31715
TOWN$_{ij}$	-0.02368	0.00380	-6.234*	-0.01623	-0.03112
HD$_{ij}$	0.00079	0.00104	0.760	0.00284	-0.00125
BACK	-0.02960	0.01238	-2.390*	-0.00533	-0.05387
BAD	0.05238	0.01238	4.230*	0.07665	0.02811
BAG	0.30065	0.01238	24.281*	0.32492	0.27639
BAN	0.08200	0.01238	6.623*	0.10627	0.05773
BAT	0.01675	0.01238	1.353	0.04102	-0.00752
YOB$_{ij}$	0.00008	0.00035	0.232	0.00077	-0.00061
SEX$_{ij}$	-0.09647	0.01377	-7.003*	-0.06947	-0.12347
OCU$_{\cdot ij}$	-0.01491	0.01617	-0.922	0.01678	-0.04659
BACK:YOB$_{ij}$	-0.00026	0.00046	-0.571	0.00063	-0.00115
BAD:YOB$_{ij}$	0.00162	0.00046	3.561*	0.00251	0.00073
BAG:YOB$_{ij}$	-0.00122	0.00046	-2.680*	-0.00033	-0.00211
BAN:YOB$_{ij}$	0.00043	0.00046	0.937	0.00132	-0.00047
BAT:YOB$_{ij}$	-0.00082	0.00046	-1.792	0.00008	-0.00171
BACK:SEX$_{ij}$	0.04536	0.01780	2.548*	0.08025	0.01047
BAD:SEX$_{ij}$	-0.01865	0.01780	-1.048	0.01624	-0.05354
BAG:SEX$_{ij}$	0.03576	0.01780	2.009*	0.07065	0.00087
BAN:SEX$_{ij}$	0.11657	0.01780	6.548*	0.15146	0.08168
BAT:SEX$_{ij}$	-0.01951	0.01780	-1.096	0.01538	-0.05440
YOB$_{ij}$:SEX$_{ij}$	0.00245	0.00051	4.802*	0.00345	0.00145
BACK:OCU$_{\cdot ij}$	-0.01684	0.02089	-0.806	0.02410	-0.05779
BAD:OCU$_{\cdot ij}$	0.01839	0.02089	0.880	0.05934	-0.02255
BAG:OCU$_{\cdot ij}$	0.01171	0.02089	0.561	0.05266	-0.02923
BAN:OCU$_{\cdot ij}$	0.08624	0.02089	4.128*	0.12719	0.04530
BAT:OCU$_{\cdot ij}$	-0.00933	0.02089	-0.447	0.03161	-0.05028
YOB$_{ij}$:OCU$_{\cdot ij}$	0.00055	0.00060	0.917	0.00173	-0.00063
SEX$_{ij}$:OCU$_{\cdot ij}$	0.00027	0.02245	0.012	0.04427	-0.04373
BACK:YOB$_{ij}$:SEX$_{ij}$	-0.00102	0.00066	-1.545	0.00027	-0.00231
BAD:YOB$_{ij}$:SEX$_{ij}$	0.00127	0.00066	1.928	0.00256	-0.00002
BAG:YOB$_{ij}$:SEX$_{ij}$	-0.00156	0.00066	-2.364*	-0.00027	-0.00285
BAN:YOB$_{ij}$:SEX$_{ij}$	-0.00342	0.00066	-5.190*	-0.00213	-0.00471
BAT:YOB$_{ij}$:SEX$_{ij}$	0.00019	0.00066	0.282	0.00148	-0.00111
BACK:YOB$_{ij}$:OCU$_{\cdot ij}$	0.00014	0.00078	0.181	0.00167	-0.00139
BAD:YOB$_{ij}$:OCU$_{\cdot ij}$	-0.00062	0.00078	-0.794	0.00091	-0.00215
BAG:YOB$_{ij}$:OCU$_{\cdot ij}$	-0.00024	0.00078	-0.314	0.00128	-0.00177
BAN:YOB$_{ij}$:OCU$_{\cdot ij}$	-0.00264	0.00078	-3.390*	-0.00111	-0.00417
BAT:YOB$_{ij}$:OCU$_{\cdot ij}$	0.00050	0.00078	0.637	0.00202	-0.00103
BACK:SEX$_{ij}$:OCU$_{\cdot ij}$	0.01250	0.02901	0.431	0.06936	-0.04436
BAD:SEX$_{ij}$:OCU$_{\cdot ij}$	0.00720	0.02901	0.248	0.06405	-0.04966
BAG:SEX$_{ij}$:OCU$_{\cdot ij}$	0.04810	0.02901	1.658	0.10496	-0.00875
BAN:SEX$_{ij}$:OCU$_{\cdot ij}$	-0.15767	0.02901	-5.435*	-0.10082	-0.21453
BAT:SEX$_{ij}$:OCU$_{\cdot ij}$	0.03342	0.02901	1.152	0.09027	-0.02344
YOB$_{ij}$:SEX$_{ij}$:OCU$_{\cdot ij}$	0.00130	0.00083	1.559	0.00293	-0.00033
BACK:YOB$_{ij}$:SEX$_{ij}$:OCU$_{\cdot ij}$	-0.00050	0.00108	-0.461	0.00161	-0.00261
BAD:YOB$_{ij}$:SEX$_{ij}$:OCU$_{\cdot ij}$	-0.00003	0.00108	-0.024	0.00208	-0.00214
BAG:YOB$_{ij}$:SEX$_{ij}$:OCU$_{\cdot ij}$	-0.00231	0.00108	-2.143*	-0.00020	-0.00442
BAN:YOB$_{ij}$:SEX$_{ij}$:OCU$_{\cdot ij}$	0.00276	0.00108	2.565*	0.00487	0.00065
BAT:YOB$_{ij}$:SEX$_{ij}$:OCU$_{\cdot ij}$	-0.00246	0.00108	-2.288*	-0.00035	-0.00457

Appendix D: The best approximating models, $H2M3_{Z2}$ for BOT and $H2M8_{Z2}$ for BUT

BOT ($H2M3_{Z2}$)	Estimate	SE	*t*-value	CI Upper	CI Lower
INTERCEPT	0.13150	0.00437	30.096*	0.14006	0.12294
$TOWN_{ij}$	-0.00665	0.00216	-3.073*	-0.00241	-0.01089
HD_{ij}	-0.00317	0.00059	-5.339*	-0.00201	-0.00434
YOB_{ij}	0.00090	0.00006	14.213*	0.00103	0.00078
$OCCUPATION_{ij}$	-0.00363	0.00209	-1.736	0.00047	-0.00773
BUT ($H2M8_{Z2}$)	Estimate	SE	*t*-value	CI Upper	CI Lower
INTERCEPT	0.13210	0.00498	26.512*	0.14186	0.12234
$TOWN_{ij}$	-0.00677	0.00217	-3.125*	-0.00252	-0.01101
HD_{ij}	-0.00319	0.00059	-5.372*	-0.00203	-0.00436
YOB_{ij}	0.00087	0.00011	7.834*	0.00109	0.00065
SEX_{ij}	-0.00173	0.00433	-0.400	0.00675	-0.01022
$OCCUPATION_{ij}$	-0.00428	0.00508	-0.841	0.00569	-0.01424
YOB_{ij}:SEX_{ij}	0.00011	0.00016	0.694	0.00043	-0.00020
YOB_{ij}:$OCCUPATION_{ij}$	-0.00012	0.00019	-0.622	0.00025	-0.00049
SEX_{ij}:$OCCUPATION_{ij}$	0.00364	0.00706	0.516	0.01748	-0.01020
YOB_{ij}:SEX_{ij}:$OCCUPATION_{ij}$	0.00010	0.00026	0.363	0.00061	-0.00042

ENDNOTES

[i] Chain shifts happen in stages progress in order, i.e., only after vowel **A** moves (first stage) into the space of vowel **B** can the latter move (second stage) into the space of vowel **C.**

[ii] Sound capture for thirty-one of the respondents was performed via an Andrea Anti-Noise monaural headset microphone (ANC-700) connected directly to a laptop computer using Praat (Boersma and Weenink 2013) at a sampling rate of 22.05 kHz and 16-bit depth. The other one hundred and one respondents were recording via an Audix HT5 headset microphone connected to a Sound Devices USBPre2 digitizer and pre-amplifier which was connected to a laptop PC running Audacity sampling at 44.1kHz and 16-bit depth.

[iii] Linear predictive coding analysis (LPC) was used with default filter orders, 12 for males and 11 for females, with adjustments of ± 2-3 from the default being done until a filter order was obtained that produced the most accurate F_1/F_2 tracings.

[iv] While occupation could be considered a determinant of either induced or choice homophily it is used herein as an indicator of choice homophily because the way it's measured it lacks a corresponding physical space. It is different from school co-attendance and town in this way because it is coded based on supra-local criteria (i.e. Standard Occupational Codes). If it measured the actual location of an individual's place of work, then it could be conceptualized as a measure of induced homophily.

[v] Measuring adult occupational status is a poor operationalization of a dimension for choice homophily in adolescence due to the fact that it is not directly related to the SES they had in their families at that time. This measure is used because parental SES affects a child's eventual occupational attainment.