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LANGUAGE IDEOLOGIES, BORDER EFFECTS, AND DIALECTAL VARIATION: EVIDENCE FROM /æ/, /aʊ/, AND /aɪ/ IN SEATTLE, WA AND VANCOUVER, BC

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Abstract

Previous studies of border regions have characterized linguistic divergence as a natural consequence of the social psychological and cognitive processes speakers apply in constructing their conceptualizations of the border and those on the other side (Auer 2005). For the border shared by Canada and the United States, in particular, Boberg (2000) highlights a resistance to the diffusion of sound change across the national border. While providing some valid descriptions, these assessments neglect the multi-faceted social function of language to both unite and distinguish speakers and social groups. They also ignore the potentially important role of cultural affinity and regional solidarity spanning a national border. As Irvine & Gal (2000) explain, ideological processes that serve to project contrasts occur recursively and simultaneously with processes that ideologically erase other contrasts at different levels of the system. These ideological processes have consequences for linguistic structure and for sound change. With its strong regional solidarity spanning the U.S.-Canadian border and lack of previous trans-border comparisons in the region, the Pacific Northwest is an ideal site to examine the effects of these ideological processes.

Despite the geographic proximity and cultural similarities of Vancouver, B.C. and Seattle, WA, few studies have directly compared their speech (see Sadlier-Brown 2012 for one exception). The Atlas of North American English (Labov, Ash, & Boberg 2006) describes the difficulty of differentiating “the West” as a dialect region from “Canada” and concludes that this must be done on the basis of their degrees of participation in similar sound changes. The ANAE relies on single time-point measurements for vowels, however, and does not examine variation in dynamic formant trajectories across the dialects, though these have been shown to differentiate

dialects and ethnolects in previous work (Janson & Schulman 1983, DeDecker & Nycz 2006, Fox & Jacewicz 2009, Jacewicz & Fox 2012, Scanlon & Wassink 2010, Koops 2010, Risdal & Kohn 2014). Prior research in B.C. has focused on the region's participation in features of the Canadian Shift such as /æ/ retraction and its questionable participation in raising of /aɪ/ and /aʊ/ (Chambers 1973, Esling & Warkentyne 1993, Hall 2000, Sadlier-Brown & Tamminga 2008, Boberg 2008, Pappas & Jeffrey 2014). These studies of Vancouver vowels have relied on single-point measurements. In Seattle, on the other hand, research primarily documents pre-velar raising of /æ/ before /g/ (Wassink 2009, Freeman 2013, Riebold 2012, 2014 and 2015). No large-scale studies have compared these features between Vancouver and Seattle speakers using dynamic methods.

With 29,372 audio-recorded vowel tokens collected via a word list reading task from a gender and age-balanced sample of 20 Seattle and 19 Vancouver speakers, the current study provides a variationist sociophonetic analysis of speakers' participation in five diagnostic dialectal features of Seattle English and Vancouver English: pre-velar /æ/ raising, pre-nasal /æ/ raising, /æ/ retraction, and the "Canadian" raising of diphthongs /aɪ/ and /aʊ/. Measurements for the current study were extracted at five duration-proportional points and comparisons of formant trajectories were included in the mixed-effects linear regression models for each diagnostic dialect feature. In addition, sociocultural interviews were conducted with each participant to better understand the speakers' orientations toward their regional and national identity as well as the cultural and linguistic ideologies they embraced. The study also considers variation between two emically-defined age groups of young adult speakers.

The results suggest that Seattle and Vancouver speakers are participating in some of the same allophonic processes, like /æg/ raising, but they are also differentiated by other processes including /æn/ raising, /æ/ retraction, /aʊ/ raising, /aɪ/ raising. In these cases, the distinction between Seattle and Vancouver relates to the degree to which a phonetic process has been phonologized, and this distinction can most accurately be captured in the phonetic form of the feature using dynamic analyses. Seattle and Vancouver speakers are also found to embrace asymmetrical language ideologies, and these act as a predictor of their linguistic behavior for features undergoing sound change. In addition, variation between the two emically-defined age groups highlights the differential use of sociolinguistic resources by speakers within the same broader age group of "adult" speakers. This research sheds light on the relationship between phonetic form, sound change and socio-indexical meaning. It also documents the variation within a less studied dialect region divided by a national border and offers a realistically complex view of the simultaneous solidarity and differentiation of identity embodied by its inhabitants.

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Chapter 1

1 INTRODUCTION

1.1 Linguistic and Cultural Convergence at the Border?

Boberg (2000) and Chambers (1998) both describe what they both view as explicit rejection of American standards by Canadian speakers throughout the 19th and 20th centuries. As Boberg puts it, the role of the political border as a corresponding linguistic boundary is “not a trivial question” (Boberg 2000). Given the expanse of American Canadian contact, this differentiation occurs differently throughout the regions and Provinces from East to West. Linguistic and cultural convergence with the U.S. has been a major concern among Canadian scholars for decades. Numerous studies have been conducted regretting the (possible) loss of distinctively Canadian features (Zeller 1993, Woods 1993, Chambers 1998, Nylvek 1992, Warkentyne 1971 and Scargill 1957 & 1974). Zeller (1993) describes the asymmetrical use of American and Canadian lexical items by border residents spanning from Toronto to Milwaukee, where Canadians are more likely to have knowledge and awareness of the American term than vice versa. Nylvek (1992) illustrates an increase in American as opposed to traditionally British pronunciations of a 10-word set of lexical alternations among speakers in Saskatchewan. As Walker (2015) observes, many of these studies depend on lexical variation, which seems to operate differently than systemic phonetic or phonological change. Chambers (1998) calls into question whether younger generations are engaging in Canadian Raising while observing that Canada, like other countries, increasingly participates in a multinational economy with a decentralized national government and internationally shared cultural heroes. These studies have indeed predicted that Canadian pronunciations are becoming more Americanized and that the patterns of variation observed in Canadian English will eventually give way to convergence with the most local U.S. dialect.

1.1.1 Resistance to phonetic and phonological change spanning the border

In reality, the situation may be structurally and socially more complex than this view conveys. While some researchers have cited cases of "convergence" across the U.S.-Canadian border, others have highlighted a resistance to convergence on the basis of resistance to sound change diffusion. Boberg (2000) addresses the issue of geolinguistic diffusion across the U.S.-Canadian border and finds that some phonological changes may be less likely to be shared across the border than others. Boberg takes a critical approach to showing how Trudgill's hierarchical gravity model for linguistic diffusion fails to account for the non-diffusion of a phonological feature spanning a national border. The model is given below:

$$I_{ij} = S \bullet ((P_i P_j) \div (d_{ij})^2) \bullet (P_i \div (P_i + P_j))$$

I_{ij} = Influence of center i on center j
P = population
S = index of linguistic similarity
d = distance

Equation 1. SOURCE, Trudgill 1974 implemented in Boberg 2000

The model has independent variable terms for the size of two cities, the distance between them, and their linguistic similarity. The influence of any one urban center *i* on another urban center *j* is a function of these three terms. Thus, Trudgill's gravity model predicts that larger and closer cities generally have a more substantial impact on nearby, smaller cities and that cities with greater linguistic similarity are more likely to impact each other. There are no terms here making reference to the national border or the cultural affinity of one city for the other. In his implementation, Boberg (2000) calculates an index for the influence of various U.S. cities on Canadian ones and vice versa as well as the impact of Canadian cities on other Canadian cities. In this schema, Detroit, MI is expected to have a huge impact on Windsor, ON given that they are very close together, have very frequent contact, and that Detroit is a much larger city. The Gravity Model calculates an index of influence of 3,976,200.0 for Detroit on Windsor, which is more than 15,000 times larger than the second largest index of influence identified by the model (the influence of New York City on Montreal at 255.0). Clearly, the enormous index predicted by the model for Detroit's influence on Windsor makes it a noteworthy case as compared to the various other trans-border city pairs for which Boberg calculates an index where the influence of one city on the other is expected to be more moderate. For instance, compared to the enormous index of influence for Detroit and Windsor (3,976,200.0), Seattle's influence on Vancouver is expected calculated to be 194.7, though Boberg does not investigate phonological diffusion for Seattle and Vancouver. With such a large index of influence, it seems that Windsor would necessarily be impacted by sound changes in progress taking place in Detroit. Boberg (2000) selects a feature of the well-documented Northern Cities Shift (raised /æ/) taking place in Detroit as a phonological shift to test for diffusion of the feature across the border. The model's prediction that Detroit sound changes should overwhelmingly impact Windsor sound changes, however, does not make accurate predictions given the lack of diffusion of raised /æ/ Boberg observes in Windsor. Boberg accounts for this by observing that the internal phonological structure of the vowel system has a huge impact as a gatekeeper for diffusion of phonetic features, such as the /æ/ split system.

Boberg does consider one other feature in multiple trans-border city pairs, aside from Detroit and Windsor, but the feature he looks at exhibits variation within a specific lexical class.

When examining the convergence between cross-border city pairs throughout other regions based on use of the /aː/ or /æ/ in foreign loan words (e.g. *pasta* as /pʰaːstə / or /pʰæstə/, on the other hand, he finds greater evidence of phonetic sharing. Overall, Boberg's findings emphasize that frequency of cross-border contact is not a significant predictive factor in accounting for diffusion of phonetic features and that the underlying similarity of the vowel systems in the city pairs (regardless of national border) is a more important factor to consider in diffusion.

In his study, data from Seattle and Vancouver were considered only with respect to the /aː/ or /æ/ in foreign loan words. Among Boberg's 54 pairs of cities, the influence of Seattle on Vancouver ranks as the fourth greatest based on the gravity model, still predicting roughly 20,000 times less influence for Seattle on Vancouver than Detroit on Windsor. Boberg makes a noteworthy observation that older generations of speakers in Seattle and Vancouver show less difference in terms of their rates of /aː/~/æ/ usage than older speakers in cross-border city pairs in the Midwest and Eastern parts of the continent. He attributes this to the similarity and recency of settlement patterns in West. Boberg (2000) emphasizes the similarity of dialects in the northwest: "...the phonological systems of western Canada and the northwestern United States are identical, and the phonetics are very similar." (p.15) Research subsequent to his writing has continued to identify phonetic variation within the West, but taking Boberg's (2000) observation at face value, Seattle and Vancouver would be more likely to share phonetic features than Detroit and Windsor, for instance.

Boberg's study does have some important limitations: First of all, the study singles out only Detroit and Windsor to test the spread of phonological features. Additionally, the data are constructed from a very small number of speakers (only 2 speakers for Windsor, who are both middle-aged). Another limitation of the study is that it uses means based presumably on midpoint vowel measurements only, not considering vowel-inherent spectral change or temporal properties of the vowels in question, which would allow a more thorough view of the vowel patterns. Boberg also notes that the attitudes and speakers' evaluative assessments to diffusion have also been left unaddressed by this work. Since his work, however, no large-scale investigations have examined the sharing of phonetic or phonological dialect features across the U.S.-Canada border the West Coast, so his hypothesis remains at least partially untested.

Here, the current work serves to fill an empirical gap. Are the phonologies of Vancouver and Seattle really "identical" as Boberg says? How similar are their phonetic systems upon closer inspection? Furthermore, is resistance to the diffusion of linguistic change a necessary outcome of a national border? Boberg puzzles over the fact that the Eastern sections of the U.S.-Canadian border are flanked by greater dialectal differences while the dialects flanking the Western stretches of the border witness greater similarity, precisely the *opposite* of what the gravity model would predict. His proposed account for this is primarily historical. While historical settlement patterns certainly play a part, Boberg's approach overlooks a critical factor in the issue at hand: speakers' ideologies about language. This dissertation will first take a critical view of the phonologies and phonetics of Canadian and American dialects in the Pacific Northwest, followed by an exploration of language ideologies and how these affect linguistic behavior. Accordingly, the remainder of this chapter introduces a problematization of Pacific Northwest dialects of English followed by theoretical approaches to border effects and a framework for language ideologies set forth by Irvine & Gal (2000). Finally, predictions will be made based on this model for the Pacific Northwest, and a specific set of research questions will be enumerated at the close of the chapter.

1.1.2 Dialects of English in the Pacific Northwest

The Pacific Northwest is a relatively understudied linguistic area and studies of how the trans-border regional identity relates to language have not been conducted. The notion of "the West" as defined by the Atlas of North American English (Labov, Ash & Boberg 2006) is problematic in itself as this grouping fails to describe potential variation throughout a geographically expansive region. Large-scale studies explicitly comparing the speech of B.C. speakers to that of Washington State speakers are non-existent. In addition, the previous studies that do exist have focused on different phonetic features in one population or the other and employed discrepant methodologies, making comparison even more difficult. To summarize, prior research in B.C. has focused on the region's participation in features of the Canadian Shift such as /æ/ retraction and its questionable participation in raising of /aɪ/ and /aʊ/ (Chambers 1973, Esling and Warkentyne 1993, Hall 2000, Sadlier-Brown and Tamminga 2008, Boberg 2008, Pappas and Jeffrey 2014). In Seattle, on the other hand, prior research documents primarily the pre-velar raising of /æ/ before /g/ and the variable use of this phonetic feature by speakers from different ethnic backgrounds (Wassink 2009, Freeman 2013, Riebold 2012, 2014 & 2015). The literature for previous studies of Vancouver and Seattle English respectively and the justification for the selection of phonetic features under consideration here will be discussed more extensively in Chapter 2.

1.1.3 Origins of dialectological studies: nationalism and language

While embarking on this investigation about the role of the border and language ideologies in dialectology, it is relevant to keep in mind the origins of dialectological inquiry. Having arisen in nationalist-focused Europe during the 1800s and early 1900s, dialectological studies were largely born to a mindset that one nation state requires one national language and that the inverse should also hold: one national language should correspond to one nation-state, a bounded political entity. Language provides a symbol of nationalist drive; a singular standard language can provide justification for the inclusion of certain territories or the exclusion of others. Early dialectological studies in France and Germany, for instance, focused on identifying regional dialects and unifying these "dialectal" speakers. A war was waged against speakers of *patois* in France in favor of forcing these speakers of regional dialectal varieties to embrace *français standard* (Walter 1988, Lapierre 1988, Hagège 2002). In this historical and cultural context, there were high stakes for the success of the one language = one nation-state approach. Furthermore, with the emergence of nation-states whose geo-political boundaries spanned relatively small areas, the question of distinguishing one's country and national identity became even more vital. How might a geographically smaller and less numerous country such as Luxembourg, Lichtenstein, or even Switzerland avoid being completely overtaken by one of its larger and more powerful neighbors like France or Germany? On the other hand, how might it gain and retain the support of one of its larger neighbors to find protection on a more global scale? Language provided a symbolic cultural tie, and simultaneously, a differentiator.

The crucial link between nationalism and language has been embodied by numerous nation-states in settings outside of WWI-era Europe and observed by scholars from a variety of backgrounds. The conflict in the Balkans, for example, has yielded many observations about the power dynamics realized through language among competing ethnic and nationalist groups. Friedman (2012) describes attempts by the nationalist Greeks in the 19th century to eliminate all other languages spoken by Orthodox Christians in the then Ottoman Empire in favor of Greek. He describes further a piece of public signage in Greece from the 1950s that forbade the use of Aromanian and Macedonian. Language has its very foundation in these social functions and has long been used to foster in-group solidarity while serving as a gate-keeper against members of the out-group (Bourdieu 1991, Gal & Irvine 1995). Simply put, this nation-state political and cultural drive set the tone for the earliest dialectological studies, and it continues to set the tone for theoretical formulations about the way national borders affect language attitudes and speech behaviors.

1.1.4 Border dynamics post-globalization

On the other hand, scholars have increasingly pointed out the misconceptualization this yields when applied to modern border dynamics. With the rapid and recent development of technologies that allow for non-stop and nearly boundless information exchange, scholars have described border relationships as 'borderless' and fluid (Ohmae 1999). Globalization has transformed the mixture of cultures and peoples throughout the world and made ideas, information, and cultural icons accessible across national and geographic boundaries. Smith (2004) summarizes a variety of post-modern approaches to borders, which are united by the common purpose of articulating the increased fluidity of borders post-globalization. Terms like "transnationalism," "denationalization," and "glocalism" capture these ideas (O'Dowd 2002, Sassen 2000, Harmsworth 2001, respectively). Economists and policy experts have focused on the exchange of goods, people, and information between urban centers, potentially spanning geo-political borders. Does this mean that borders are no longer relevant? Do they cease to describe and encapsulate legitimate cultural or linguistic differences between the sides that they divide? If media from any particular culture and communicative exchange with members of another culture are now available for consumption by anyone on the opposite side of the border, does this suggest that borders no longer have an effect on the exchange of language and culture?

Geopolitical borders, then, present a fascinating locus of inquiry. While especially in a modern information-exchange society, they must be viewed as ideologically, culturally, and linguistically "leaky", to borrow V. Friedman's language, their very existence seems to trigger a social psychological process that cyclically reinforces and justifies their existence. S. Friedman (2007) describes the multi-faceted ideological and concrete purposes of borders:

> *Borders are fixed and fluid, impermeable and porous. They separate but also connect, demarcate but also blend differences... Borders are used to exercise power over others. They regulate migration, movement, travel, the flow of people, goods, ideas, and cultural formations of all kinds... They insist on purity, distinction, difference but facilitate contamination, mixing, creolization.* (S. Friedman 2007, p.273)

She describes *borderlands* as regions (e.g. the Balkans, Alsace-Lorraine, Israel-Palestine, etc.) whose histories and cultural developments have been characterized by a complex intermingling of different ethnic, religious or nationalist groups. These borderlands, as the enumerated examples illustrate, are often rife with contentious violence or ethnic tension that persists for centuries. Clearly, ethnolinguistic justifications for geo-political sovereignty are not an unfamiliar issue for Canadians, given the ongoing movement in Quebec, but the *borderland* notion seems much less applicable to the region surrounding the present-day Canadian-U.S. border in the West.

1.1.5 The U.S. – Canadian border in the West

The U.S.-Canadian border is a cultural and historical contrast to the European nation-state fixation and to the notion of *borderland* elaborated above by S. Friedman. The settlement patterns of the Canadian and American West, in particular, have allowed for significant exchange and overlap throughout the region's history. During much of the 19th century, British Columbia and Washington State were co-participants in an economy defined by the Hudson Bay

Company. As Boberg (2000) points out, the phonetic and phonological differences between Western Canadian dialects and Western U.S. dialects seem to begin with fewer differences than their respective Eastern counterparts. Walker (2015) comments on the observed homogeneity of regional varieties of Canadian English extending throughout the West explaining that this is likely due to the rapid and relative recent settlement of the territory during the later 19th century. The social dynamics of the U.S.-Canadian border are certainly different than the borders of many European nations and also differ between the Western and Eastern parts of the North American continent. This is not to say that Canadians and Americans at any point along the border view themselves as culturally or linguistically identical, nor is it meant to imply that the social dynamics surrounding the border are monolithic across 5,000 miles it stretches. On the contrary, each border region must be assessed independently and the border effects of that particular region considered as unique as the socio-historical factors they represent.

1.1.6 "Cascadia" and the U.S.-Canadian border in the Pacific Northwest

Perhaps at no other point along the U.S.-Canadian border do regional identity, attitudes and policy become as meaningful and relevant as on the West border between Washington State and British Columbia. In the West, a strong regional identity spans the national border in direct contrast to the tension and animosity present in other border regions described. If volumes have been authored on the contentious and violent borderlands worldwide which are characterized by the ethnic conflict S. Friedman describes, equally impressive is the body of work proposing Cascadia as the ideal candidate for a move toward trans-national policies and a trans-border regional identity (Alper 1996, Cold-Ravnkilde, Singh, & Lee 2011, Smith 2004). Cascadia has been described as a reference case for "the neo-liberal vision for a trans-border region" (Sparke 2000). In an economic climate where urban centers are increasingly the key players, Seattle and

Vancouver are both recognized as important tone-setters for policies within the region. After considering how policies and practices adopted by each city have fostered trans-border regionalism, Smith (2004) concludes that:

> *Whether it is neo-liberal activists working to omit the border or bio-regionalists seeking to use it to lever better sustainability, the urban Cascadia links are clear and present. That, combined with the growth of more specific Cascadia activity—at the state/provincial and municipal levels—supports the notion of an emerging cross-border region—with city- regions at their core.* (Smith 2004, p. 116)

"Cascadia" is a concept that spans public consciousness as well as academic domains. The strong unity among Pacific Northwesterners south and north of the Canadian border has received the attention of grass roots social organizers, authors and other popular culture commentators. The *Cascadia Now!* Cascadian Independence Project argues that on the basis of shared geographic, climatic, economic, and cultural identity, the bioregion extending from British Columbia through Washington State and into Oregon should play host to transparent and collaborative policies, and ultimately, be recognized as a sovereign and independent entity.[1] Bumper stickers and t-shirts are commonly observed in Seattle with slogans like "Free Cascadia!" or with images of the Cascadia flag and one of the region's fictitious mascots: Sasquatch or perhaps the Pacific Northwest Tree Octopus, invented by Internet satirist, Lyle Zapato[2]. These folk artifacts highlight the salient sense of regional identity and its foundational elements of shared ecosystem and environmental activism throughout the Cascadia region.

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[1] http://cascadianow.org
[2] http://zapatopi.net/treeoctopus/

1.2 Language Ideologies

1.2.1 Social psychological and cognitive processes of differentiation

Despite this attested regional solidarity, the growing consensus among sociologists and anthropologists even post-globalization is that borders seem to *cause* as much differentiation as they *demarcate* (Bourdieu 1991, Gal & Irvine 1995, Irvine & Gal 2000, Auer 2002.) With a focus on the structural outcomes for language, Auer (2005) invokes a cognitive spatial theory to account for numerous cases of linguistic divergence across a national border between Germany and its neighboring nation-states.

> *It is the cognitive-mental act of construing those on the other side of the border as being different from those within one's own social group (nation) that has an effect on language.* (Auer 2005, p. 13)

Gal & Irvine (1995) likewise emphasize the important notion of contrast:

> *First, we focus not on the general social embeddedness of language, but on the construction of linguistic contrast and difference. This we argue, cannot be understood without a study of the ideas about social and linguistic difference held by socially-positioned speakers. Thus, our perspective directs attention to the ideological aspects of linguistic differentiation: the ideas with which participants frame their understanding of linguistic varieties and the differences among them, and map those understandings onto people, events, and activities that are significant to them.* (Gal & Irvine 1995, p. 970)

1.2.2 Theories of the ideological construction of difference

While Auer's (2005) description of dialect divergence on the basis of perceived differences at the border encompasses one important type of ideological process, it fails to recognize that ideologies of perceived difference *and* perceived sameness coexist and are applied in real time throughout different levels of the linguistic system. Gal and Irvine's (1995)[3] system captures the realistic complexity of ideological processes based on both perceived difference and perceived similarity. Gal (forthcoming) likewise emphasizes that similarity and difference are flip sides of the same coin and that both are vital in sociolinguistic differentiation. The processes of *iconicity, recursivity,* and *erasure* proposed in Irvine & Gal (2000) are especially well-suited for modeling the ideological construction of difference between speakers from different nationalities and the simultaneous ideological construction of sameness based on the unique solidarity of the Pacific Northwest region. Gal & Irvine (1995) and Irvine & Gal (2000) remind readers that meta-processes of dialect differentiation are inherently framed by the observers' beliefs and ideological processes, whether he or she is a participant (speaker) of the dialect in question or not. They illustrate that these ideological processes, engaged in by speakers and linguists carrying out observations, have structural consequences for language.

The foundational semiotic process in the development of socioindexical meaning development is *iconicization* in which a linguistic form or variety becomes representative of a group. In this process, the form is thought to represent a certain social image or qualities of the group. The subsequent semiotic processes operate on these established *iconic* forms. A process called *fractal recursivity* involves a conceived opposition based on existing or perceived difference. This difference, which may occur at the level of intergroup difference such as based on national identity or intragroup speaker variation, is then projected from one level of the system to another. For instance, this ideology of perceived differences might cause acoustic differences to be perceived when they do not exist as in the case of Niedzielski 1999. Finally, a

[3] The system was introduced in Gal & Irvine, though further elaborated in Irvine & Gal (2000). Reference here is to the work in which these first appeared, though the reader is directed to both for a complete discussion.

process of *erasure* causes linguistic observations or realities not fitting with the ideology to go unperceived. In this sense an existing sociolinguistic variation may be imagined away.

To illustrate these processes, Irvine & Gal (2000) draw from an example of phonological borrowing in southern Africa. In this case study, accounting for how clicks were borrowed into Nguni (Bantu) languages from the indigenous Khoi languages, the ideological processes of *recursivity* and *erasure* co-exist. For Nguni speakers, the clicks they overheard in Khoi were an iconic representation of foreignness and social distance as they manifested an inter-group contrast between the Nguni and the Khoi. This contrast was projected onto a different level of the system when they were then borrowed into Nguni to serve a similar purpose of creating social distance within the Nguni group. These non-native clicks entered the Nguni language via avoidance register in which speakers avoid pronouncing sound sequences that exist in the names of respected people. (The proto-typical social image for this process offered by speakers is the daughter-in-law who cannot speak her father-in-law's name.) Irvine & Gal (2000) explain that the use of clicks in deferential avoidance speech by the Nguni also embodies the perceived deference of the Khoi to them, based on their social domination. Interestingly, though processes of *erasure* are also evident in this case. While it is ideologically held that this linguistic variation is due to the deferential role women must play to their father-in-laws, this view actually ignores use of avoidance register by men and use of avoidance register for exaggerated conscientiousness in political discourse, which both show that the forms are not isolated to women. The ideology also erases the more realistic variation in social relationships between the Nguni and the Khoi in which individuals from each group might serve, marry, or consort with individuals in the other group. Thus, the processes of both *fractal recursivity* and *erasure* are involved in this case of phonological borrowing.

Irvine & Gal (2000) also note Labov's (1963) study of vowel patterns on Martha's Vineyard as another example of a contrast at one level of the system being recast as a contrast at a different level of the system over time. What originated as a contrast between the ethnic groups on the island in the 1930s eventually manifested as a contrast between Islanders and Mainlanders in the 1960s. As the tourism industry grew, the salient social categories on the island changed, and this social split increased the phonological divergence between the groups. Irvine & Gal (2000) comment that Labov did not fully explore the ideological content of this change, but that this sort of sociolinguistic analysis "seems to beg for just this kind of analysis." (p.47)

1.2.3 Other implementations of linguistic differentiation

The idea of constructing and identifying differences is also at the foundation of studies in folk dialectology. Research tasks in folk dialectology often begin by asking speakers to identify or mark on a map areas where people "speak differently" than they do, which may or may not correspond with linguistic realities (Preston 1986, 1989 & 1999, Clopper & Pisoni 2004). Evidence from Evans (2011) seems to confirm that the ideology of difference around the national border exists for Washington State speakers. Evan's work provides folk perceptual judgments for Washington State, specifically showing that speakers along the length of the national border are characterized as sounding "Canadian," and for some participants, regions as far South as Everett, WA (only 30 miles north of Seattle) may be perceived as sounding "Canadian" (Evans 2011). Conversely, Evans (2013) reports a minority of outliers completed the Washington State map task by stating that "everybody sounds the same." Becker (2014) also provides evidence that the ideology of sameness is related to production for Oregon speakers. In this case, she finds perceptual judgments of "non-accent" to be a significant predictor of participation in the regional phonetic process of BEG and BAG tensing. If an ideology of sameness is a corollary to the ideological construction of difference (the lack of constructing a difference), it is again clear that this process is related to speakers' linguistic behaviors in ways that might lead to divergence or convergence. Finally, Niedzielski (1999)'s study of Detroit speakers demonstrates in a very tangible sense that the social perception of "differentness" based on nationality affects speech processing and phonetic judgments of a stereotypical speech feature. In this work, listeners who believed they were listening to a Canadian speaker made significantly different perceptual judgments than listeners who believed they were listening to an American speaker, despite being exposed to an identical acoustic signal. The ideological construction of difference, it seems, has consequences for both perception and production. While studies of the U.S.-Canadian border in Washington State specifically have not been conducted, making it difficult to know whether participants' judgments correspond with linguistic reality, previous studies of the U.S.-Canadian border shed some light on how the ideological construction of difference proceeds and how this relates to language use.

1.2.4 Predictions for the effects of language ideologies in the Pacific Northwest

Theories of the ideological construction of difference predict that dialects surrounding the U.S.-Canadian border will diverge on the basis of perceiving speakers on the other side of the border as "different." Yet, the Pacific Northwest is a region with strong identity and a substantial movement toward trans-border collaboration which might also lend itself to a certain *erasure* of trans-border variation. If perception of regional sameness predicts higher levels of participation regional phonological processes, there seem to be two opposing social psychological or cognitive processes at work to affect speech in the Pacific Northwest. If perceived difference based on national identity causes linguistic divergence across borders, what do we expect in the case of a region with exceptionally strong solidarity, which also happens to be traversed by a national border? Acknowledging that processes of *recursivity* and *erasure* co-occur continually and simultaneously, we might expect to see the effects of both processes affecting different levels of the system. This predicts that speakers may show contrasts on the basis of other perceived contrasts and that they may, simultaneously, deny or ignore other existing contrasts. Do speakers' linguistic productions and ideologies reflect both of these processes? Do Seattle and Vancouver speakers manifest the same use of these ideological processes or is there variation between the two cities? To answer these questions, it is also relevant to consider how particular phonetic realizations become *iconic* of a group and how they are able to encode information about national and regional identity, among other more local identities. Thus, an additional theoretical question for this work is how, precisely, this socioindexical information relates to phonetic form. How can theories about phonetic form be integrated with the process of phonologization or conventionalization to improve understanding of *iconic* (socioindexical) variables?

1.3 Relationship Between Phonetic Form and Social Meaning

1.3.1 Phonologization

With respect to phonetic form, phoneticians interested in sound change and phonologization have posited similar processes of reanalysis, but have not identified a link to the socioindexical meaning of the variant in the process. Hyman (1976) uses two diagnostics to define phonologization: 1) the exaggeration of a phonetic effect beyond what can be considered universal and 2) the development of a categorical rule referring to the phonologized property. What exactly does "beyond universal" mean? Here, formant trajectory analyses are critical in differentiating the conventionalized or phonologized effects from the non-conventionalized ones. "Beyond universal" might indicate a larger than expected alternation between observations of the baseline environment and the conditioning environment, but "beyond universal" also relates to the temporal location of the phonetic effect. Namely, the spread of the phonetic effect to be more temporally distant from its conditioning trigger is indicative of greater conventionalization or phonologization. A universal phonetic effect (with no degree of phonologization) in Hyman's terms would be a poor candidate for *iconicity* or *fractal recursivity*, because it is, by definition, an effect that occurs consistently across all speakers due to factors of human anatomy or articulation. In order for an iconic relationship to be created indexing group membership or social identity, the phonetic effect must "go beyond universal," to borrow Hyman's language, to differentiate some sub-section of the population. Subsequent to Hyman's first writing on phonologization, researchers have identified the reanalysis of phonetic coarticulation as a major factor in diachronic sound change (Fruehwald 2013, Bermúdez-Otero 2007). Generally speaking, coarticulation is the effect of a preceding or following sound on a particular target sound. For example, a vowel may exhibit a coarticulatory effect of its following consonant dependent on place and manner of articulation or voicing. It is in this distancing of this phonetic effect from the coarticulatory trigger over time that phonologization is said to occur. When from a synchronic perspective, a variant exists at some intermediary step between coarticulation and phonologization, an opportunity for socioindexical meaning is created.

1.3.2 Dialectal and social variation in vowel-inherent spectral change

Production research shows that there are ethnolectal and generational differences in vowel-inherent spectral change (VISC) among groups of speakers and perceptual studies confirm that listeners make use of this knowledge to draw both phonemic and social conclusions in speech processing (Janson & Schulman 1983, DeDecker & Nycz 2006, Fox & Jacewicz 2009, Jacewicz & Fox 2012, Scanlon & Wassink 2010, Koops 2010b, Risdal & Kohn 2014). When processing authentic speech, the listener is simultaneously processing formant trajectory information, which serves to distinguish phonemes, along with socioindexical meaning, and each informs the other. To understand how the ideological construction of difference operates in a complex trans-border region, theories of phonetic conventionalization and indexicality of social meaning should be integrated. As Wassink (2015a & 2015c) observes, examining vowel-inherent spectral change (VISC as coined by Nearey & Assmann 1986) can elucidate the phases by which phonetic conventionalization and phonologization take place, linking these phases in turn to their socioindexical value. How is the conventionalization or phonologization of a phonetic process associated with its status as a dialect marker? An underlying goal of this research is to describe the correspondence between the varying degrees of phonologization that can be observed for the five diagnostic variables examined in this analysis and their ability to serve as an icon of a particular group. This account illustrates how speakers' productions show different levels of phonologization that correspond with *iconicity*, as defined by Irvine & Gal (2000), at different levels of the social system.

1.4 Overview

This dissertation provides a sociophonetic analysis of five key, and potentially diagnostic features of Pacific Northwest English in two different cities: Seattle, Washington and Vancouver, British Columbia. These allophones include /æg/, /æn/, /æ/ in environments favoring retraction, as well as diphthongs /aʊ/ and /aɪ/. The work provides an empirical contribution to understanding dialectal variation in "the West" or "Third Dialect" area (Labov, Ash, and Boberg 2006 and Clarke, Elms, and Youssef 1995, respectively). The investigation is grounded in previous research on linguistic border effects, employs phonetic methods recognizing the importance of dynamic features like vowel-formant trajectories and integrates these with theories of social meaning through the conventionalization of phonetic processes. Analyses of these features demonstrate the distinguishing features of the Pacific Northwest region, while also identifying variation within the region and its speakers based on social groupings. Using word list data provided by men and women speakers in two age groups (18-24 and 25-36) plus an in-depth sociocultural identity survey, the study responds to several questions.

1.4.1 Research Questions

To reiterate, this work addresses the following questions:

1) How similar are the Pacific Northwest dialects spoken in Vancouver, B.C. and Seattle, WA? To what extent do Seattle speakers engage in phonetic processes previously identified as characteristic of Vancouver and to what extent do Vancouver speakers engage in phonetic processes previously identified as characteristic of Seattle?

2) What do the sociocultural identities of Seattle and Vancouver speakers suggest about their regional and national identities and their language attitudes?

3) How do phonetic and phonological features among Seattle and Vancouver speakers index overlapping regional, national or other local social identities?

4) What can dynamic information like vowel formant trajectories explain about the conventionalization of phonetic processes and what does this say, in turn, about the *iconic* relationships of social meaning?

5) Finally, how do Seattle and Vancouver speakers illustrate the processes of *erasure* and *fractal recursivity*? How do these affect their linguistic production? What does this suggest about the importance of ideology to language change around a national border?

1.4.2 Results

In this work, I illustrate that Seattle and Vancouver exhibit some similarities with respect to their phonetic processes (namely /æg/ raising), but that they exhibit many differences with respect to other phonetic process (/æn/ raising, /æ/ retraction, /aʊ/ raising, and /aɪ/ raising). In these cases, the differences can be understood in large part as contrasts in the extent to which a phonetic universal has become conventionalized or phonologized in the two cities. I argue that these differences and the temporally-sensitive vowel formant analyses they necessitate should be incorporated into methods for studying dialectal variation and differentiation. Differences such as the ones between Seattle and Vancouver should be viewed as qualitative differences between the dialects rather than only a quantitative difference in their participation of the same sound changes. Results from the structure and distribution of the five phonetic processes explored here reveal their differential availability for adoption in processes social-meaning construction such as *iconicity*, *fractal recursivity* and *erasure*. Furthermore, Seattle and Vancouver speakers show asymmetrical engagement in the ideological processes of *fractal recursivity* and *erasure*, which are associated with linguistic production. I argue that both regional and national identities coexist for speakers of English in the Pacific Northwest and that the phonetic patterns of Seattle and Vancouver speakers serve to unite their overlapping regional identity while at once distinguishing their unique national identities.

Results from this dissertation shed light on the questions posed above, while also raising many questions for future work. Chapter 2 presents a more in-depth overview of previous dialectal studies in the Pacific Northwest for both Seattle and Vancouver, B.C. Chapter 3 gives an outline of the methods used in this investigation, including a discussion of the importance of incorporating dynamic formant trajectory data and several proposals for how this can be accomplished. Chapter 4 provides findings of the phonetic analyses of each of the five features under consideration for Seattle and Vancouver separately followed by a comparison of the cities. Chapter 5 presents findings of the sociocultural identity survey for both Seattle and Vancouver, B.C. Chapter 6 offers a discussion of the findings and their relevance to the outlined research questions of this section. To conclude, Chapter 7 offers a brief summary and directions for the future.

Chapter 2

2 VOWEL SYSTEMS AND CHANGES IN PROGRESS

To examine the theoretical questions outlined in Chapter 1, a set of diagnostic variables is selected to define and differentiate Seattle and Vancouver English. In addition to the often-cited Canadian Raising phoneme /aʊ/, /æ/ has been identified as a diagnostic variable which distinguishes many North American dialects. No previous studies have compared /æ/ realizations between these two dialects, but studies of /æ/ independently conducted in Seattle and Canada (and in Vancouver specifically) suggest different trajectories and trends for this phoneme in the two dialects. The qualities of /æ/ identified in Seattle and Vancouver are one element of a larger vowel systems that may be shifting in different directions on either side of the border. This chapter presents the defining features of these two dialects of North American English, as discussed in previous studies, with a focus on background information about vowel systems and changes in progress. Special attention is given to studies of /æ/ and to the few existing comparative studies that examine a specific linguistic variant among Washington or B.C. speakers. Because studies of /æ/ among Washington speakers have largely focused on the pre-velar environment and provide little description about /æ/ in other phonetic environments, one study of /æ/ among Oregon speakers is included in this summary. Riebold (2012) is unique in addressing /æ/ in non-prevelar contexts for American Pacific Northwest speakers.

2.1 Differentiating Canadian and U.S. Dialects

In the *Atlas of North American English* (henceforth, ANAE) Labov, Ash, and Boberg 2006 identify "the West" and "Canada" as dialectal regions and provide a broad overview of distinguishing features. It is noteworthy, however, that these dialectal regions correspond with vast geographic areas (the two geographically largest dialectal regions mapped on the continent), and they do not fully address phonetic details of locations as specific as Seattle and Vancouver. The "West", sometimes labeled as the "Third Dialect" per Clarke, Elms & Youssef (1995), was largely characterized by its lack of participation in the Northern Cities Shift or the Southern Vowel Shift and by the presence of the *cot/caught* merger. In a sense, it has been negatively defined by a lack of participation in other well-documented vowel changes occurring in U.S. English, but due to a scarcity of research, has had little positive identity to define or unite it as a dialect region. The following changes are identified for the West:

- Raising and fronting of /æ/ words such as *man* and *that*
- Fronting of /aw/[1] or Canadian raising of *house*
- Raising, fronting, lowering or backing of /ɛ/ in *said*
- Lowering and centralization of /ey/ or tensing and fronting as in *say*
- Fronting of /ow/ as in *go*
- Fronting of post-coronal /uw/ as in *do, two*
- Presence of the *cot-caught* merger
- Presence of the *pin-pen* merger (/i/ and /e/ become homophonous before nasal consonants)
- *up* (fronting or backing of /ʌ/)[2]

Figure 1. SOURCE, Labov, Ash and Boberg (2006)

The presence of the low-back merger leads the definition of the dialect region, but the other changes described seem less clear. The first four changes, in particular, are relevant to the current study. While /æ/ is generally described as raising and fronting, the changes described for /ɛ/ and

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[1] The diphthongs involved in Canadian Raising are represented as /aw/ and /ay/ based on their original form in the ANAE, but will be referred to with IPA characters /aʊ/ and /aɪ/, respectively, for purposes of the current work.
[2] From The Atlas of North American English online version http://www.atlas.mouton-content.com

/ey/ are somewhat unclear. This account also identifies possible raising of /aw/ in the West, which calls into question the differentiation of “the West” and “Canada” in the first place.

2.1.1 Canadian Raising among Washington and Vancouver speakers

Given that the most notable diagnostic established in the ANAE (Labov, Ash and Boberg 2006) to distinguish “the West” from “Canada” is the lack of Canadian Raising in the former and its uniform presence in the latter, Sadlier-Brown (2012) examines Canadian Raising in Vancouver and comparatively among speakers from Washington State and British Columbia asking whether it can reliably be used to differentiate Canadian speakers from their neighbors to the South. Her study includes data from eight young adult speakers, four from Washington (two males and two females aged 19-22) and four from Vancouver (two males and two females 20-24). In contrast to the Vancouver subjects who were all from Greater Vancouver, the Washington participants were from four different towns: Olympia, Shelton, Aberdeen and Cosmopolis. All were native speakers of English who reported a middle-class background. The data were collected by sociolinguistic interview with one local interviewer and were recorded using a Zoom H4 Handy Recorder. Linear predictive coding was used to estimate the target F1 and F2 of each vowel token, at vowel center (for monophthongs) or at diphthongal nucleus (for diphthongs). (The single point measurements were taken at a central point in the vowel’s steady state if no peak was present.) The data were normalized according to the Lobanov (1971) method in the Vowels package in R (Kendall and Thomas 2009). Approximately 800 tokens were available for the entire study, with an average of about 100 tokens per speaker. A two-way ANOVA was performed in R to identify the effects of sex and age.

Sadlier-Brown (2012) finds that the Washington speakers do participate in raising of both /aw/ and /ay/, as evidenced by significant differences in the F1 mean (diphthongal height) of raised and unraised environments ($p<0.05$), however, the four Vancouver speakers in the sample showed a stronger differentiation by raised and unraised environment ($p<0.001$). The two groups also showed differences in the height of raising; Washington speakers' raised /awT/ variants were not raised as high as their /e/ vowel, while Vancouver speakers consistently raised higher than their /e/ vowels. The Washington speakers also displayed more idiosyncratic variation in raising of both /ayT/ and /awT/ than did Vancouver speakers. Yet, the regional difference between Vancouver and Washington speakers for F1 in /awT/ tokens comes close, but does not reach significance at $p = 0.052$. Sadlier-Brown also compared fronting among the Vancouver and Washington speakers by using their F2 measurements. She finds that tokens of /ayT/ are significantly fronter than /ay/ for both Vancouver and Washington speakers, though /aw/ does not follow the same pattern. None of diphthongal variants approached the frontness values of their front vowel counterparts for either the Vancouver or Washington speakers. In other words, /aw/, /awT/, and /ay/ all remained significantly further back than /æ/ and /ayT/ remained similarly farther back than /e/.

Sadlier-Brown comments that while Washington speakers display a significant difference between /aw/ and /ay/ in raised and unraised environments, regional differences persist. The height of Washington speakers' raised /awT/ tokens is considerably lower than those of the Vancouver speakers and the incidence of non-raising is also higher among Washington speakers. Sadlier-Brown suggests that this difference in the height of raising is likely the source of the widespread popular perception of raising as a primary difference between Canadian and American speakers. The fact that Washington speakers are identified as raisers using the typical methodology for assessing raising may force reconsideration of diagnostic tests used to analyze the phenomenon, since the current criteria for raising do not seem to align with perceptual realities in this regard. Sadlier-Brown's study is one of the only to examine and compare features of Vancouver or British Columbia English with those same features in Washington State English.

While Sadlier-Brown's study is a starting point, the comparative literature available to detail differences between Vancouver and Seattle dialects of English is quite sparse. The comparative research that does exist has identified and centered on a small group of variables: namely, Canadian Raising of /aw/ and /ay/. To understand more about the nuances that distinguish Canadian and American dialects of English in the Pacific Northwest, broader comparative studies are needed. Studies with larger speaker samples, consistent methodology, and a look at the larger vowel system would provide much additional information about distinguishing features of the two neighboring dialects. Because these types of comparative studies are hard to come by, independently conducted studies of vowel changes in the Canadian English of Vancouver and Seattle English will presented below.

2.2 The Canadian Shift

2.2.1 Clarke, Elms, and Youssef (1995)

Clarke, Elms, and Youssef (1995) first documented and discussed the Canadian Shift, calling this the "Third Dialect," which they view as a substantial shift affecting the front lax vowels of Canadian English. They view the shift as conditioned by the *cot*/*caught* merger, anticipatory coarticulation of the following consonant and gender differences. Prior to this research, /æ/ (along with other front vowels) were considered to be part of a very stable and homogenous pan-Canadian vowel system. Clarke et al. compare the Canadian Shift to the Northern Cities Shift and discuss the linguistic and social constraints on its progression. Their sample includes 16 Canadian native speakers (eight male and eight female) who were in their early to mid-20s and from Ontario. Nearly 1,900 tokens of /ɪ/, /ɛ/, /æ/ /a/ and /ʌ/ were included from a word-list reading task. The word-list contained stressed, mostly monosyllabic words in a range of phonetic environments. Tokens were impressionistically transcribed for the presence or absence of vowel shifting independently by two of the authors and cases of nonagreement were addressed until consensus was reached. The results of transcription were supplemented with acoustic analysis in some cases. Conditioning phonological environments (place, manner and voicing) and social factors (sex) were considered using GOLDVARB 2.

Clarke et al. find that/ɪ/ lowers to /ɛ/, and /ɛ/ in turn lowers toward canonical /æ/. The low front /æ/ vowel exhibits a very different change than in the Northern Cities Shift, retracting and lowering in the direction of central, open /a/ in all environments besides the pre-nasal environment. They hypothesize that this downward, backing of /æ/ may be permitted or encouraged by the fact that the largely merged *cot*/*caught* classes have remained in the low back of the vowel space with variable rounding. Clarke et al. also note the fronting of tense, back rounded vowels /u/ and /o/, though they conclude that these changes are largely distinct from the changes to the front vowel system. They also comment that in terms of both their front and back vowel changes the Canadian and California Shifts appear to be identical.

Their analysis of conditioning environments shows that the Canadian Shift is in part dependent on the manner of articulation of the following consonant. Namely, nasal vowels inhibit lax vowel lowering for /ɛ/, /æ/, and /ʌ/. Fricatives favor lax vowel lowering more than any other environment, with a factor weight of 0.60 /æ/ and 0.62 for /ɛ/. For /æ/, /l/ was found to have the strongest effect on lowering with a factor weight of 0.73. Neither place of articulation or voicing of the following consonant did not reach levels of significance for the lowering of /æ/, although Clarke et al. do observe that a following voiceless consonant seems to promote lowering and shift. (There is no effect of pre-velar environment to suggest that /æ/ is raising before /g/.)

With respect to nonlinguistic factors involved in the shift, Clark et al. report that women are leading the change. Their data for/æ/ lowering confirm findings by Esling and Warkentyne (1993). For /æ/ retraction, females had a factor weight of .61 as compared to .39 for males. While Clarke et al. observe that the Canadian Shift is more advanced among younger than older speakers, their sample does not allow for a rigorous age comparison. Likewise, they suggest that the Canadian Shift is affecting primarily middle-class rather than working class speakers, but are not able to present an analysis with their current sample, as it is comprised entirely of middle-class speakers.

Clarke et al. provide a vital first look at patterns of vowel change affecting Canadian English and offer some important insights into the constraints affecting this change in progress. Their lack of discussion of pre-velar raising for /æ/ suggests that this may be a more recent development in the Canadian Shift affecting regions outside of Ontario. Their discussion of phonetic environments favoring retraction offers direction for future considerations of /æ/ retraction before laterals and fricatives. With additional acoustic information, more insights may be made about the importance of place and manner of articulation. Finally, Clarke et al. also raise an interesting question in observing the similarities between the Canadian and California Shift. They remark that a fruitful area of investigation would be to determine whether the changes involved in the Canadian shift are concurrently taking place in urban centers of the Western United States.

The ANAE (Labov, Ash, Boberg 2006) describes Canada as very similar to the dialectal regions found in the Midlands and the West and acknowledges some variation that separates the

Atlantic Maritime provinces from the rest of Canada. The descriptions of the Canadian dialectal region focus on the Canadian Shift and Canadian Raising as the primary changes that distinguish Canada as a dialectal region. The Canadian Shift is triggered by the low-back *cot-caught* merger which leads to the retraction of /æ/ followed by lowering and backing of /ɛ/. With respect to raising, the ANAE finds some presence of raised nuclei for /aw/, but not for /ay/ in Vancouver, and therefore omits Western Canada from the core area where Canadian Raising is said to occur. Basic phonetic parameters are also defined for the Canadian Shift: /æ/ has a normalized F2 of less than 1825 Hz and /ɛ/ displays a normalized F1 exceeding 650 Hz. The presence of Raising is defined as having a 60 Hz or greater difference in the nuclei F1 of raised (*house, about*) tokens as compared with the nuclei of unraised /aw/ tokens (*loud, now*).

Finally, while /æ/ retraction and vowel chain shifts similar to the Canadian shift have been noted in other dialects, evidence suggests that these shifts have reportedly arisen independently of /æ/ retraction in the Canadian Shift. Clarke, Elms, and Youssef (1995) note the resemblance between the Canadian Shift and the vowel shifting patterns observed for California English. Kennedy and Grama (2012) describe the California Shift, which is similar to the Canadian Shift in that it involves lowering and backing of the vowels in KIT, DRESS, and TRAP. They acknowledge the similar directional pattern of the California and Canadian Shifts, but speculate that their motivations must be different. While /æ/ retraction as part of the Canadian Shift has been considered to be an outcome of the *cot/caught* merger, they describe LOT as more centralized in California English than Canadian English, which calls into question LOT's involvement in the typical pull-chain account for /æ/ retraction in California English. It is curious that Canadian and California English should display such a similar trend while not being geographically contiguous neighbors of each other, since there is currently no evidence documenting the same type of shift in the geographic space between them (that is, in Oregon and Washington).[3]

2.2.2 /æ/ retraction in Vancouver

Numerous studies have documented /æ/ retraction in Vancouver and B.C. (Esling and Warkentyne 1993, Hall 2000, Sadlier-Brown and Tamminga 2008, Boberg 2008,). Esling and Warkentyne (1993) first observed the apparent change in progress toward /æ/ retraction (and lowering) in Vancouver using data from the Survey of Vancouver English, which began in 1978 and was designed to allow for an urban dialectal study. The survey collected data from nearly 300 randomly selected speakers native to the Vancouver area, of which the data from 192 speakers is included in Esling and Warkentyne's analysis. They used both acoustic analysis and auditory judgments to assess the status of /æ/ in a wide range of speakers. Their analysis considered three age groups and four SES divisions. The youngest speakers in their sample ranged from 16-34, the middle-aged speakers from 35-60 and the oldest speakers exceeded 60 years of age. These speakers fell into four SES groups: middle working class, upper working class, lower middle class, and middle middle class. For the acoustic analysis, Esling and Warkentyne employ long-term average spectral analysis (LTAS) to capture and measure acoustic characteristics that persist over an extended period of speech for an individual. They argue that LTAS allows consideration of individual's quasi-permanent speech features; those that are likely to be part of the individual's underlying phonology as a result of physical traits or long-term habitual articulations correlated with the individual's socioeconomic class or region of origin. The LTAS analysis entails excerpting a comparable 60-second section of a reading passage for

[3] No large-scale studies have documented the California Shift as far north as Oregon or Washington, though Becker et al. 2014 have begun looking at participation in the California Shift among Oregon speakers.

each speaker and conducting a standard deviation analysis of the differences between and within the a priori age and socioeconomic groups. These results were also compared with formant frequency analyses of the individual vowel classes for the groups. Vocalic inventories were taken for 40 tokens for each of ten vowels in the Canadian Vowel system in identical lexical environments as the reading passage provided, and F1 and F2 information (presumably at mid-point) was extracted using linear predictive coding (LPC). Esling and Warkentyne use both a traditional F1-F2 plot and a means-limit matrix approach to assess the distribution of formant values for /æ/ across different groups in the survey. The means-limit approach trimmed each group at 5% to remove outliers and compared the means of the remaining group with the limits of all over groups at three standard deviations. Due to conflicting results between the two methods, they invoke a third method (auditory analysis) to confirm their findings.

The LTAS analysis revealed that there were no significant global voice quality differences between age groups in the survey, but did find greater dissimilarities between SES groups. In particular, major acoustic differences were found between upper working class and middle middle class women that suggest long-term voice quality differences for an oral-reading task style. The formant analysis and accompanying plots suggested that middle middle class women had more fronted values for /æ/ than middle working class women. However, average spectral analysis showed that the spectral peaks appeared at significantly different locations from the formant analysis revealing that, in fact, middle middle class women had more retracted realizations of /æ/ than upper working class women. Using a means-limit approach, they confirmed that middle middle class women were significantly differentiated from all other SES groups within the same age group in terms of /æ/ pronunciation. Middle working class women were also distinct from the other SES groups in their age bracket. Auditory transcriptions of all

/æ/ tokens by the authors supported the finding than older women's usage generally favors [æ] except among the middle middle class group, where a more backed variant has taken hold. Younger women, especially in the middle class groups, showed a clear preference for the backed variant over the standard variant.

Overall, Esling and Warkentyne found older speakers in the sample to have more fronted /æ/ realizations, while younger speakers had more back realizations of /æ/. The change appeared to be lead by middle-aged, middle-class women. Older female speakers maintained the conservative front /æ/ variant. Men were shown to participate in the change, as well, but lagged behind women by about a generation. Esling and Warkentyne provide a foundational assessment of this socially stratified change in progress among Vancouver speakers and also illustrate the important implications different methodologies have on insights about the change. The complexity of their results highlights the importance of using more long-term and dynamic spectral information as opposed to relying exclusively on single-point formant data. It is also important to note that their study used non-normalized data and employed necessarily distinct tools and methods than those currently available to researchers of sociophonetics and vocalic trends.

Subsequent studies have provided more details about /æ/ retraction in specific phonetic environments, compared the Vancouver trend with trends in other regions, and confirmed the social aspects of /æ/ retraction. Hall (2000) compares /æ/ retraction among four female Toronto speakers with four female Vancouver speakers between the ages of 19-21. All eight subjects were middle class university students who were born and raised in or near the city they were grouped by. Hall elicited data in casual, conversational style as well as by reading passage and word list. She examined eight phonetic environments: _n, _n + obstruent, _ m, _ anterior voiceless fricative, _anterior voiced fricative, _stop, _ velar nasal, _ other consonants including {l, r}. The interviews conducted by phone (those for Vancouver speakers) were recorded with a speakerphone and tape recorder. Hall classified her tokens as retracted (based on auditory impression), and calculated rates of occurrence for the backed vowel in each environment and speech style.

She finds that Vancouverites show more retraction on the basis of auditory classification than Toronto speakers overall and that retraction is conditioned by phonetic environment. She reports that Vancouver speakers have retracted variants between 25 to 50 percent more often than their Toronto counterparts. Like Boberg to follow, she finds significant retraction preceding anterior nasals {n, m} as well as before nasal + obstruent clusters. For both regional groups of speakers combined, the rates of retraction in casual speech were highest for /æ/ preceding anterior voiceless fricatives (54.8%), and reached nearly 50% for /æ/ preceding /n/ (50.0%), /n/+obs clusters (46.5%) and m (48.4%). Tokens of /æ/ followed by voiced fricatives, stops, velar nasals and other consonants showed very low rates of retraction. Pre-lateral liquid tokens of /æ/ showed occasional retraction. When Vancouver and Toronto speakers' /æ/ tokens are examined separately by phonetic environment, the importance of region is even more striking. She finds that in casual speech, Vancouver speakers produce retracted /æ/ 100% of the time before /n/ as compared to 0% for Toronto speakers. Rates of retracted /æ/ show a similar division before /n/ + obstruent clusters and /m/ in casual conversation. Rates of retraction before an anterior voiceless fricative range from 56.3% to 69.3% for Vancouver speakers depending on task type.

Hall emphasizes that /æ/ retraction is not stylistically invoked across the varying task types that make up her study. No consistent pattern appears with respect to the formality of the task type and /æ/ retraction. For some phonetic environments, the highest rates of retraction occur in the more careful word list style, in others the reading passage style, and still other phonetic environments show highest rates of retraction in the most casual conversation style. She concludes that the variant is not stigmatized or highly conscious and that speakers make no obvious attempt to use the standard (unretracted) variant in careful speech. Hall adds that none of the Vancouver speakers became aware of the aspect of speech she intended to study, providing additional evidence that the /æ/ variable is not one Vancouver speakers are highly conscious of. Hall's study provides important direction in addressing the role of phonetic environment and regional variation in /æ/ retraction. It would be advantageous to confirm Hall's finding using a consistent recording method for all data collection and a more rigorous acoustic analysis. Further investigation into the effects of task type and formality would also be useful.

Boberg also emphasizes the vital role of vocalic variation in the perception of regional speech and emphasizes the status of /æ/ allophones, in particular, as "one of the most intricate and regionally diagnostic variables in North American English." He also notes that the allophones act as below-consciousness variables:

> *Another consideration is that many of the vocalic variables examined here seem to operate below the level of conscious awareness, being indicators of regional identity rather than markers of social class that respond to stylistic variation.* (Boberg 2008, p 152).

Consistent with Hall's assessment, he suggests that /æ/ retraction among Vancouver speakers is not a stigmatized feature for which speakers show any stylistic variation.

Boberg (2008)'s analysis of /æ/ is included as part of his *Phonetics of Canadian English* study, which sought to document in greater detail variation by region, sex and attitude among speakers of Standard Canadian English. The subjects were 51 female and 35 male McGill University undergraduate students from across different regions of Canada. Twelve speakers were included from British Columbia (8 female and 4 male) providing a larger subject base than Labov, Ash, and Boberg's (2006) ANAE and a larger speaker base than Hall's (2000) study of /æ/, though Boberg's British Columbia subjects are not guaranteed to be from Vancouver, and they became residents of Montreal near the age of 18 since they are attending McGill. The sound files were recorded using Marantz cassette recorders and Audiotechnica omnidirectional lavalier microphones. Data was elicited via demographic questionnaire, word list reading, conversational interview and written opinion survey, though the analysis of /æ/ comes only from the word list reading task. The word list contained 145 productions, covering the English full vowel system in stressed position and in a range of allophonic environments including /t/, /d/, /n/, /l/, and /r/. With additional tokens targeting consonantal features, the entire list contained 180 words.

The 145 tokens of interest were measured as they were in the *Atlas* (Labov, Ash and Boberg 2006, 36-40), which entailed a single-point measurement of F1 and F2 using linear predictive coding analysis in CSL 4400 (Kay Elemetrics). Measurements were made at a diagnostic point in the trajectory of the vowel nucleus; at the maximal F1 point for vowels tending to lower and at the point of inflection point of F2 for vowels tending to front or back in the vowel space. Vowels without clear inflectional points were measured at a point within the steady space. The speaker formant data was normalized by the Nearey Method (1977), where men's formant values are adjusted up and women's down by a scale factor that is derived from the difference between the natural log means of the speaker and the group's formant values. After the data were normalized, mean formant values were calculated for each speaker and for each vowel, and these were used to calculate regional means for each vowel. MANCOVA tests were run using SPSS to assess the significance of region on phonetic measures without differentiation by speaker sex.

Boberg finds that region has no significant effect on participation in the Canadian Shift of short vowels /i, e, æ, o, ʌ, u/, and declares this shift to be a pan-Canadian change. He acknowledges a marginally significant effect of region on F2 of /e/ and F1 of /u/ which he deems related to the rate at which different regions are progressing through the change. Vancouver speakers were among the most advanced for low F2 values for /e/ (below 1800 Hz), as were Toronto speakers. Vancouver and Toronto speakers also shared higher F1 values for /u/ suggesting a lowering of /u/ in words like *cook, foot,* and *stood*. To examine Canadian Raising, Boberg's word list also collected and compared 5 tokens of /aw/, four tokens of /awT/, and seven tokens of /ay/. Across the sample, Boberg finds that the mean F1 differences between raised and unraised /aw/ are quite robust at 142 Hz, but interestingly, still less robust than the difference in F2 for raised and unraised /aw/ at 229 Hz. This suggests that while Canadian Raising is largely a uniform feature of Canadian English, the acoustic reality of the phenomenon is characterized by more *fronting* of /aw/ nuclei before voiceless obstruents than it is *raising*, at least in some regions of Canada. Raising of the two vowels /aw/ and /ay/, however, appears to be only weakly correlated based on F1 of /aw/ and of /ay/ (r = .51). Significant effects of region were found on /aw/ raising and on the fronting of /awT/. Comparisons of British Columbia with other regions were not found to be significant, though based on small F1 differences between raised and unraised /aw/ for three of the eight speakers, Boberg suggests that participants from the Vancouver-Victoria region may show a possible weakening of the traditional raising pattern. He does not offer any speculative reason for this "possible weakening" and emphasizes that it should be substantiated with a larger sample. British Columbia is also differentiated by the phonetic quality of raised /awT/ as compared to other regions; tokens remains significantly further back for raised /awT/ and do not exhibit the fronting pattern noted for Ontario and other parts of the country.

Phonetic Environment	**Mean F1 in Hz**	**SD**	**Mean F2 in Hz**	**SD**
/ay/	844	20	1429	30
/ayT/	734	12	1652	23
/oy/	520	16	928	17
/aw/	870	25	1603	15
/awn/	814	26	1841	46
/awT/	731	33	1704	54

Table 1. SOURCE, Boberg (2008)

In diagnostically analyzing /æ/, Boberg (2008) addresses the West in particular as having a "less clearly organized system involving a continuous range of allophones" where /æ/ is raised and fronted before /g/ as well as in pre-nasal position. He describes both Seattle and Vancouver as participating in this pattern, along with most of the Northwest portion of the continent moving westward from Wisconsin or Minnesota. He also considers pre-velar and pre-nasal /æ/ raising in these dialects phonetically distinct, with the height of vowel nuclei in /æg/ words raising in a co-articulatory motion with anticipation of the coming velar consonant rather than the tensing and raising of the nuclei observed in pre-nasal contexts. The direction of the glides for pre-nasal and pre-velar raising is also distinct; pre-nasal /æ/ exhibits an in-glide, pre-velar /æ/ exhibits an up-glide. The result is that /æg/ tokens become merged with /eyg/ tokens. Boberg's word list contains four tokens of /æN/, three tokens of /æg/ and six tokens of /æ/ in other environments.

For his sample as a whole, Boberg finds the following means for allophones of /æ/:

Phonetic environment	**Mean F1 in Hz**	**SD**	**Mean F2 in Hz**	**SD**
/æ/	884	12	1724	32
/ær/	630	64	1956	55
/æg/	774	48	1951	84
/æN/	717	42	2089	66

Table 2. SOURCE, Boberg (2008)

He finds that all regions of Canada participate in pre-nasal /æ/ raising, and with lesser consistency, /æg/ raising. Western Canada (speakers from British Columbia and the Prairies, in particular) shows the greatest /æg/ raising in the sample. Speakers from British Columbia have a Mean Cartesian Distance of 392 Hz between tokens of /æ/ and /æN/ and a Mean Cartesian Distance of 323 Hz for /æ/ and /æg/. He does also notes large standard deviations for Western Canada, however, suggesting considerable inter-speaker variation in /æ/ raising. He points out that B.C. speakers, like the rest of Canadian speakers, show pre-nasal /æ/ raising, though their allophonic difference (ranging from 300 to 400 Hz) is less extreme than in other parts of the country. Western Canadian speakers, on the other hand, show strong /æg/ raising, differentiating them from Eastern Canadian speakers. The Mean Cartesian Distance from /æ/ for B.C. speakers is 392 Hz for /æN/ and 323 Hz for /æg/, though he does note large standard deviations. Some Western Canadian speakers in the sample showed strong /æg/ raising and very little /æN/ raising.

With respect to /æ/ retraction, Boberg uses the relative distance of /æ/ from /uw/ based on F2 to assess degree of backness for /æ/. He finds that across all regions of Canada, B.C. speakers and Toronto speakers show the most innovative pattern of /æ/ retraction, F2 values that are 100 Hz lower for /æ/ than for /uw/ indicating that /æ/ is backer than /uw/. In contrast, in the Prairies, Newfoundland, and the Maritimes, /uw/ remains farther back, and /æ/ remains quite fronted and speakers F2 measurements for /æ/ exceed their measurements for /uw/ by 100 Hz or more. Boberg's finding that Toronto speakers have relatively backer /æ/ than /uw/ seems to contradict Hall's (2000) finding based on auditory impression that Toronto speakers do not participate in /æ/ retraction, though the chronological and methodological gaps in their studies render any comparison inconclusive.

Boberg's (2008) study is a landmark to better understanding the Canadian Vowel System and regional variation within it. It identifies some important vocalic variables that distinguish British Columbia and Vancouver from other parts of Canada. Given that Boberg's subjects were living in Montreal at the time of data collection, a follow-up study investigating these variables in Vancouver itself might reveal more. In addition, single-point analyses of vocalic variables, especially diphthongal variants, present some limitations (Wassink and Koops 2013, Evanini 2009). It would be useful to expand upon Boberg's results by providing more information about the formant trajectories of these select vocalic variables. Boberg's metric for /æ/ retraction measures the variable as inherently relative to /uw/, which may confound to some degree two potentially unrelated changes in progress. This view obscures whether /æ/ is backing or /uw/ is fronting or whether both are happening independently.

Pappas and Jeffrey (2014) investigate typical raising allophones along with /æ/ retraction and /e/ lowering among 23 speakers from Vancouver and Victoria, providing the most recent analysis of /æ/ available in the literature. Their sample was comprised of twelve speakers from Vancouver (six male and six female) and 11 speakers from Victoria (five male and six female) who fell into two distinct age groups with 12 older speakers being born between 1947 and 1963 and 11 younger speakers being born between 1983 and 1991. The data were collected by open-ended conversational interviews and by a word-list reading task using a Marantz PDM 660 recorder and a Sony ECB 4 microphone. They follow the same methodology outlined by Boberg (2008) for measuring the F1 and F2 of target vowel in PRAAT (5.3.05). This involves placing the cursor at the maximal point of F1 for vowels whose main gesture involves tongue lowering and raising and at the point of inflection in F2 for vowels involving a horizontal tongue direction. In other cases, measurements were taken from the middle of the steady state of the vowel.

Pappas and Jeffrey normalized their data according to the Labov ANAE Telsur G value provided in the NORM online suite (Thomas and Kendall 2007). This calculates scaling factors as the ratio of a speaker's natural log mean of formant values against the equivalent log mean for the group as a whole. These results were used to calculate each speaker's means for the vowels and allophones in question and descriptive statistics were then computed using the software R (2.15.2).

Their assessment of raising examines both /ay/ and /aw/ before /t/. Using an unraised-to-raised height difference of 60 Hz in F1, Pappas and Jeffrey find Canadian Raising to be a robust phenomenon in British Columbia. They find a mean difference of 102 Hz for the F1 of /ay/ versus /ayT/, and a mean difference of 79 Hz for /aw/ versus /awT/. By the 60 Hz difference diagnostic, nineteen of the their speakers raise /ay/; fourteen raise /aw/. City of origin is a significant factor for /ay/ raising with all Vancouver speakers being raisers, and the non-raisers hailing from Victoria. Pappas and Jeffrey also confirm Boberg's (2008) finding that raising of /ay/ is only very weakly correlated with raising of /aw/. In examining F2 for the raising diphthongs, Pappas and Jeffrey find little evidence of fronting for /ayT/ and /awT/, though they do note that Victoria speakers show greater fronting than Vancouver speakers.

Pappas and Jeffrey define retracted /æ/ as having a normalized F2 value of less than 1825 Hz, lowered /e/ as having an F1 value over 650 Hz. They find fairly uniform patterns for /e/ and /æ/. By these criteria, eighteen of the individual 23 speakers in their sample are /e/ shifters, and the overall group mean for F1 of /e/ is 693 Hz. Twenty of the 23 speakers in their samples are /æ/ shifters, and the overall group mean for F2 of /æ/ is 1686 Hz. It is also noteworthy that the three non-shifters for /æ/ are from Victoria, not Vancouver. All of the non-shifters for /æ/ are part of the older speaker group rather, while all eleven of the younger speakers are /æ/ shifters.

Their analyses of age and gender groups suggests that the change for /e/ is nearly complete, while the change for /æ/ is still progressing. Pappas and Jeffrey also find a high correlation between year of birth and /æ/ retraction for both men and women (r = -0.68 for women and r = -0.7 for men). When the data are plotted by speaker sex and age it appears that, consistent with Esling and Warkentyne's early observations about women as the leaders of the /æ/ change, both men and women are advancing in /æ/ retraction, but men seem to be lagging behind by about a generation.

Pappas and Jeffrey's (2014) pilot serves to confirm many observations made in Boberg (2008) as well as in Sadlier-Brown and Tamminga (2008). Namely, Canadian Raising and Canadian Shift are robust in British Columbia, though Pappas and Jeffrey's work suggests some differences in the way Victoria and Vancouver speakers are participating in these changes. While Pappas and Jeffrey's methodology is useful for making consistent comparisons with prior research on the Canadian Shift and Canadian Raising, it is not consistent with the normalization or formant trajectory approaches that have been used to examine /æ/ raising among Seattle speakers. In order to compare changes involving /æ/ in these two neighboring populations, a unique methodology must be used to address them both.

2.2.3 Summary

To summarize, prior observations of the Canadian Vowel Shift and /æ/ retraction in Vancouver suggest that:

- It is a change in progress being led by middle-class women, but advancing among men and women.
- Pre-lateral and pre-fricative environments may favor /æ/ retraction; pre-nasal and pre-velar environments inhibit retraction and promote tensing and raising.

- Retracted /æ/ is a below-consciousness variable, not stigmatized or subject to stylistic variation.
- Retracted /æ/ may be an indicator of West Coast Canadian English.
- Retracted /æ/ may be characterized by a normalized F2 less than 1825Hz in a single-point analysis.
- Retraction of /æ/ may also be observed by relative Mean Cartesian Distance of /æ/ to /uw/ in which /æ/ has a lower F2.

2.3 Seattle and Washington State Vowel System

Though according to the ANAE, Seattle falls into the large dialect region called "the West," ongoing research suggests that this massive geographic space is comprised of several sub-dialectal regions, with the American Pacific Northwest making up one. Still, relatively few studies have addressed English in the dialectally young Pacific Northwest region. Boberg (2008) describes Seattle speakers as participating in the pre-nasal and pre-velar raising of /æ/, similarly to Vancouver speakers.

2.3.1 Historical Accounts

Reed (1952) provides one of the first descriptions of English in Washington State calling it "one of the last linguistic frontiers in the United States" (Reed 1952, p. 186). He describes the settlement patterns of the past century, highlighting that emigrants to the area have largely been Midwesterners from Illinois, Indiana, and Ohio. These settlers seem to set a linguistic tone for the region, one resulting in an essentially Midwestern norm of pronunciation throughout most of the state. He observes a lack of *cot*/*caught* merger, particularly in the western half of the state, though acknowledges that adolescents may be ceasing to distinguish the low-central from low-back variants. The words *Mary, marry,* and *merry* are merged for most Washington speakers, Reed observes. He also comments on the loss of aspiration in *wh-* words, stating that [hw-] is rarely overheard in comparison to [w-] and describes hyper-correction by which the aspiration is added back for elegance in certain items. He also notes lowering of /ɪ/ to /e/ in words like *milk*. Interestingly, he also notes that *hang* and *catch* are regularly pronounced 'heng' and 'ketch' suggesting raising of the /æ/ phoneme in certain lexical items, and possibly in the pre-velar environment. He briefly describes the dialectal differences attributable to different immigrant and indigenous ethnic groups throughout the state and concludes that Washington's dialectal diversity is an ideal group for experimental research.

In a later study, Reed (1961) addresses the phonemic inventories of Pacific Northwest speakers, including Washington and Oregon as well as parts of Montana and Idaho. He notes that while [æ] predominates in words like *glass, half, aunt,* and *can't*, a small number of "cultured speakers" produce [a] in these words. Reed speculates that the occasional use of these forms may be relics of New England pronunciations and may have become prestige forms among educated speakers. He also notes the pre-velar merger of /e/ and /ɛ/ in words like *egg*. Reed observes a handful of lexical items for which /ɛ/ and /æ/ seem to be in variation and roughly equal in their distribution among speakers: *catch, wheelbarrow,* and *parents* make this list. He does also note that in words like *bag,* there is variation between [æ] and [æ^{I}], suggestive of pre-velar raising and tensing. Reed's observations provide some insight into the state of Washington State and Pacific Northwest English in the 1950s and 1960s. From the mention of pre-velar raising for /ɛ/ in *egg* and /æ/ in *hang*, however, it is difficult to pinpoint the extent of lexical and speaker variation or broader vowel changes that were affecting the region. Yet, Reed's early observations suggest that the Washington State pre-velar merger and the divergent vocalic changes from Northern Cities speakers may not be only recent developments.

Foster and Hoffman (1966) provide observations of Seattle English among speakers in their twenties who had grown up in the Seattle area. They focus mainly on the *cot*/*caught* merger, which they describe as well-advanced for most speakers. They find the low back rounded vowel to be more common than the low back unround one in words like *cot, swamp, laundry* and *water*. They also state that [æ] is virtually universal for words like *ask, aunt, glass,* and *rather*. They do also mention some degree of raising of the diphthong /aw/ before voiceless consonants in northern areas as is found in Canadian Raising, but that this raising remains associated with Canadian speakers: "In the case of [ɜʊ] for [aʊ], Seattle-area residents recognize in the user of [ɜʊt] or [hɜʊs] one of their neighbors from British Columbia" (Foster and Hoffman 1966, p. 122). Foster and Hoffman, like Reed before them, identify primarily changes to the back vowel system as principle characteristics of the Washington State and Seattle-area dialectal region. Perhaps precipitated by these changes to the back vowel system, recent work on Seattle English has identified several key changes to the front vowel system as distinguishing features of the dialect, suggesting that these changes are relatively recent developments that have more noteworthy since their time of writing.

2.3.2 Recent accounts of pre-velar raising of /ɛg/ and /æg/ in Seattle English

The majority of current research on Seattle English has examined the changes in progress to the front vowel system, namely the raising of /ɛ/ and /æ/ in pre-velar environments. Drawing on a large corpus from Washington speakers, Wassink et. al. 2009 present an analysis of vowel changes for 17 speakers (12 female, 5 male) made up of three age cohorts and three ethnic groups. The oldest speakers in the study were born between 1900 and 1950, the middle-aged speakers were born between 1951 and 1971, and speakers in the youngest group were born between 1976 and 1986. The data were collected with word-list tasks, semantic experimental tasks, reading passages, a demographic interview and a conversation. Approximately 550 vowel tokens were collected per speaker using a M-Audio Microtrack Compact Flash Recorder and an Audio Technica microphone. Formant frequency measurements were taken at the onset, offset as well as at 20%, 50%, and 80% of the vowel's duration. The acoustic analysis of the tokens was conducted in PRAAT using a customized script, and the data were normalized using Uniform Scaling normalization (Nearey 1977). Euclidean distances were used to represent the vowel-inherent spectral change in the time-proportional segments from 20% to 80% of each vowel's duration. A two-dimensional assessment of vowel overlap was presented using VOIS3D (Wassink 2006). This presents spectral overlap data as a plot of the two-dimensional elliptical spaces occupied by each vowel (or allophone) based on the vowel's normalized F1 and F2 axes. The degree of overlap with another vowel or allophone is reported as a real number, a percentage from 0 to 100%, and these overlap fractions were calculated for men and women for each of the three different task types (word list, reading passage and demographic interview).

Wassink et al. (2009) find that while all of the PNW speakers in their sample share similarities in the basic shape of their vowel systems, some older speakers may have unmerged *cot*/*caught* vowels. Young female speakers, on the other hand, show a complete merger. Based on the Euclidean Distances they observe for /e:/ and /e/ (221 Hz and 241 Hz, respectively), they find evidence of monophthongized /e:/. For /æ/, they observe raising and fronting of pre-velar (BAG) tokens. Wassink et al. also find that /æ/ does show pre-velar tensing and raising, however, they emphasize that /æ/ does not show pre-nasal tensing and raising as its F1 slope does not significantly differ from /æ/ preceding other consonants. This lack of pre-nasal raising distinguishes Pacific Northwest /æ/ from its position in the Northern Cities Shift (as well as in the Canadian Shift). The study indicates gender as well as style-based differences in the extent of merger. Based on mid-point data, females appear to merge /ɛ/ and /e:/, but a larger view of the segment reveals that the trajectories for the two still proceed in different directions. Using overlap fractions and formality of task type, both Wassink et al. observe that both men and women show a greater tendency to overlap vowel categories for the more casual environments. However, men and women show inverse patterns for the merger of /ɛg/ words and /eyg/ words: men show a complete merger in the most casual conversation task, while women show only a 33% overlap in the conversation and a greater overlap in the most formal word list environment (86%). Men and women also seem to have different preferences for which of the three vowel classes they merge. In this analysis, women show higher rates of overlap between /æg/ and /ɛg/ while men show higher rates of overlap between /æg/ and /eyg/.

Freeman (2013) examine the BAG, BEG, BAGEL merger in more detail and sheds light on the social differentiation of the change. She provides evidences that /eg/ and /ɛg/ are merged in Pacific Northwest English (PNWE) based on a lowering of the former and raising of the later and that pre-velar raising of /æ/ targets this new area of merger rather than the higher space occupied by /e/. Freeman points out that while mergers generally violate the preferred balance of a phonological system, the paucity words belonging to the /eg/ class may nullify the often-cited motivation to maintain distinction. (There are literally no minimal pairs resulting from a potential merger of /eg/ and /ɛg/ or /æg/ words.)

Freeman's data is part of the larger PNWE project, drawing from the same data set as Wassink et al. 2009, but with some additional interviews specifically added to elicit greater tokens targeting pre-velar front vowels. The sample under analysis includes data from 20 Seattle-area Caucasian speakers of PNWE who were balanced for age and sex. Ten speakers between the ages of 18 and 36 made up the younger group; ten speakers between 37 and 62 made up the older group. Subjects were recorded with a friend or family member when possible using a Samson H4Zoom HandyCorder. The interviews began with two informal tasks (conversations and a demographic interview) and moved on to three more formal tasks (an oral linguistic questionnaire, a reading passage, and a word list task with three repetitions.) Freeman's analysis includes 27 base words (with about 5 repetitions) of /æ/, /ɛ/ and /e/ from the reading passage and the word list tasks, with a special focus on the pre-velar environment. Transcripts of the reading passages and word-list were force-aligned using P2FA (Yuan & Liberman 2008), and these phone-level boundaries were hand-corrected in PRAAT. Vowel measurements (onset, offset, duration and formant data) were extracted using a PRAAT script at 20%, 50% and 80% of vowel duration. Potential outliers (formant values exceeding two standard deviations at each time point) were hand-checked for accuracy. Speaker data was normalized according to the Bark Difference Metric in NORM Vowel Normalization suite (Thomas and Kendall 2007). This vowel-intrinsic method converts raw Hertz to Bark z-scores and then subtracts F1 from F3 to model vowel height and F2 from F3 to vowel frontness/backness. The normalized midpoint distributions were plotted as ellipses using the phonR package (McCloy 2012). The overlap of vowel distributions was quantified using VOIS3D (Wassink 2006). Formant trajectories for the vowels were modeled using Smoothing-Spline ANOVA's in R. These plots model curves in the vowel formant trajectories with greater detail than single point or vector analyses. Freeman's analysis measured 2,556 tokens, which were largely balanced by speaker group.

Across the sample as a whole, Freeman finds that /ɛg/ and /eg/ overlap at a spectral location mid-way between /e/ and /ɛ/ suggesting lowering for pre-velar /e/ and raising for pre-velar /ɛ/. All three of the pre-velars have rising upglides, do not differ significantly in duration from the non pre-velar counterparts. This means that /eg/, /ɛg/ and /æg/ may continue to be differentiated for speakers not based on their spectral location, but on duration. For speakers in Freeman's study, canonical /e/ has an F1 of 424 Hz and F2 of 2283 Hz as compared with lowered /eg/, which has an F1 of 514 Hz and an F2 of 2076 Hz. For canonical /ɛ/ F1 and F2 are at 601 Hz and 1870 Hz, respectively, while raised /ɛg/ tokens reach 505 Hz and 2043 Hz. The 3D spectral overlap fraction for /eg/ and /ɛg/ reaches 91% suggesting that preceding a voiced velar the two are nearly completely merged. This overlap of /e/ and /ɛ/ appears to be the target for pre-velar /æg/ raising as canonical /æ/ has a F1 of 743 Hz and 1737 Hz as compared to raised /æg/ at 622 Hz and 1901 Hz. The spectral overlap percentage for /æg/ is about 95% with /ɛ/, and over 60% with each /eg/ and /ɛg/. When 3D rather than 2D overlap percentages are computed, the overlap percentages reveal the potentially crucial role of duration in continuing to differentiate some classes. For instance, /æg/ shows a 61% overlap with /ɛg/ in 2D, but only a 47% overlap with /ɛg/ in 3D, due to differences in duration. The results of Freeman's SS-ANOVA confirm that /ɛg/ and /eg/ have very similar trajectories, and that their onsets are very close to monophthongal /ɛ/. The trajectory for /æg/ is overlapping /ɛ/ at its midpoint, but it begins lower and ends more front than /ɛ/. These differences in trajectory and duration may serve as perceptual cues to continue differentiation of the word classes.

Freeman also reports social differentiation between her groups of speakers in terms of age and sex. While the merged /eg/ and /ɛg/ classes are ubiquitous for all groups in her sample, /æg/ class words show differences by group. Older men show the highest degree of overlap between /æg/ and /ɛg/ at 89% (/eg/ at 99%), followed by older women who show only a 49% overlap between /æg/ and /ɛg/. Notably, the youngest speakers in the study show the least degree of overlap between /æg/ and /ɛg/ or /eg/. Younger males show an overlap of 46% between /æg/ and /ɛg/, and the overlap is less still for young females speakers at 41%. This finding suggests that the more innovative pattern may be a merger of the /eg/ and /ɛg/ classes, but a spectral differentiation of /æg/ from the merged /eg/~/ɛg/ class. More data is needed to confirm this speculation.

Riebold (2012) considers what /æ, ɛ, e/ are doing in non-merger environments. His sample is small (*n* = 4), and three of the four speakers are from Corvallis, Oregon, not the Seattle area. The speakers were all white, middle-class speakers between the ages of 24 and 26. The data were collected via directed interview, reading passage and three repetitions of a word list, though only data from the 33 (times three repetitions) word list items were analyzed as part of the current study. Riebold used a PRAAT script to extract formant information at onset, midpoint, and offset of each vowel nuclei and to measure the duration of each segment. He analyzed a total of 394 tokens of /æ/, /ɛ/ and /e/.

He finds that /æ/ is raising pre-nasally and may also be raising to a lesser extent before non-nasal and non-velar obstruents. Based on the similarities between the observed merger environment (pre-/g/) and the non-merger environment (preceding other consonants), he suggests that the merger may be spreading to new environments. Riebold also suggests that /æ/ may show backing pre-laterally. In comparing /æ/ tokens according to manner of articulation of the following consonant, he finds that nasals are considerably higher and fronter than stops, which are just slightly more fronted than fricatives, and the pre-obstruent /æ/ tokens are more front than the pre-lateral tokens. Riebold's study provides a very interesting assessment of how the front vowel system, including /æ/, might be changing in non-prevelar environments, though more data is needed from Seattle area speakers to better understand these developments, especially to offer comparisons to the retraction observed for /æ/ in Vancouver.

Riebold (2014 and 2015) considers the spreading innovation of the pre-velar /æg/, /ɛg/, /eg/ merger among three non-white ethnic groups in the Seattle area. Using data collected for the second phase of PNW English project also analyzed by Freeman (2013), he discusses the merger among Japanese American, Mexican American and Yakama Nation speakers in Washington State. This second phase of the PNWE project was revised to elicit more tokens to address the pre-velar raising observed by Wassink (2009) after the first phase of the project. The Japanese American speakers were Seattle residents, and the Mexican American and Yakama Nation speakers were from the Yakima Valley area. These three ethnic communities were selected, in particular, due to their early presence or immigration to Washington, with the peak of Mexican immigration more recent than the other two groups. Data were collected from participants in their homes using a Zoom H4n Flash Recorder. Reading passage and wordlist data from 24 speakers were analyzed for this study. The data were normalized according to the Bark Difference Metric, and smoothing spline analysis of variance was used to examine the formant trajectories. Tokens were plotted using traditional normalized F1 by F2 methods, and spectral overlap percentages were also calculated using VOIS3D. Riebold considers whether the three ethnic groups in his is study are participating in raising and, if so, whether they show indications of merger. For his analysis, raising of is defined as significantly raised or fronted as compared to non-pre-velar tokens and merged is defined by having an overlap fraction indicative of partial or full merger.

Contrary to common assumptions that ethnic groups display inherently different trends than Caucasian speakers, Riebold (2015) finds that all three ethnic groups are participating to varying degrees in the same changes observed for Caucasian speakers. Considering speakers of all ages, sexes, and ethnicities all together, participants show a complete merger of /ɛg/ and /eg/ (3D Overlap Fraction at 0.81). Yakama Nation speakers were the most advanced in this trend with all gender and age subgroups showing full merger (all groups > 0.82), and no sub-group of age or gender in any ethnic group showed less than a partial merger of /ɛg/ and /eg/. In terms of merging /æg/ with /ɛg/, female speakers and younger speakers across all three ethnicities show a greater degree of raising than males or older speakers. The Japanese American, Mexican American and Yakama Nation speakers all showed evidence of raising /æg/ to /ɛg/, but unlike the first two groups, Yakama Nation speakers do not merge /æg/ and /ɛg/. For all ethnic groups, females and younger speakers show a greater degree of raising and merger of /æg/ and /ɛg/. Among Japanese American and Mexican American speakers, the youngest speakers partially merge /æ/ with /ɛg/. Yakama Nation speakers appear to participate least of the three groups in raising /æg/ to /ɛg/. In comparison with Freeman's finings for Caucasian speakers, however, Riebold speculates that there may be prestige differences for pre-velar raising among ethnic speakers. For Freeman's speakers, older men were show to lead in raising /æg/ to /ɛg/, while the opposite is true of Riebold's sample.

In considering SS-ANOVA plots of the vowels in question, Riebold's findings for ethnic group speakers are consistent with Freeman's findings for Caucasian speakers. In particular, he finds that pre-velar /eg/ tokens are similar to /e/, but end lower and backer; moving in the opposite direction from the pre-velar tokens /æg/ and /ɛg/. Pre-velar /æ/ and/ɛ/on the other hand start in approximately the same location as their non-pre-velar counterparts, but are differentiated by mid-point by both raising and fronting and this differentiation continues through the offset. Riebold, like Freeman, also suggests based on 3D overlap fractions that duration may continue to differentiate raised /æg/ from /ɛg/. Again, this finding mirrors Freeman's findings for Caucasian speakers suggesting that ethnic minorities in the Seattle area should be considered part of the same speech community as Caucasian speakers in the same area.

2.3.3 Summary

To summarize, the following observations of front vowel shift (including /æ/) have been made for Seattle speakers:

- Pre-velar lowering of /e/ and raising of /ɛ/ results in a nearly complete merger of /eg/ and /ɛg/ for Seattle talkers, though the two may remain distinct by durational differences.
- Pre-velar tensing and raising of /æ/ to overlap the merged /eg/ ~ /ɛg/ class is common among Caucasian and ethnic speakers from Washington state.
- This feature remains below the level of consciousness for many speakers, though it may be reaching the level of conscious awareness for some.
- It shows sensitivity to stylistic variation in different experimental task settings, with its use declining in more formal contexts.
- Prestige and stigma may operate differently among White speakers as compared with Japanese American, Mexican American and Yakama Nation speakers.
- Lack of pre-nasal raising of /æ/ may distinguish Washington speakers from Northern Cities and Canadian speakers.
- Speakers from Washington State may show some degree of raising of typical Canadian Raising diphthongs /aw/ and /ay/ in pre-voiceless environments, yet the degree of raising remains acoustically (and perceptually) distinct from the Raising more commonly exhibited by Vancouver speakers.
- No accounts have documented /æ/ retraction among Washington or Seattle speakers.

Taken together, these studies suggest that Vancouver and Seattle are participating in different vowel shift patterns and that, despite their close geographic proximity, the dialects remain quite distinguishable based on a handful of vocalic variables including height of traditional Canadian Raising and discrepant changes within the front vowel system. The dialects may show similarities with respect to /æ/ raising in pre-velar and pre-nasal environments, but are reportedly undergoing different changes with respect to /æ/ in other phonetic environments. Specifically, /æ/ retraction has not been documented among Seattle speakers, while it has been well documented among Vancouver speakers in non-pre-velar environments. Furthermore, the methodologies used to document /æ/ changes within the two dialects do not allow for one-to-one comparison. To allow for sound comparison, the current project will provide an extensive production study before beginning the outlined perceptual experiments. Methodology for this production study will be introduced in more detail in the following chapter, but a summary of the relevant literature guiding these methodological choices is given below.

2.4 Methodological Choices in Previous Research

The aforementioned studies of vowel changes in Canadian and American dialects of English Pacific Northwest span over a half-century and have made use of a vast range of methods and technologies in their analyses. New technologies and tools (such as Forced Alignment and online normalization tools) are continually reshaping phonetic analysis. There is a methodological gap not only between early and later studies, but even among more recent studies, between the schools of researchers investigating Canadian and American vowel shifts. Most previous studies of the Canadian Vowel Shift have relied on single-point analysis of vowels and on classification of vowel phonemes by unidimensional F1 or F2 standards (Boberg 2008, Sadlier-Brown 2012, Pappas and Jeffrey 2014). Studies of vowel changes in American dialects of the Pacific

Northwest have relied largely on spectral overlap comparisons between phonemes and on formant trajectory modeling via SS-ANOVA analyses (Wassink and Koops 2013, Freeman 2013, Riebold 2014). Normalization methods have also been notably different between these schools with the former more inclined to rely on Labovian methods and the former more inclined to rely on the Bark Difference Metric. These methodological differences may have arisen in part due to the nuanced questions under investigation as part of the Canadian Vowel Shift and the Seattle-area raising and merger phenomena, and may have been perpetuated by subsequent researchers out of desire to remain consistent with previous studies on the topic. Nonetheless, the discrepancies make a cross-border dialectal comparison difficult. The various approaches to token identification, normalization and acoustic analysis are discussed below.

2.4.1 Forced Alignment

The Penn Phonetics Lab's Forced Alignment tool (henceforth P2FA) allows for efficient automatic identification of vowel tokens in an audio file when a phoneme-level transcription of the file is available (Yuan and Liberman 2008). The phoneme level transcriptions (written in Arpabet) are taken from the CMU online pronouncing dictionary. P2FA uses Gaussian mixture models and monophone Hidden Markov Models to automatically identify segments (or speakers) within an audio file. The training data for the model was 25.5 hours of audio taken the SCOTUS corpus arguments recorded in 2001. Yuan and Liberman's (2008) main objective was to use the tool for the purpose of speaker identification, though its performance at Forced Alignment of words and phoneme boundaries has become invaluable to phoneticians working with large data sets. The tool provides a benefit to researchers in that it allows more tokens to be identified and analyzed more quickly within an audio file than by manual listening identification. This is especially so when identification of phonemes involves unscripted conversational data such as those from typical sociolinguistic interviews, although forced alignment of word list data is also beneficial when many repetitions are elicited. There is a potential drawback in that automatic recognition of phoneme boundaries tends to be less accurate than manual recognition by a trained phonetician. Yuan and Liberman (2008) find that the majority of word onset boundaries differed by less than 50 milliseconds between automatic and manual identification, yet for phoneticians interested in phone-level analyses, phone boundaries for automatically identified segments must be hand-checked for accuracy. For maximum accuracy, audio files should also be checked to ensure that the transcriptions are exact and that all undesired background noise is flagged and removed.

Once vowel segments have been automatically identified and hand-checked using Forced Alignment, phoneticians must decide what information to extract about the segments they will examine. Formant and duration information from the identified segments can be automatically extracted using a PRAAT script. Such a script returns formant information as a comma or tab-delimited file, which can be easily converted into an Excel spreadsheet. Various Excel functions can be used to aid in the identification of possible outliers or mistaken measurements from PRAAT. For instance, an Excel function can be directed to flag or highlight any formant measurement that falls more than two standard deviations from the mean for all the tokens sampled (or all tokens within a particular class).

2.4.2 Single Point Analysis vs. Time-Proportional Representation

While studies of Vancouver English and Seattle English have both relied on PRAAT (Boersma and Weenik 2013) as the tool par excellence for acoustic analysis, the type of formant information extracted for segments has not been consistent between these two research paradigms. One crucial difference involves the number of time points at which formant data are extracted. Boberg (2008), Sadlier-Brown (2012), and Pappas and Jeffrey (2013) have followed a Labovian "central tendency" approach to extract formant data at single time point within the vowel's nucleus, either at a peak or within a steady date (Labov 2006). Wassink and Koops (2013), Freeman (2013), and Riebold (2014) have opted to extract formant data at time-proportional intervals (at 20%, 50% and 80% of each vowel's duration). While he admits that no systematic study has been done to compare single-point and multi-point methods, Di Paolo and Yeager-Dror (2010) and Evanini (2009) both discuss the drawback of single point analyses: this inherently means losing potentially relevant informant about a vowel's trajectory over time, which is a considerable loss for diphthongal vowels and acoustically-complex monophthongal vowels, as well. Such an approach could fail to capture changes apparent- or real-time changes within one dialect (such as monophthongization or diphthongization), and might also fail to identify important differences in vowel trajectories between different dialects in a comparison. Studies have shown that speakers are perceptually sensitive to nuanced differences in formant trajectories and use more information than a vowel's formant structure at midpoint to identify a talker's region of origin or ethnicity (Wassink and Koops 2013). Finally, while midpoint data is thought to avoid the potential effects of neighboring consonants at onset or offset, this also obscures the possible relationship between phonologized coarticulatory effects that result in language change over time.

2.4.3 Normalization of Raw Formant Data

For the sociophonetician, normalization strives to minimize variations in the acoustic signal that are due to talker-specific characteristics of vocal anatomy while preserving acoustic differences that indicate variation within the phonological system of a speaker and across groups of speakers. As with other methodological issues, there is singular approach to normalizing raw formant data, and NORM, an online normalization suite (Thomas and Kendall 2007) has made available for linguistics several different approaches. Adank, Smits and van Hout (2004) and di Paolo and Yeager-Dror (2010) outline different normalization techniques and describe their appropriateness for different analyses. Normalization methods differ in whether they are *vowel-intrinsic* or *vowel-extrinsic*. As the terms imply, *vowel-intrinsic* normalization techniques are suitable for analyses that do not contain data from the entire vowel system, but rather focus on a select subset of phonemes or a select area of the vowel space, such as front vowels. When *vowel-intrinsic* methods are applied, each vowel token is essentially compared to itself. On the other hand, *vowel-extrinsic* techniques are more appropriate when data from the entire vowel system is examined or compared, and they compare information from each vowel token to other vowels in the system. Normalization techniques may also differ in whether they are *speaker-intrinsic* or *speaker-extrinsic*. Parallel to the distinction between for vowels, *speaker-intrinsic* methods compare data from each speaker to him or herself; *speaker-extrinsic* methods compare data from each speaker to a grand mean calculated for all speakers (di Paolo and Yeager-Dror 2010, Adank, Smits and van Hout 2004).

Previous studies of vowel changes in Vancouver English and Seattle English differ in their normalization approaches. Recent acoustic analyses of pre-velar raising in Seattle have relied on the Bark Difference Metric as a vowel-intrinsic normalization technique (Freeman 2013, Riebold 2014). Recent studies of Vancouver English (Boberg 2008, Sadlier-Brown 2008, Pappas and Jeffrey 2014) have used Labov's method, which is a modification of the Nearey Method (Nearey 1977). The Bark Difference Metric method involves computing z-scores from the F1, F2, F3 and differences in formant z-scores for the height (F3-F1) and backness (F2-F1) dimensions. NORM implements the Bark Difference Metric according to the formula in

Traunmüller 1997: $Zi = 26.81/(1+1960/Fi) - 0.53$. One possible disadvantage of this method is its reliance on F3. In the event of a poor quality audio recording or a type of recording with altered values for F3 (telephone data, for example), the metric will be less accurate. This same principle makes the Bark Difference Metric unfit for normalizing data from rhoticized vowels. Yet for the current project, its benefits outweigh drawbacks: as a vowel-intrinsic approach, it is appropriate for use with a subset set of the vowel system, as will be analyzed in the current study of /æ/ and the front vowel system. It is also less sensitive to differences in phonological inventory between dialects, which is an advantage as the current study provides a comparison across two dialects. Labov's Method, on the other hand, is speaker-extrinsic, uses a log-mean and compares data from each individual to a grand mean, a constant "Telsur G" value, calculated from Labov's corpus containing data from 345 American English speakers. An obvious advantage of using this approach is its comparability with previous seminal works in North American dialectology such as those provided in the *ANAE* and Boberg (2008). One disadvantage of this method is that the grand mean for all speakers has been observed to change significantly above the 345 individual speaker count (Labov, Ash, and Boberg 2006), which implies that the method would be most appropriate for studies with extremely large subject counts. Another disadvantage vis-à-vis the current study is that this vowel-extrinsic method works best with data from the entire vowel system, rather than just a subset of phonemes.

2.4.4 Classification and Comparison of Vowels

The ANAE, Boberg (2008), Sadlier-Brown (2012) and Pappas and Jeffrey (2013) rely on a priori defined normalized frequency values for their classifications of phonemes. For instance, retracted /æ/ is defined as having a normalized F2 frequency of less than 1825Hz. Studies of Seattle English (Wassink 2006, Wassink et al. 2009, Freeman 2013, and Riebold 2014) have presented acoustic analyses in terms of spectral overlap using VOIS3D to model the degree of similarity in F1, F2, and duration demonstrated by two phonemes or allophones. The VOIS3D program returns an “Overlap Fraction” as a real number which can be represented as a percentage from 0-100%. This approach is inherently agnostic regarding the distinct strategies and targets speakers may have in their realizations of different tokens (fronting, raising, or both). (Both studies of /æ/ raising and /aw/ raising have shown the tendency for movement on one dimension (F1 or F2) to accompany movement in the other dimension, which means it is prudent to leave acoustic analyses open to detecting movement in both dimensions.) This approach is also inherently more reflective of perceptual realities experienced by listeners, since differences on F1, F2, duration, or overall trajectory may serve as acoustic cues for listeners. For the current purposes of comparison across two dialects that may demonstrate substantially different trends for /æ/ movement (one characterized primarily by a change in F1; the other more fundamentally by a change in F2), it will be advantageous to remain agnostic about the direction and degree of the changes at hand by representing the overlap of F1, F2, and duration for Vancouver and Seattle speakers allophonic realizations of /æ/.

2.4.5 Smoothing Spline ANOVA

Another method to represent dynamic differences between Vancouver and Seattle speakers' realizations of /æ/ is using a Smoothing Spline ANOVA (see Gu 2002 for an introduction). Like VOIS3D analyses, a Smoothing Spline ANOVA of formant trajectories allows for comparison of normalized F1, F2, and duration information. To the author's knowledge, no studies of Vancouver English have utilized SS-ANOVAs to examine formant trajectories of vowels involved in Canadian Raising phenomena or in the Canadian Shift. Koops (2010) finds that speakers from different ethnic backgrounds in Houston may show significant differences in their execution of formant trajectories over time and that analyses of the spectral properties (F1 and F2) of the vowel nucleus alone may fail to capture distinctions that listener's, in fact, rely on as perceptual cues. SS-ANOVA's, which represent the dynamic properties of the vowel as a whole, are able to more faithfully capture cross-dialectal differences in nuances like relative nucleus-glide timing (see Johnson 2005 and Thomas 2004 for more). This issue is of special interest in light of the current study's intention to better understand how phonetic information relates to stereotype formation and perception of dialectal origin. In light of Sadlier-Brown's (2012) findings that Washington and Vancouver speakers may both produce raised /aw/ tokens and yet remain perceptually distinct for speakers, the rich comparison of formant data by SS-ANOVA will allow for greater insight into dynamic differences speaker productions and differences in formant trajectories that may serve to perceptually differentiate Vancouver talkers from Seattle talkers. Although /aw/ raising is most often cited as a stereotypical feature of Canadian dialects, listeners may be relying on cues from many other acoustic properties including nuanced differences in formant trajectories for a host of other vowels including /æ/. For the richest possible understanding of these nuanced differences in production (which may in turn serve as perceptual cues of ethnicity or nationality), use of SS-ANOVAs to model entire formant trajectories is preferable to single-point vowel comparisons of Vancouver and Seattle speaker data.

2.5 Phonetic Motivations for Diagnostic Features

An important question in considering diagnostic features of Seattle and Vancouver dialects concerns the status of allophonic or phonetic processes observed. As described in Chapter 1, a central issue in studies of sound change is how (some) phonetic universals may become exaggerated beyond what can be considered a coarticulatory effect due to anatomical or physiological factors. The notion of phonologization (Hyman 1976) articulates the way a phonetic universal may become more than just that, acting instead as an arbitrary feature of the language's phonology. This distinction, then, between the phonetic universal and the phonologized feature is critical in its ability to differentiate dialects or languages. (This leaves for the future the complex question of speakers' varied styles and the degree of control they exhibit over coarticulatory and phonologized processes.) (Eckert, Age as a Sociolinguistic Variable 1998)A phonetically universal effect would be predicted to occur in every language or at least in every dialect of the same language, while a phonologized feature occurs arbitrarily and contrastively in some, but not others. While sociolinguists have relied on the notion of "phonologized patterns" to observe differences between different dialects or languages, they have not often used the dynamic methods necessary to investigate phonetic form of the features they are labeling as "phonologized" and relying on as important diagnostics (Labov, Ash and Boberg 2006, Bobgerg 2010). Phoneticians, on the other hand, have explored the coarticulatory effects of segments on their neighbors, but have generally not addressed the idea that coarticulatory phonetic processes may vary across dialects or groups of speakers. Roeder (2009) observes that in their investigations of phonetic effects of coarticulation, neither Stevens & House (1963) nor Hillendbrand, Clark, & Nearey (2001) discuss whether the effects of coarticulation can or do vary across dialects or speakers. This view of universal coarticulatory processes is an over-simplification and fails to capture potential variation between dialects of speakers with respect to their participation in or exaggeration of processes that might give rise to phonologized traits and dialect markers.

The phonologized processes of a particular dialect do not evolve overnight, and the variation dialects show between universal phonetic effects and phonologized or allophonic contrasts are an important differentiator in and of themselves. To better understand this variation in the extent of phonologization, dynamic analyses of formant structures are crucial because they can identify the locus of the effect as being strictly tied to the presence of a phonetic trigger or gradually less proximal to that trigger and more a part of the phonological system of the dialect. Since the phonetic or phonologized effects are due in each case to the following segment, an investigation must consider whether coarticulatory motivations are exaggerated in phonetic processes like raising and retraction by examining the extent of the difference in the allophonic environments as well as the temporal location of the effect in the vowel's formant structures. For a phonologized feature, this is predicted to occur earlier in the segment's duration; for a phonetic or coarticulatory universal, this is predicted to occur in the immediate presence of the triggering segment that follows. The following provides a summary of the phonetic/allophonic processes at work for each of the 5 variables identified as diagnostic of Seattle and Vancouver English. These fives cases are similar in the sense that the most critical conditioning environment for the vowel is the following segment. (The relevant quality of the following segment varies across these cases between place of articulation, manner, or voicing quality of the following segment, but the conditioning environments of all 5 of the diagnostic variables are related to the following segment.) While most of the previous studies reported in this chapter have not used dynamic methods to assess these phonetic/allophonic processes, the previous literature helps to guide predictions about how Seattle and Vancouver speakers are expected to vary in the extent of their phonologization of these 5 processes.

2.5.1 /æg/ Raising

A velar stop is pronounced by raising the tongue dorsum, which has an effect on the vowel preceding it. A following velar environment has the effect of lowering F1 values and raising F2 values resulting in the visible “velar pinch” where the second formant raises towards the third on a spectrogram (Ladefoged 2001). Lowering F1 and raising F2 causes a vowel to become more raised and fronted in the vowel space. This coarticulatory effect is predicted to affect vowels preceding both voiced and voiceless velars. This would predict a coarticulatory effect causing lower F1 values before both /k/ and /g/ than before /t/ or /d/, for instance, but the effect of /g/ goes beyond that of /k/ in raising the vowel. Prior to work on Pacific Northwest English, this process was also observed by Zeller (1997) for Wisconsin speakers. Given the settlement histories of the Northwest, a sociohistorical account seems probable: this feature was likely introduced to the Northwest region in some capacity by settlers who originated in Wisconsin and Minnesota and migrated West, also accounting for its appearance on the Canadian plains (Rosen 2016). (This is not to say that the feature has not subsequently undergone additional exaggeration or diffusion through the population.) Like for Zeller’s Wisconsin speakers, previous research by Wassink et. al. (2009), Freeman (2013) and Riebold (2013, 2014, and 2015) shows that the effect of /g/ on /æ/ is much greater than effect of /k/ for Seattle speakers and that it also occurs with greater temporal distance from the trigger. The effect on F1 is accompanied by an effect on F2. This suggests a conventionalized raising of /æ/ specifically before the voiced velar, /g/ as compared to before /k/. The conventionalization of pre-velar raising in this voiced environment may have historically been facilitated by the compensatory lengthening of /æ/ (and other vowels) before a voiced consonant (Wassink and Riebold 2013; Baker, Mielke and Archangeli 2008). Wassink and Riebold (2013) point out that systemic factors may also play a role: there is no substantial /eyg/ word class, so raising of the /æg/ class to /eyg/ does not create an inherent problem for lexical differentiation.

As described for Seattle, there is reason to believe that a sociohistorical explanation for the origin of /æg/ raising also applies for Vancouver since it has been observed throughout the Canadian plains (Rosen and Li 2016). While /æg/ raising is mentioned and thought to exceed /æn/ raising (Boberg 2010), no dynamic segemental analyses exist to determine whether /æg/ raising extends beyond the a phonetically universal effect of the following velar. If Vancouver speakers are participating in conventionalized /æg/ raising like what has been documented for Seattle, they would be predicted to show significant differences between the /æk/ and /æg/ environments, where the /æg/ environment shows an exaggerated lowering of F1 from segment onset, prior to the coarticulatory effect of the following consonant. Likewise, a corresponding effect earlier in the segment on F2 would be evidence for conventionalization of /æg/ raising. Similar articulatory and sociohistorical explanations for the origins of /æg/ raising in Seattle and Vancouver also do not preclude the dialects from undergoing independent changes that might unify or differentiate them based on their realizations of /æg/ raising. The results for this analysis will be presented in section 4.1.

2.5.2 /æn/ Raising

The articulatory gesture of lowering the velum for a following nasal segment is expected to lower F1 values of a neighboring vowel (Ladefoged 2001, Baker, Mielke, and Archangeli 2008). Neither Stevens & House (1963) nor Hillenbrand, Clark, & Nearey (2001) consider the effect of a following nasal consonant on /æ/. Labov (1994) states that pre-nasal /æ/ raising is a hallmark of American English, and the ANAE makes further discussion of this as a dialect differentiator. Dinkin (2011) makes clear that a raised pre-nasal system is not monolithic and emphasizes that pre-nasal raising, like other phonetic or allophonic processes, follows a life-cycle. Among speakers of a relatively small geographic area in Upstate New York, he finds evidence of 4 different types of “raised pre-nasal” systems in which pre-nasal /æ/ tends to be the highest and frontest of the allophonic realizations of /æ/, but varies in the extent to which it is separate from /æ/ in other environments. While pre-nasal /æ/ raising is a common phonological process of many dialects of American English, it is not a categorical or binary feature.

In addition to the predicted phonetic effects of a following nasal consonant, Plichta (2004) and Roeder (2009) suggest that pre-nasal /æ/ raising may also have had a perceptual impetus, pointing to evidence that nasal vowels are perceived as higher than oral vowels (Beddor & Hawkins 1990, Stevens 1998). In this view, pre-nasal /æ/ raising would have arisen because a vowel flanked by a nasal consonant would have sounded higher to new learners, and thus, the target for production would have been higher than for a vowel in the absence of a nasal consonant. Though there are strong coarticulatory and perceptual motivations for pre-nasal raising, other evidence suggests that phonologized pre-nasal raising is not a guaranteed outcome.

While many or most dialects of *American* English do show an exaggeration of the coarticulatory effect based on raised and fronted /æn/ from onset, there are several examples to illustrate that phonologized /æn/ raising is not a necessary outcome for the coarticulatory effect of /n/ on the preceding vowel. In British dialects of English, some pre-nasal environments are identified as contributing to phonological lengthening and backing of the /æ/ vowel, the opposite of the fronting and raising effect predicted by the “phonetic universal.” This puts some pre-nasal vowels, in particular those that occur before /nC/ or /mC/ in the BATH class rather than the TRAP class (Wells 1982, Kortmann et al. 2004). Given its history as a British colony, this may be relevant to the participation in pre-nasal raising in Vancouver. The participation of ethnic speakers from other native language backgrounds in pre-nasal raising has also been called into question. Roeder (2009) shows that for Mexican heritage speakers in Michigan a lack of pre-nasal /æ/ raising contrasts sharply with the patterns of young local, native English speaking, women. In her study, local young females illustrated strong phonologized raising and fronting of /æ/ before /n/ while Mexican heritage speakers in the community showed no significant differences in the pre-nasal environment. Thomas (2001) found a similar lack of pre-nasal raising for Mexican speakers in Texas. Interestingly, this raises a question about whether Vancouver might exhibit less pre-nasal /æ/ raising due to its large ethnic population. Though without considering the pattern of individual speakers, this remains only speculative.

Based on previous studies of American English, Seattle speakers are expected to phonologized raising of /æ/ in the pre-nasal environment. This will be evident based on lower F1 values and higher F2 values from the onset of the vowel, prior to any anticipated coarticulatory effect of /n/. Based on Boberg's (2010) findings about weaker pre-nasal raising for Western Canada than Eastern, less phonologized pre-nasal raising is anticipated for Seattle speakers. Vancouver speakers are still expected to show the coarticulatory effect of a following nasal on the F1 and F2 values of /æ/ just prior to the triggering consonant, but not necessarily from onset of the segment. This difference in the degree of phonologization of pre-nasal raising is a potential differentiator for Vancouver and Seattle dialects.

2.5.3 /æ/ Retraction

Very few studies of /æ/ backing in Canadian English and other dialects have investigated the effects of following phonetic environment, and many have relied on impressionistic coding (Esling & Warkentyne 1993, Piercy 2011). In Hall's (2000) small study, however, laterals and fricatives were observed to be an environment favoring retraction for Vancouver speakers. Retraction of /æ/ is phonetically-conditioned before a lateral consonant like the American English /ɫ/, and a front vowel like /æ/ is predicted to be retracted, showing lower F2 values heading into the transition (Ladefoged 2001). The question of phonetically-motivating /æ/ retraction before fricatives is much more complicated. There are (at least) two potential explanations for the case of /æ/ retraction before fricatives. One explanation might propose that what began as a coarticulatory retraction before laterals has extended into other phonetic environments, such as preceding fricatives or even stops. Some of the first observations of /æ/ retraction as part of the Canadian Shift attribute it to the pull shift created by the *cot-caught* merger (Clark, Elms, and Youssef 1995, Esling and Warkentyne 1993). In this pull shift, the other front vowels are also thought to be lowering and backing following /æ/. While there are few studies examining how this change in progress is advancing in different phonetic environments, DeDecker and MacKenzie (2000) do consider the effect of following phonetic context on impressionistically-coded lowering for the front vowels /ɛ/ and /ɪ/. They find that the probability of lowering is greatest before a lateral consonant and second greatest before fricatives for /ɛ/. For /ɪ/, fricatives slightly lowered the probability of lowering. Nasals and stops, in their study, are found to have much smaller probabilities of lowering.

Alternatively, a sociohistorical explanation may be more plausible in this case: the relevant role of fricatives in promoting /æ/ retraction relates to the canonically TRAP-BATH split in British English dialects like RP. Many dialects of British English in the Southeast maintain a split between the vowels of the TRAP-BATH word classes. While TRAP is pronounced /æ/, it is realized more like /ɑ/ in BATH. This phonemic split is thought to have arisen from a process of /æ/ lengthening before voiceless fricatives, which over time yielded a qualitative difference (Wells 1982). In British English /æ/ is pronounced more like /ɑ/ before word-final /s/, /f/, /v/, /θ/, / ð/ and /ʃ/ as well as before word-final consonant cluster beginning with the fricatives, although lexical counterexamples do exist. The change seems to have progressed via lexical diffusion rather than regular sound change, leaving some candidate phonetic environments unaffected by the change and in contrast with the lexical set of BATH words realized with /ɑ/. The environments where /æ/ showed more retraction in Hall's small study correspond with the environments identified as part of the TRAP – BATH split in British English. British Columbia and mainland Vancouver were administered and inhabited by British colonials only a century and a half ago. Unlike for Eastern parts of Canada and the U.S., British colonials arriving on the West Coast would have done so well after this change had progressed in Southeastern England. The TRAP-BATH split began in Southern England in the 1600s, meaning that it would not have been very advanced at the time the first settlers arrived on the East coast, but it would have been well advanced by the time of settlement in Vancouver in the early to mid 1800s (see Beal 2004 and Bailey 1999 for the timing of this change in Southern England). While immigration to B.C. from the U.S., Asia and other parts of Canada has also been common, it would not be a surprise to see residual evidence of this "British" presence in Vancouver speech today. Per Mufwene's Founder Principle, the linguistic features of a founding population for a colony, island or other settlement often persist with disproportionate force in the community's pool of linguistic variants (Mufwene 1996). Of course, the presence of the TRAP-BATH split in the speech of some British settlers of Vancouver does not preclude the independent evolution of this feature among Vancouver speakers over the last century and a half. Piercy (2011) reports that for dialects of Southwestern English, which did not undergo the same phonemic split as dialects of Southeastern English in the 17th and 18th century, there is currently a change in progress by which younger speakers are progressively backing the BATH class. Given the questionable phonetic motivation for /æ/ retraction before fricatives in Vancouver and its distributional historical association with split dialects of British English, it is likely that sociohistorical factors play a role in /æ/ retraction in Vancouver English.

Both Seattle and Vancouver speakers are expected to exhibit lower F2 values for /æ/ before laterals than in other phonetic environments. Based on previous research Vancouver speakers are expected to show lower F2 values for /æ/ than Seattle speakers across all following phonetic environments. If Clarke, Elms, and Youssef (1995) and Hall's (2000) findings are replicated here, Vancouver speakers will also show more retraction of /æ/ before fricatives. For Vancouver speakers, /æ/ retraction may be part of a broader trend of vowel-lowering as articulated in the Canadian Shift, but the effect may also be due in part to sociohistorical factors. In this case, more phonologized retraction for Vancouver speakers would manifest with lower F2 values from onset for /æ/ before fricatives than for Seattle speakers, and there may also be durational differences. for /æ/ before fricatives

2.5.4 Pre-voiceless raising of /aʊ/ and /aɪ/

The lowering of F1 in diphthongs before a voiceless coda is a perceptually motivated process. Moreton (2004) documents the interesting contrast that monophthongs are found to have higher F1 values before voiceless consonants than voiced ones while for *diphthongs*, a following voiceless consonant causes *lower* F1 values. He follows Thomas (2000) arguing that this is due to hyperarticulation before voiceless consonants, causing a diphthong like /aɪ/ to be pronounced more peripherally with lower F1 values and higher F2 values before a voiceless consonant. He illustrates that for American speakers the diphthongs /aɪ ɔɪ eɪ aʊ/ are all realized with lower F1 and higher F2 values before a voiceless consonant than a voiced one and that these changes also act as perceptual cues for the voicing of the following consonant. This principle has become a phonologized effect in many languages and dialects: it acts to preserve the /aɪ/ diphthong in pre-voiceless contexts in monophthongizing dialects of African American English and Southern English and it also has become phonologized in Canadian Raising (Thomas 2013, Chambers 1973). Britain (1997) documents the same type of allophonic raising of /aɪ/ before voiceless consonants in British English of the Fens (Bailey 1999), which is believed to have had an independent genesis from the raising observed in Canada.

While Moreton's hyperarticulation hypothesis is expected to apply equally to /aɪ/ and /aʊ/, prior research suggests that these do not always pattern in the same way for Canadian speakers. Boberg (2008) finds only a weak correlation of /aɪ/ raising and /aʊ/ raising, and also identifies regional differences with respect to whether raised /aʊT/ manifests on the F2 or F1 dimension. Sadlier-Brown (2012) seconds that /aɪ/ and /aʊ/ do not operate in the same way for the Washington and Vancouver speakers she analyzes. Give this previous research, the pre-voiceless lowering of F1 and raising of F2 for diphthong is expected to affected both Seattle and Vancouver speakers. While Seattle speakers are expected to show the hyperarticulatory effect of the following voiceless consonant F1 and F2, the effect for Vancouver speakers is expected to be larger and more temporally distant from the hyperarticulatory trigger. Thus, the dialects are expected to be differentiated by the degree of phonologization they show for these changes. In addition, there may also be different strategies employed by the speakers in these communities with respect to how this hyperarticulation before voiceless consonants is realized.

2.5.5 Summary

Overall, this discussion of phonetic motivations for sound changes makes clear that dialects and communities of speakers in the extent to which they exploit co-articulatorily or perceptually-driven universals, taking them from predictable, universal processes to seemingly arbitrary, phonologized ones. It is precisely in this variation that we expect to find criteria for the differentiation of dialects. While Labov, Ash and Boberg (2006) characterized Canada and the West based on their “extent” of participation in the same sound changes, it is not clear that this characterization captures the reality of their differences. Likewise, Boberg’s (2000) claim that Seattle and Vancouver have “very similar” phonetic systems obscured the important variation between them with respect to phonologization described above. The current study will take a more dynamic look at the phonetic processes and degrees of phonologization involved for Seattle and Vancouver vis-à-vis the 5 diagnostic variables described in this chapter as the locus of differentiation for the two dialects.

Chapter 3

3 METHODS

3.1 Data Collection and Processing

3.1.1 Speaker Sample

This chapter presents methods, procedures and findings from the production study to investigate the trajectories of /æ/, /aʊ/ and /aɪ/ between the two populations in the study. The production study collected data from 20 Vancouver speakers and 20 Seattle speakers between the ages of 18 and 35. Subjects were divided into two age groups with one ranging from 18-25 and the other from 26-35. The sample was balanced for age group and for gender, such that for both Seattle and Vancouver, the sample of 20 speakers is divided as follows:

	Age Group I (18-25)	Age Group II (26-35)
Male	5	5*
Female	5	5

Table 3. Number of subjects of Vancouver and Seattle *For Age Group II in Vancouver, four male speakers were interviewed.

Subjects were recruited through networks at the University of Washington, University of British Columbia and Simon Fraser University as well through local contacts made by the researcher. This portion of the study was comprised of two sections: A production task and a cultural identity survey conducted as a sociolinguistic interview. Two sub-tasks were presented as part of the production task, a shorter one designed to get an overview of participants' overall vowel systems and a longer task designed to focus on their pronunciations of the canonical raising phonemes as well as the front vowels under consideration here. The cultural identity survey sought to learn more about subjects' local, and regional and national identities, their level of exposure to speakers from the other city, and other preferences or values that might indirectly index with municipal or national identity.

3.1.2 Emically-Defined Age Groupings

Group 1 included speakers from age 18-25; Group 2 included speakers from age 26-36. The two age groupings described above were defined ***emically*** on the basis of shared life experience (Eckert 1998). In contrast, *etically*-defined age groups lump speakers into groups based on where their chronological age falls with respect to a series of equally spaced intervals, such as age 20-30 years and age 31-40, and so on. While the two age groups under consideration do not represent a full range of age groups typically used to conduct apparent-time research on language variation and change (ranging from young children to the elderly), the current study fills a different void by considering the variation *within* the broader age category of young adult speakers. As Eckert (1998) points out, the relationship of chronological age to linguistic production is mediated by the speakers' social experiences and the important life milestones they have attained. Studies of language variation and change have too often grouped "adults" into a monolithic category without considering the effect of important life changes within adulthood. Eckert mentions family status, job status and retirement as important examples. For the age groups in the current study, the Group 1 chronological age restrictions are defined around the early post-secondary and collegiate experience. While speakers may vary in whether they still live at home or with college-aged peers, few American and Canadian speakers in this age range are married with their own children. In North America, this age range (18-25) generally corresponds with the pursuit of college education or perhaps early graduate school. The lower bound of the Group 2 age bracket intends to capture the beginning of life as a working adult and (co-)head of household. By age 26, most American and Canadian speakers have completed their post-secondary education. American health insurance companies, for example, use age 26 as the cut off for dependents to be insured by their parents. Many 26-year-olds are in more serious relationships with romantic partners and, between age 26 to 36, are likely to experience the birth of their first child. U.S. Census data reports that women marry at age 27 on average and men at age 29 (U.S. Census Bureau 2016). Thus, the current study provides an analysis of variation in the speech of these two adult groups, defined by their social experiences.

3.1.3 Word-List Reading Task

Questions (1) and (3) were addressed using a word list elicitation task to obtain pronunciations from 20 Seattle speakers and 20 Vancouver speakers, which were recorded in person by the researcher using a Zoom4H handheld digital recorder. The word list contains a total of 220 tokens and speakers were asked to repeat the word list three times yielding 660 total tokens per speaker. The word list was comprised of real word tokens for each of the phonemes: /aʊ/, /aɪ/, /æ/, /ɛ/, and /e/. Five tokens of each phoneme were elicited for each of six environments: _[+lab], _[+cor], _[+vel], [+lat], [+nas], [+cont] in both [+vce] and [-vce] environments (as phonological inventory allows). Pre-lateral and pre-nasal tokens are only available for the pre-voiced condition. Lexical words from English were selected if the vowel and following consonant occurred tautosyllabically. Syllabifications that would leave the vowel in an open syllable and syllabify the following consonant as the onset of the following syllable were avoided. One exception was for /e/ preceding a voiced bilabial. Because only four common closed syllable tokens of the form [Ceb] could be found, one of the five tokens for the category included a voiced bilabial followed by a syllabic or liquid as in “table” and “gable.” Borrowings, toponyms, and proper names were also avoided. The Carnegie Mellon University Online pronouncing dictionary was used as a resource in looking for words. A full outline of the elicitation task is available in Appendix A.

	/aɪ/		**/aʊ/**		**/æ/**		**/ɛ/**		**/e/**	
	-vce	+vce	-vce	+vce	-vce	+vce	-vce	+vce	-vce	+vce
_[lab]	5	5	n/a	n/a	5	5	5	5	5	5
_[cor]	5	5	5	5	5	5	5	5	5	5
_[vel]	5	n/a	n/a	n/a	5	5	5	5	5	5
_[+cont]	5	5	5	5	5	5	5	5	5	5
_[nasal]	n/a	5	n/a	5	n/a	5	n/a	5	n/a	5
_[l]	n/a	5	n/a	5	n/a	5	n/a	5	n/a	5
TOTAL	20	25	10	20	20	30	20	30	20	30

Table 4. Distribution of tokens elicited in production task by phonetic environment

3.1.4 Subject recruitment

Speakers were recruited through university networks at the University of British Columbia, Simon Fraser University, and the University of Washington. Other personal networks were used to recruit speakers in the Group 2 bracket. All interviews were recorded in *.wav* format by the researcher using a handheld Zoom4H digital recorder. The interviews took place in September and October of 2014. When possible, the interviews were recorded in soundproof phonetics laboratories on the aforementioned campuses. Some interviews were recorded in private rooms at libraries or community centers or in the speaker's home, if no other option was available. Each subject received a $10 gift card as compensation for his or her participation.

3.1.5 Processing of sound files

Once recorded, the sound files were assigned unique identifier codes and were stored on the password-protected laptop of the researcher. Each sound file was split into two sections using

Audacity software so that the word list reading and interview tasks could be analyzed separately. The divided sound files were exported in *.wav* format and narrowly transcribed into TextGrids using PRAAT. False starts, misread words, stutters, coughs, laughs and background noises were removed from the stretches of speech. Sound segments were broken into small chunks (no greater than 16 seconds) to improve the accuracy of the Forced Aligner. The TextGrids were exported as tab-delimited texts files in order to provide the proper input for the Forced Aligner.

The sound files were aligned using the University of Pennsylvania FAVE-align forced aligner (Rosenfelder et al. 2011). Each stressed vowel in the TextGrid was hand checked for accuracy. The hand correction process was facilitated by a PRAAT script (Riebold 2013) that moves from one stressed token to the next with a zoom set to display phonetic detail. The boundaries for each vowel token were adjusted so as to avoid the transitions associated with the flanking consonants. The greatest area for adjustment to the boundaries produced by FAVE-align was at the initial transition between initial consonant and the onset of the vowel nucleus. Specifically, the onset boundary of the vowel often had to be dragged towards the vowel nucleus so as to exclude the aspiration from voiceless consonants and the onset of voicing for voiced consonants. Following the forced alignment and hand correction of each segment, the FAVE-extract script was used to extract the formant data about aligned tokens (Rosenfelder et al. 2011). FAVE-extract produces an extensive set of information about the vowel segments including time-scaled formant measurements for F1 and F2 at 20%, 35% 50%, 65% and 80% of the vowel's duration as well as the information about the phonetic environments preceding and following the extracted segment. FAVE-extract was used to extract the information for all stressed target vowels in the word-list reading task, aside from the carrier phrase words *say* and *again*. Several commonly mispronounced words were removed from the data set for all speakers:

Bethesda, dessert, and *lead*. Data from all speakers were maintained in an Excel file and saved as a comma-separated value (*.csv*) file for use in the statistical analysis software R.

Following previous work by Riebold (2015), the extracted measurements were hand-checked to ensure that no errors were present and data were corrected or removed when incorrect measurements were found. Using a procedure in Microsoft Excel, tokens were flagged when they showed large changes in formant measurements from one time point to the next. For instance, from 20% to 35%, a token was flagged if it showed a difference of more than 100 Hz. This token was then hand-checked and retained if its measurements appeared to be accurate or removed if background noise or weak formant structure seemed to be a cause for mismeasurement. The final number of tokens for the cities is 15,230 for Seattle and 14,142 for Vancouver. The number of tokens included in each analysis varies, and this information is presented at the beginning of each sub-section in Chapter 5: Results.

3.1.6 Normalization

Normalization methods are a crucial topic for sociophoneticians hoping to make observations about phonetic realities among different social groups of speakers. The necessity for normalization comes from the observation that the acoustic signals of individual talkers exhibit different types of variation, not all of which appear to be "meaningful" to vowel perception for the interlocutor. Some acoustic variation can be attributed to anatomical and physiological differences between individuals with respect to biological sex and the length, size or other idiosyncrasies of a speaker's vocal tract (Ladefoged and Broadbent 1957). Other acoustic variation may be socially meaningful, indicating a talker's region of origin, socioeconomic background or sexual orientation. From the sociophonetician's perspective, the primary purpose of normalization is to filter out the differences in the acoustic signal that are due to anatomical differences in the length and properties of individual talker's vocal tracts while preserving the meaningful social differences expressed in a talker's acoustic signal. The appropriateness of a normalization technique is defined largely by the type of information at the researcher's disposal. The appropriateness of normalization techniques can be assessed from two important axes: the number of speakers for whom data is available and the amount of information available for each speaker's vowel space. In addition to variation by type of information used, normalization algorithms also differ by the metric they employ. Scale factors and range factors are two commonly used metrics. Previous accounts have assessed and compared normalization methods using different criteria Disner (1980), Hindle (1978), Adank et al. (2004) and Clopper (2009) to name a few.

Vowel-extrinsic, formant-intrinsic procedures draw on information from the entire vowel system in the normalization of a single vowel token. Gerstman (1968), Lobanov (1971), Watt and Fabricius (2002), and Nearey (1978) are examples of vowel-extrinsic, formant-intrinsic methods. The normalization methods in this class differ with respect to how the values of other vowel formants are used in the process. When data is available for only one isolated vowel in a speaker's system, a vowel-intrinsic normalization method is necessary. Sydral and Gopal's (1986) Bark Difference Metric method is a commonly used vowel-intrinsic method, which was modified by Thomas and Kendall (2007) so as not to rely on *F0*. This method transforms Hertz in psychoperceptual units (Bark) and then uses the differences between tokens to model the degree of advancement (frontness) or height for each token. Labov et al.'s (2006) ANAE method is the only classified as speaker-extrinsic in that it incorporates data from more than one speaker at a time. Because this method is designed for a large speaker population (Labov's study contained nearly 350), it is not a suitable method for the current study.

Adank, Smits, and Van Hout (2004) provide an examination of several commonly chosen normalization methods and analysis of how well each meets the defined goal of filtering out anatomical variation and retaining dialectal or social variation. They use a variety of normalization methods to assess data from sociolinguistic interviews in two distinct varieties of Dutch in the Netherlands and Flanders (Belgium). They found that Lobanov (1971) and Nearey (1978)'s single log-mean preserved phonemic distinction best of all the methods they examined, while factoring out gender-related variation to chance levels. Lobanov's (1971) z-score transformation, Nearey's (1971) single log-mean, and Gerstman (1968)'s range transformation were found to be the best at reducing anatomical variation while preserving sociolinguistic variation in the signal, and when compared by multivariate analysis, Lobanov (1971) emerged as the best procedure. Clopper (2009) echoes the finding that Lobanov (1971) outperforms Gerstman (1968) at aligning the vowel spaces of two different talkers.

Following the findings of these previous studies, the current project employed Lobanov (1971) normalization. Lobanov (1971) is a z-score transformation for each formant and each talker. The vowel spaces for talkers are centered on individual formant means, and the range of normalized values is scaled for each talker such that the vowel space is constrained within 2 standard deviations of each formant's mean. The formula for Lobanov's z-score transformation is given below where *f* is the original formant frequency in Hertz, μ is the mean of the formants across all vowels for that talker in Hertz and σ is the standard deviation for that formant across all vowel tokens for that talker.

$$z = \frac{f - \mu}{\sigma}$$

Equation 2. Lobanov z-score transformation (Lobanov 1971)

One disadvantage to the Lobanov method of normalization is that the scaled F1 and F2 measurements are not very intuitive for sociophoneticians accustomed to working with vowel measurements in Hertz. While it is possible to scale Lobanov normalized z-scores of formant measurements back to Hertz, this procedure is problematic and is not recommended by Thomas and Kendall (2007). To overcome the challenges of familiarity, descriptive statistics using raw Hertz values are presented at the beginning of each section. While inferential statistics (mixed-effects regression models) are conducted on normalized F1 and F2 values, descriptive summaries in Hertz provided prior to the presentation of mixed-effects modeling are meant to assist the reader in better understanding the mean differences in allophonic environments or vowels using Hertz for familiarity.

3.1.7 Vowel inherent spectral change

Theories of Vowel Inherent Spectral Change (VISC) first described by Nearey and Assmann (1986) refer to the inherent change in the spectral properties and formant structure of a vowel over its duration. Such a theory recognizes the dynamic properties of traditionally labeled monophthongs as a gradient version of the dynamic properties observed for so-called diphthongs and would propose similar analyses for each. Numerous production studies have highlighted the varying dynamic properties of formant trajectories across speakers. For instance, Thomas (2004) and Koops (2010a) observed that cross-dialectal differences can and do emerge in the execution of diphthongization, illustrating the importance of considering the dynamic properties of each vowel's trajectory without any a priori or static assumptions about how this trajectory will be realized. By incorporating slope of F1 and slope of F2 into an analysis of monophthongal *pin/pen* vowels for an African American speaker in Seattle, Scanlon and Wassink (2010) detected differences in the glides of the two "merged" phonemes that were not detectable by mid-point analysis alone. Nearey (2013) describes significantly different formant trajectories for monopthongal /æ/ in three distinct dialects of North American English in Texas, Western Michigan and Northern Alberta. For the dialects under comparison, he finds greater differences in F1 trajectories than in F2 trajectories, corresponding with greater variation in the movements of vowel height across the segments than frontness. Risdal and Kohn (2014) also find ethnolectal and generational differences in formant trajectory for European American and African American speakers in North Carolina (discussed in more detail below). Presumably, the differences in trajectories between groups of speakers or the same speaker's allophonic realizations would otherwise be overlooked if analyzed by a methodology designating a single static point of interest in the vowel's trajectory.

Likewise, numerous studies have demonstrated listener's perceptual sensitivity to vowel trajectory information both for phoneme identification as well as for the identification of socio-indexical variation proper to different groups of speakers. Competing theories of VISC have emphasized different types of formant information as perceptually-relevant for the identification of phonemes. Major theories have argued for the importance of onset-offset information, onset and slope information or, alternatively, onset and direction of change information. The majority of recent studies have favored the onset-offset approach as being the most relevant for listeners' perceptual identification of phonemes, but this does not necessarily fulfill the goals of the sociolinguist. While phoneticians may emphasize onset-offset information as the minimally necessary information to allow for accurate segmental identification, the sociolinguist seeks to better understand how listeners may attribute socio-indexical differences to the variation they perceive in formant trajectories. Hillenbrand (2013) argues that listener access to more complex models of formant trajectories does not significantly improve segmental identification of phonemes as compared to identification rates when given two-point onset-offset information. Other studies suggest, however, that providing a listener with acoustic cues including more detailed formant information (such as the detail represented polynomial fits) may serve a purpose other than segment identification. Namely, nuanced differences in formant trajectories, as captured by multi-point models of trajectory curves, contain socio-indexical information which listeners rely on to make distinctions about a talker's dialect of origin, age, gender, and ethnicity. Fox and Jacewicz (2009) and Jacewizc and Fox (2011) find that dynamic formant trajectory information interacts with sociolinguistic variables and that there are substantial differences in formant trajectories as a function of speakers' age and dialect. Morrison (2013) highlights the relevance of formant trajectory to identification of individuals as used for forensic purposes. While onset-offest models might provide the minimal necessary information to allow for segment identification, these studies highlight the importance of incorporating different types of vowel trajectory information dependent on the researcher's goals. They also illustrate a need for further research to better understand how dynamic vowel trajectory information may provide socio-indexical cues in perception.

3.1.8 Multi-point time-proportional approach

The current analysis relies on data from five time-proportional points across the vowel's duration. Moving away from single-point analyses and incorporating the notion of VISC, Di Paolo et al. (2011) recommend that multiple measurements be used for all vowel analyses, even those traditionally considered to be steady monophthongs (including /æ/). They suggest the proportional distance approach, which adjusts its multiple measurements according to the duration each vowel token (e.g. at 20%, 35%, 50%, 65%, and 80% of the vowel's duration). This has the advantage of comparing different tokens at similar points along their trajectories allowing for a more dynamic view of vowel articulation. Another advantage of this approach is that it is not biased by an a priori assumption of where in the vowel's duration the articulatory goal is realized.

3.2 Visualization of Data and Descriptive Statistics

Prior to inferential statistics, various methods of data visualization were used to accompany descriptive statistics. For each allophonic analyses, ellipses plots of normalized F2 by F1 were created in R using the ggplot 2 package (Wickham, 2009) to illustrate the position of the allophones relative to neighboring vowels. For instance, /æg/ and /æk/ tokens are plotted relative to neighboring front vowels /e/ and /ɛ/. On the other hand, retraction-favoring environments for /æ/ are plotted in elliptical F2 by F1 plots relative to back vowels. These plots contain data from 5 time points across the vowel's duration. Descriptive analyses of the vowels are offered first on the basis of their proximity and overlap with neighboring vowels. For each allophonic environment in each city, formant trajectories were plotted by plotting normalized formant values over the 5 time points (position) on the x-axis. The plots were separated by Speaker Age and Sex sub-groups to allow for comparison of variation between social groups. These data are described for each city in each of the five sub-sections prior to the inferential statistics.

3.3 Inferential Statistics

3.3.1 Different types of analyses with dynamic formant information

More recently, sociolinguists interested in investigating variation between speakers or groups of speakers have begun to capitalize on the rich information captured by vowel trajectories. Various methods can be employed to realize dynamic models of acoustic properties. Among them, SSANOVA, Functional Data Analysis are possible candidates, as well as a comparison of vowel trajectory curves within a mixed-effects linear regression model. To date, the extent of comparison between different types of dynamic approaches to modeling formant trajectories is fairly limited. Studies employing a dynamic approach tend to compare their results to static models, but few studies explicitly compare the outcomes of different types of dynamic models.

3.3.2 SSANOVA

Smoothed splines are curves fit to data points that represent a vowel's trajectory at multiple intervals. These curves are based on the F1, F2 and occasionally F3 values extracted at a relatively large number of time points over the course of a segment.[1] An Analysis of Variance (ANOVA) test can then be used to determine whether significant differences exist between two curves or splines. Using Bayesian confidence interval, the locations of significant differences in two curves can be determined. The information provided by such a multi-point analysis can identify significant differences between two formant trajectories at any point that would be overlooked by single-point models, which specify a prior a unique temporal point of interest (Gu 2002).

Nycz and DeDecker (2006) employed SSANOVA to illustrate differences in the allophonic realization of /æ/ for eight speakers of North American English. They extracted 50 points across the duration of vowels and used these to create smooth curves of the vowel's trajectory, which they compared by SSANOVA. They find that SSANOVA analyses can shed light on differences between allophonic realizations of a phoneme that would otherwise appear similar based on single, fixed-point analyses. Koops (2010b), Wassink and Koops (2013)

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[1] The exact number of points necessary to inform such an analysis is not well-established, but previous studies have used between 20 and 50 time points across the duration of a vowel.

likewise employ SSANOVA to illustrate differences in vowel formant trajectories between speakers from different age and ethnic groups.

Docherty, Gonzalez and Mitchell (2015) compare different types of static and dynamic methods for capturing acoustic properties of vowels for 18 Western Australian speakers of English. As compared with static fixed-point analysis and static target estimate analysis, dynamic models using SSANOVA with formant information extracted at 40 time points allowed for greater differentiation between and within vowel classes. For example, the dynamic approach illustrated differences in slope across the vowel trajectories for the same vowel in different phonetic contexts. Docherty et al. caution that while SSANOVA analyses may be better equipped than static analyses at capturing trajectory variation across conditions, they may over-emphasize the differences found between vowel trajectories.

3.3.3 Functional Data Analysis

Another method for modeling dynamic qualities of vowels is Functional Data Analysis (FDA). FDA is a set of statistical tools that allows for the comparison of curves, like those displayed by vowel formants over time. FDA models these curves by fitting them with polynomial functions. Risdal and Kohn (2014) use Functional Data Analysis with cubic polynomial functions to make comparisons between speakers of two different dialects in North Carolina. Using sociolinguistic interview data from 8 younger generation speakers of African American English and 26 older generation European American speakers of Southern English, they compare the formant trajectories of front, lax vowel. Formant values for F1 and F2 were extracted at 21 equidistant, time-proportional points across each vowel’s duration, and polynomial curves were fit to these data. They relied on statistically significant differences in cubic coefficient values to correspond to degree of diphthongization, finding that for older European American speakers, there was great diphthongization of front, lax vowel (BIT, BET, and BAT) than for African American speakers based on more positive cubic coefficient values. They conclude that this dynamic approach to accounting for VISC captures fine-grained ethnolectal and generational differences between speakers that would otherwise remain obscured in traditional static approaches.

The selection of a particular method for representing dynamic formant information in an analysis depends on the researcher's goals and the data at his or her disposal. In particular, one question remains unanswered: exactly how much temporal detail is needed? Without explicit comparisons of one method to another across different types of data sets, it is difficult to make specific observations about the benefits each method offers or about how much temporal detail is required. The answer may depend in part on the researcher's goals and the nature of the data. As time-proportional approaches have become more common, researchers have begun to observe that a relatively small number of time points may suffice to compare the basic shapes of formant trajectories and identify differences between allophonic environments and sub-groups of speakers. When using FDA, 3rd order polynomial functions (cubics) seem largely sufficient to representing a general curve shape and detecting different trajectories or diphthongization strategies between speakers (Morrison 2013). For a sociophonetician interested in examining the variation across speakers of different genders, age groups, and dialects, an analysis of formant data at five time points across a larger speaker population is preferable to a comparison of few speakers with formant data at 50 time points.

3.4 Mixed-Effects Linear Regression Modeling

This study uses mixed-effects linear regression models to conduct inferential statistics in response to the aforementioned research questions. Mixed-effects models include both fixed effects and random effects as predictors of a continuous dependent variable (in this particular case). As Baayen (2008) explains, statistical literature distinguishes predictors that are expected to have repeatable effects when extended to new data as *fixed effects* (these might include voicing of the following phone or the preceding phone) and predictors that are sampled from a larger population and do not have repeatable effects on new data (such as the individual speaker or lexical item) as *random effects*. The random effects included in a mixed-effects model provide some control for these unrepeatable factors, thus increasing certainty about the influence of the repeatable predictors on the dependent variable. Baayen (2008), Gorman (2009) and Gorman and Johnson (2013) describe the benefits of mixed-effects modeling for speech data. Unlike an ANOVA, the fitted coefficients from a linear model are interpretable as the effect size, allowing the researcher to differentiate a significant, but tiny effect or a non-significant but huge effect and the directionality of each. The inclusion of random effects allows for a "nested" model of related properties of a talker's identity or a particular lexical item across speakers without giving rise to collinearity.

Thirty separate mixed-effects models were constructed in R using the lme4 package (Bates et al. 2015) to provide an analysis of the five different types of variables and environments considered. Cities were examined first in isolation, and models were constructed for both F1 and F2, followed by a model for both F1 and F2 that spans both cities. This modeling process was repeated for pre-velar /æ/, pre-nasal /æ/, environments of /æ/ retraction, /aʊ/ raising and /aɪ/ raising. The following section describes the treatment of predictor variables included in the mixed-effects linear regression models.

3.4.1 Time point as an ordered factor

The current study uses an ordered factor created from the five time points to make comparisons of the trajectories of vowels in different allophonic contexts and by different sub-groups of speakers. As an ordered factor, vowel trajectory is included in the mixed-effects linear regression models as a possible predictor. This allows modeling and comparison of basic trajectory shape, including linear, quadratic, and cubic shapes similar to the approach in FDA where polynomials are fit to the curves. Such a comparison requires relatively few time points allowing for an efficient modeling of the basic shape of vowel trajectories and provides a simple computation using R. To use "ordered Position" in the analysis, the formant measurement data were reshaped to be in "long form." (This means having one column with 5 possible values for position and having one F1 column and one F2 column.) Then, the as.ordered( ) function was used to convert the vector (Position) into an ordered factor, and the ordered factor was saved as a new column (Position.ord).

```
dataframe$Position.ord <- as.ordered(dataframe$Position)
```

This approach is particularly useful to sociolinguists who tend to work with larger data sets from more talkers. Because the five time points are sufficient for illustrating the basic shape of a trajectory, the amount of data required is manageable and efficient.

The interpretation of an ordered factor based on time point is intuitive as it relates to the slope, quadratic (parabolic), cubic and quartic differences in trajectory shapes found in the data. These correspond respectively to polynomials of different degrees. As a predictor in a regression model, a linear or 1st order polynomial ($y= ax+ b$) identifies differences in the slope of the trajectories. Interpreted relatively to the baseline coefficient, the coefficients of the ordered Position term in linear regression model reveal changes to the slope that make it steeper or less steep in a particular allophonic environment. The coefficients of the quadratic or 2nd order polynomial ($y= ax^2 + bx + c$) reveal differences in the parabolic shape or curve of a vowel's trajectory. If the coefficient is closer to 0, the bowl is bigger; showing a less skinny parabola. If the coefficient is bigger, the parabola becomes taller and skinnier. Finally, a 3rd order polynomial ($y= ax^3 + bx^2 + cx + d$) can reveal differences in the cubic shape of a vowel's trajectory. This degree of polynomial may be especially useful for modeling the trajectories of diphthongs or vowels/allophones with greater degree of VISC. Differences in the cubic coefficients of the trajectories may be used as an indicator of greater diphthongization. (Risdal and Kohn 2014, Morrison 2013) Quartic differences among vowel trajectories are not common. One point to keep in mind is that the intercept of a linear mixed-effect regression model using time point as an ordered factor will reflect coefficients at the first of the ordered time points (20% time-proportional duration, for the current study). This serves the purposes of the current study well as there is an important focus on whether the coarticulatory effects of following phonetic environment are exaggerated (phonologized) enough to be detected at the vowel's onset.

3.4.2 Treatment of other fixed variables

All but two of the possible predictor variables for the linear regression models naturally lent themselves to a categorical representation. Predictor variables such as Following Phone, Preceding Phone, Voicing of the Following Phone, Manner of the Following Phone, City of Origin, and Sex were represented as categorical variables.

3.4.3 Duration

The inclusion of duration information about each vowel in the linear regression model raises some methodologically questions that affect the interpretation of effects related to duration. The first issue relates to the use of seconds or milliseconds to convey duration information in the model, and this choice impacts a researcher's impression of the size and strength of the variable's effect. Conveying duration in seconds may result in fewer significant changes being identified, and for those that are identified, the coefficients and effect of the change appear to be enormous. This impression is due to a discrepancy of scale, however, since the coefficients represent the amount of change in Lobanov-normalized F1 or F2 measurements over the course of one duration unit as one second. Given that the mean duration for the majority of vowel tokens in these regression analyses is between 0.2 and 0.3 seconds, the coefficient corresponding to the amount of change in Lobanov normalized F1 or F2 per *second*, is over-exaggerated by nearly three to five times (since the tokens are generally between a fifth and a third of a second long). If these results are not interpreted with caution, duration appears to be a much larger effect than any other in the analyses, which is not accurate. On the other hand, opting to represent duration in milliseconds creates something like the opposite problem: the amount of change to the normalized F1 and F2 values per *millisecond* of the vowel's duration appears to be miniscule to the point that, in isolation, it would not be detectable by the human ear. Representing duration in milliseconds may also increase the number of statistically significant effects identified as it essentially provides a very fine-grained view of the changes in F1 and F2. Given the dilemma of these two methods for representing duration, milliseconds were selected over seconds as the best option for representing time for the current data set. While the coefficients for statistically significant effects of duration are very small, they must be considered as an effect that repeats between 200 and 300 times over the course of the average vowel in this data set.

To reduce any possible effects of varying speech rates between talkers or different repetitions of items in the word list, duration in milliseconds was also Lobanov normalized by speaker. This procedure was done separately for each of the data sets used in an analysis so that, for instance, for the model of F1 for /æk/ and /æg/ in Seattle, the normalization procedure addressed the duration of only Seattle talkers for only the vowels and environments in question. Normalization of duration for different vowels and environments was conducted separately because substantial variation was expected between the vowels in the different analyses (some being diphthongs and others being monophthongs with additional variation in voicing of the following consonant).

3.4.4 Age

To provide more consistency with other variables and test for variation based on emically-defined age groups, Age was represented as a categorical variable (termed Age Group) in the linear regression models.

3.4.5 Responses to Sociocultural Survey Questions

Participants also provided responses to 16 one to seven Likert scale questions, which were tested as possible predictors in the mixed-effects regressions. Participant responses to each question were z-score normalized separately to ensure that differences in use of the scale did not skew the results. The normalized responses to the sociocultural questions were tested for significance as continuous fixed predictors.

3.4.6 Random effects

Terms like individual Speaker, Following Phone and Position.ord were modeled as random effects. A goal was to include as many random effects as possible, without causing the model to fail to converge. Tests of random effects were conducted to determine how the random effects should be included. The examples below illustrate this process for the pre-velar /æ/ data across both cities. Models with random effects terms of trajectory shape and following by speaker plus a separate random effect of lexical item failed to converge. Two such examples are given below:

F2.lmer1 <- lmer(normF2 ~ FollowingPhone*Position.ord*City + City*FollowingPhone*Sex*(as.factor(AgeGroup)) + **(1 + Position.ord + FollowingPhone | Name) + (1|Word)**, data=ae1)

F2.lmer1a <- lmer(normF2 ~ FollowingPhone*Position.ord*City + City*FollowingPhone*Sex*(as.factor(AgeGroup)) + **(1 + Position.ord | Name) + (1 + FollowingPhone | Name) + (1|Word)**, data=ae1)

A model containing a random term for vowel trajectory by speaker was compared by ANOVA against a model containing a random term for following phone by speaker.

Model 1

normF2 ~ FollowingPhone * Position.ord * City + City * FollowingPhone * Sex * (as.factor(AgeGroup)) + (1 + Position.ord | Name) + (1 | Word)

Model 2

normF2 ~ FollowingPhone * Position.ord * City + City * FollowingPhone * Sex * (as.factor(AgeGroup)) + (1 + FollowingPhone | Name) + (1 | Word)

No significant difference was found between the models. (In this case Pr>chisq =1.)

Including Lexical Word as a random term was found to significantly improve the models. For the example models given below, an ANOVA comparison showed significant improvement for Model 1 (Pr>chisq =<2.2e-16).

Model 1

normF2 ~ FollowingPhone * Position.ord * City + City * FollowingPhone * Sex * (as.factor(AgeGroup)) + (1 + FollowingPhone | Name) + (1 | Word)

Model 2

normF2 ~ FollowingPhone * Position.ord * City + City * FollowingPhone * Sex * (as.factor(AgeGroup)) + (1 + FollowingPhone | Name)

The final models included possible random effects of vowel trajectory by Speaker (for random interspeaker variation in vowel trajectories) and lexical word as shown below.

F2.lmer <- lmer(normF2 ~ FollowingPhone*Position.ord*City + City*FollowingPhone*Sex*(as.factor(AgeGroup)) + **(1 + Position.ord | Name) + (1|Word), data=ae1)**

3.4.7 Model-fitting

The mixed-effects models in this set of analyses are modeling very complex interactions of multi-faceted phonetic and social variables. The phonetic and social variables of relevance to each individual analysis were selected a priori on the basis of previous literature. For example, in the analysis of pre-velar raising, duration and following phone (/k/ vs. /g/) were originally included along with sex and age group because previous research has identified each as significant predictors of /æ/ raising. Age Group and Sex were initially included in each of the models, to identify social variation between groups of speakers. If these social variables were not significant predictors, they were subsequently removed from the model. P-values at $p < .05$ or less were considered statistically significant. A deductive approach was taken to reducing the complexity of the models and removing non-significant predictor variables by comparing step-wise iterations of mixed-effects models by ANOVA. The first model for each analysis tested predictor variables in a very complex model including a four-way interaction. If there were no significant four-way interactions, subsequent models were constructed to "unpack" the interactions and achieve a simpler model. Statistically significant effects were also considered more critically with respect to their effect size. The subsequent model was compared against the first to determine whether one provided a significantly better fit for the data. The Akaike information Criterion (AIC) and Bayesian Information Criteria (BIC) were also considered to determine whether the improvements of a more complex model were merited.

Finally, when a best model of phonetic and social predictor variables had been identified, speakers' normalized responses to the 16 sociocultural survey questions were tested in ad-hoc model comparisons to determine whether any were significant predictors of normalized F1 or F2 values. One sociocultural question at a time was added to the best-fit model as a possible predictor variable and new model was compared against the best-fit model by ANOVA. Sociocultural survey responses that did not yield a significantly better model and that were not statistically significant predictors were not retained in the final model. The terms of each individual mixed-effects model are summarized in more detail prior to the presentation of results in Chapter 5.

3.5 Methods for Analysis of Sociocultural Identity Survey Data

All sociocultural surveys were conducted orally by the researcher, and all interviews were conducted concurrently with the completion of the production task. These sociocultural survey questions were interspersed with the repetitions of the word list reading task such that there were three stretches of sociocultural identity questions of about six to eight minutes, depending on the respondent. These were transcribed and stored in separate text files for each speaker. The numeric responses to the Likert scale questions were stored in a Microsoft Excel spreadsheet along with basic demographic information for each respondent. Basic descriptive statistics such as means and standard deviations were computed for these questions using R. Note that these descriptive means and standard deviations are presented in the city descriptions as non-normalized raw means. This is meant to allow for a more reader-friendly interpretation of respondents' ratings, though participants ratings were normalized prior to the regression as described below.   Emergent coding was used to analyze the qualitative responses by considering each free-response followed by a comparison of the two, discussion and summary.question one at a time. For each city, a separate text file was created to contain all speaker responses for each question. Common themes in participants' responses are presented in this question with quotes to illustrate. After conducting an independent qualitative analysis for each city, the results for both quantitative and qualitative responses were compared. Participant responses to the one to seven Likert scale questions were normalized as z-scores. Statistically significant predictors were identified separately for each question using linear regression models. The results will be presented first for Seattle and then for Vancouver.

Chapter 4

4 PRODUCTION STUDY RESULTS

This section presents acoustic findings from the production study and methodology described in Chapter 3. The full word list reading task is available in Appendix A. The research questions vital to this analysis are presented here for convenience. Descriptive results will be presented first for each Seattle and Vancouver individually, followed by statistical results and a comparison of speech in the two cities. The findings will be discussed relative to the enumerated research questions in the summary section.

4.1 *Vowel System Overview*

4.1.1 Seattle

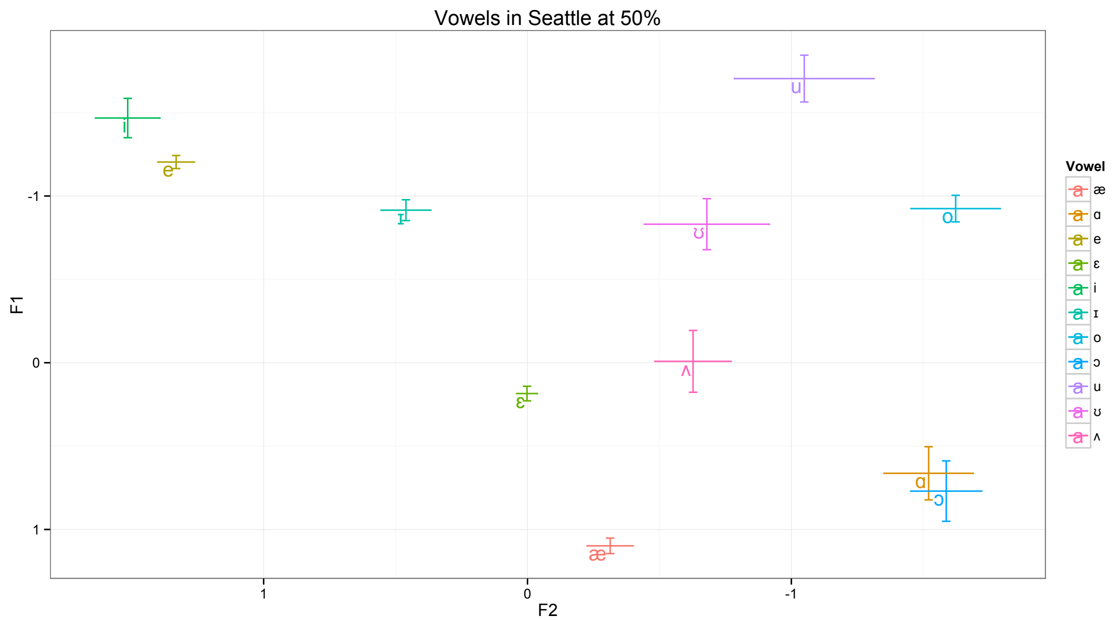

Figure 2. Lobanov normalized vowel space Seattle (inverted F2 on x-axis; inverted F1 on y-axis) for Seattle speakers with population means with confidence intervals illustrating across speakers for the vowel at 50% of time-proportional vowel duration.

The vowel space overview for Seattle speakers show presence of the *cot*/*caught* merger and some degree of /u/ fronting.

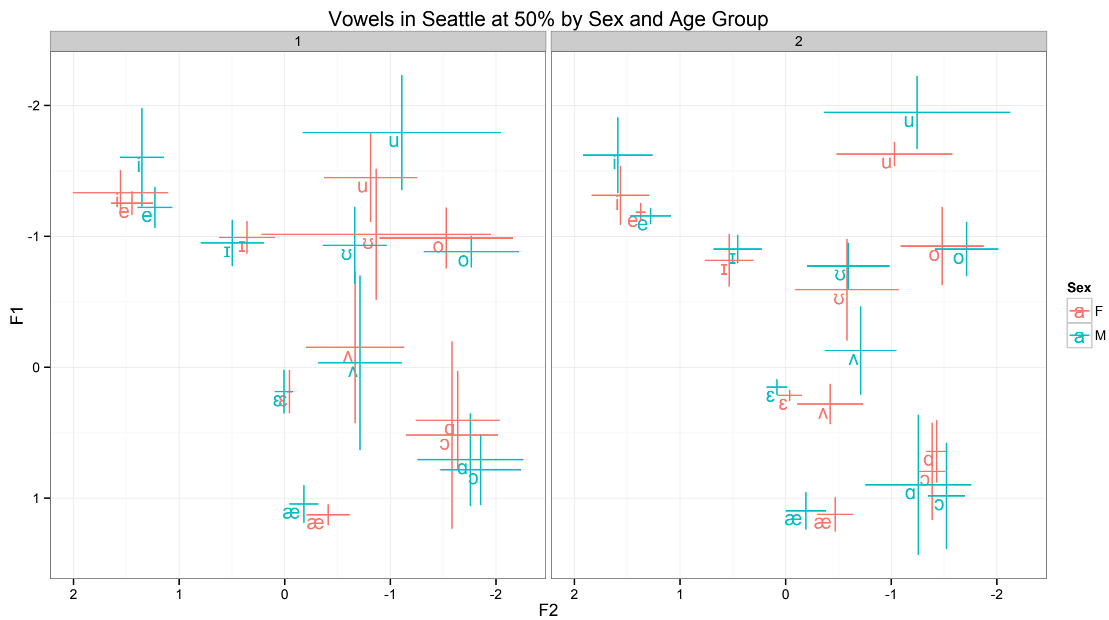

Figure 3. Lobanov normalized vowel space for Seattle by sex and age group (inverted F2 on x-axis; inverted F1 on y-axis) by age group and sex for Seattle with confidence intervals indicating the variation across speakers for the category

A comparison of the full vowel space at midpoint by speaker sex and age suggests a relatively consistent and stable system between the two age groups, yet more variation for speakers in the Group 1 age bracket. In particular, Group 1 speakers show larger error bars for /o/, /u/, /ɔ/, /ʌ/, /ʊ/ and /i/. In general, the variation (indicated by error bars) appears larger for central and back vowels than for front vowels. For Group 1 Seattle speakers, /u/ may be relatively fronter and lower in the vowel space than for Group 2 speakers. Comparing male and female speakers within each age group, women show more retracted variants of /æ/ for both age groups than their male peers. They also show considerably lower and fronter realizations of /u/ than male speakers. Seattle females in both age groups also have relatively fronter /o/ realizations than male speakers.

4.1.2 Vancouver

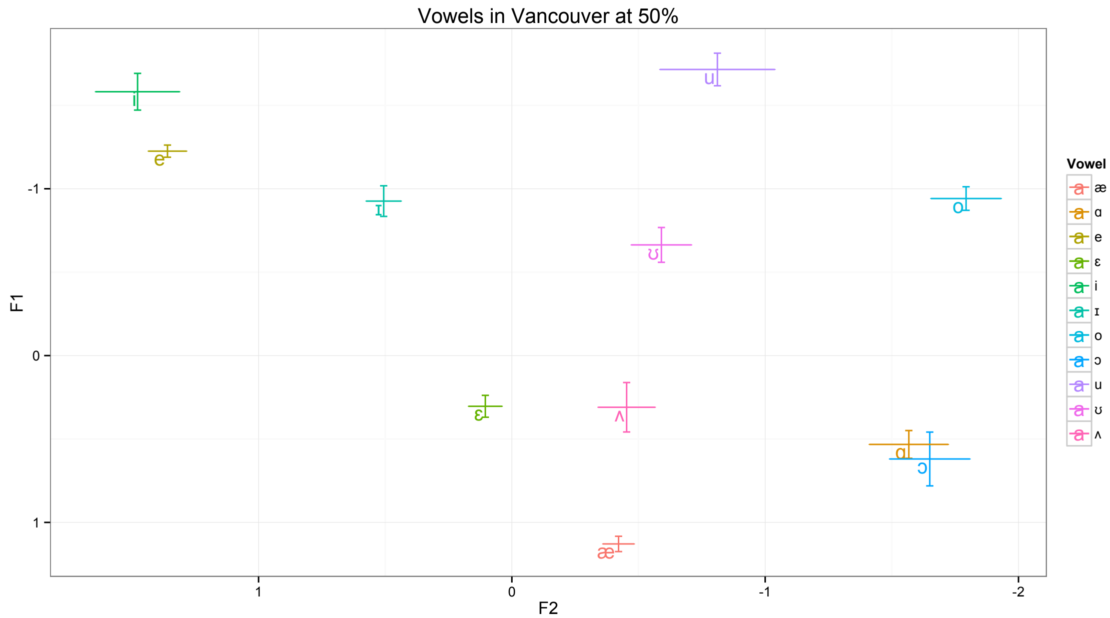

Figure 4. Lobanov normalized vowel space for Vancouver speakers Lobanov normalized vowel space at 50% of time-proportional vowel duration (inverted F2 on x-axis; inverted F1 on y-axis) for Vancouver speakers showing population means with confidence intervals illustrating variation across speakers

The Vancouver vowel system observed for speakers in the current study is in accordance with previous research on Vancouver English. Features previously used to define the dialect region are likewise present in the current data: *cot/caught* merger, /u/ fronting, relatively lowered and retracted manifestations of front vowels /ɪ/, /ɛ/, and /æ/ as described for the Canadian Shift. The typical Canadian Raising diphthongs /aʊ/ and /aɪ/ are not included here and will be discussed in more detail in subsequent sections.

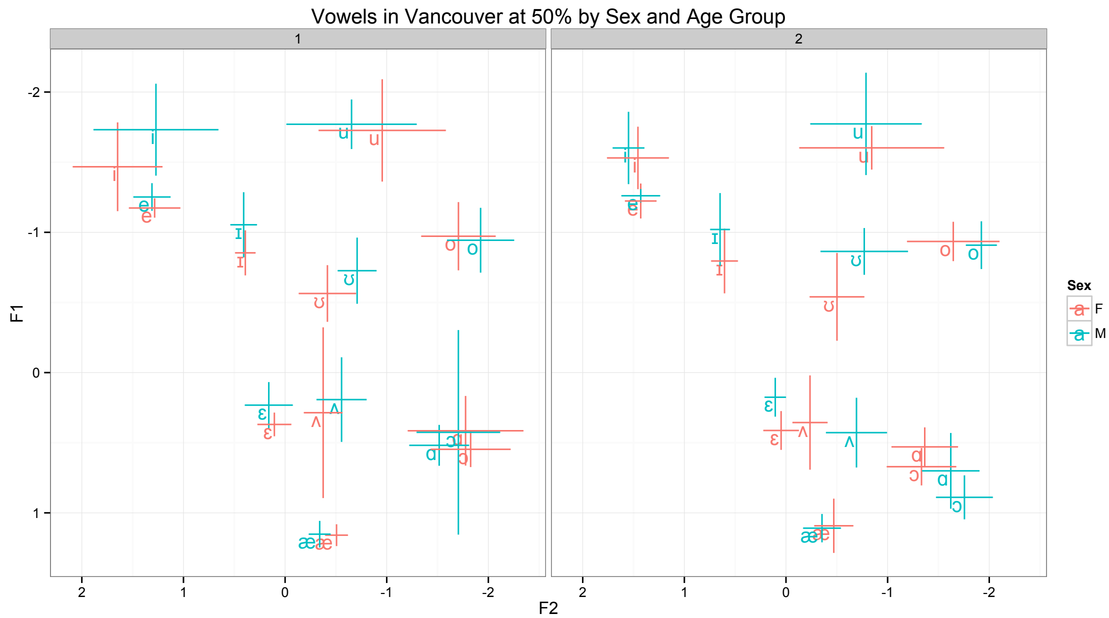

Figure 5. Lobanov normalized vowel space for Vancouver speakers by Sex and Age Group: Lobanov normalized vowel space at time-proportional 50% vowel duration inverted F2 on x-axis; inverted F1 on y-axis) by age group and sex for Vancouver with confidence intervals indicating the variation across speakers for the category

Based on F1 and F2 values at mid-point, the vowel systems observed for Group 1 Vancouver speakers are largely similar to those of Group 2 in this study. There appears to be more variation in the Group 1 age group than the Group 2 one as indicated by larger error bars for several phonemes including /i/, /ʌ/ and /ɔ/. For high, front /i/, females show a fronter and lower realization of /i/ than male speakers in their age group. Vancouver females in both age groups have more retracted variants of /æ/ than male speakers. Older Vancouver females have more fronted /o/ variants than their male counterparts.

4.1.3 Comparison of Seattle and Vancouver

The overall vowel spaces for Seattle and Vancouver speakers are largely similar, with Vancouver speakers showing more fronted /u/ than Seattle speakers. For /o/ however, Seattle speakers have a slightly fronter variant. For both cities, /u/ shows more variation across speakers than other phonemes, particularly on the front/back F2 dimension. Vancouver shows a slightly lower and fronter realization of /ɛ/ than Seattle speakers, while Seattle shows a slightly higher and fronter realization of /æ/. For all phonemes, there is more variation across speakers on the front/back (F2) dimension than on the height (F1) dimension as indicated by long horizontal error bars in the image below.

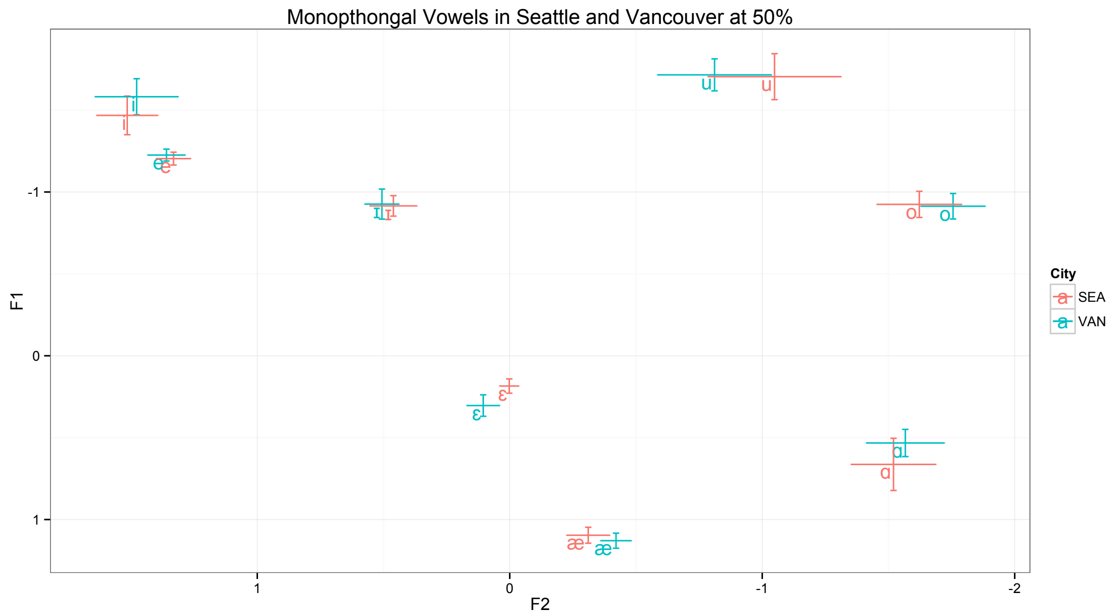

Figure 6. Lobanov normalized vowel space for Seattle and Vancouver: Lobanov normalized vowel space for both cities at 50% time-proportional vowel duration (inverted F2 on x-axis; inverted F1 on y-axis) with confidence intervals indicating the variation across speakers

These overviews are meant to provide a basic look at the speakers' vowel systems, but more in-depth analyses must be conducted to determine the statistical significance of variation by sex and age group, the effect of following phonemes, and the dynamic realizations of vowels when formant trajectories are taken into account.

4.2 Front Vowel Systems Overview

4.2.1 Seattle

The table below displays for Seattle speakers unnormalized mean F1 and F2 values as well as normalized mean values for the front vowels /æ/, /ɛ/, and /e/ in different phonetic environments; namely, before /g/ and /n/ versus all other following consonants. These F1 and F2 means are averaged over five points of measurement over the vowel's duration.

Seattle Vowels	F1 (Hz)	SD F1 (Hz)	F2 (Hz)	SD F2 (Hz)	Dur (Ms)	SD Dur (Ms)	Lob. Norm F1	Lob. Norm F2
æC	814	142	1700	212	156	56	1.076	-0.375
æg	675	169	1941	255	167	55	0.254	0.243
æN	642	145	1993	365	196	54	0.046	0.363
eyC	434	78	2328	331	171	63	-1.182	1.216
eyg	502	112	2184	326	160	54	-0.753	0.845
eyN	460	88	2336	497	194	57	-1.022	1.227
ɛC	663	115	1819	231	107	38	0.169	-0.081
ɛg	563	131	2168	278	173	53	-0.422	0.814
ɛN	627	124	1926	177	121	39	-0.062	0.185

Table 5. Front vowels before /n/, /g/ and /C/ for Seattle. Mean of unnormalized F1/F2 values and duration, standard deviations of unnormalized F1/F2 values and duration, plus Lobanov normalized z-scores across all five time-proportional points.

For Seattle speakers, both /æN/ and /æg/ are higher in the vowel space than /æ/ before all other consonants. /æN/ has lower F1 and higher F2 values than /æg/, suggesting more raising of /æ/ before a nasal following phone than a voiced velar one. For /ɛ/, likewise, following phones /n/ and /g/ seem to produce raising in comparison to /ɛC/. The height of raising does not follow the same pattern for /ɛN/ and /ɛg/ as for /æN/ and /æg/: /ɛN/ have a higher F1 and lower F2 value than /ɛg/, indicating that /ɛN is lower in the vowel space than /æg/. For /ey/, /eyC/ tokens are higher than both /eyN/ and /eyg/ tokens, with /eyg/ being the lowest in the vowel space of the three categories as defined by its higher F1 value. It also seems to be accompanied with a backing gesture, having an F2 value much lower than /eyC/ or /eyN/. While /eyN/ tokens seem to lower slightly in comparison to /eyC/, they also front slightly, and do not show the lowering and backing of /eyg/.

Within each set of vowels, the pre-velar environments display a higher standard deviation for the height dimension than the pre-nasal or other consonantal environments. This could indicate either considerable variation between or within speakers; it could also indicate a more dynamic trajectory for pre-velar tokens, as these values are a mean of measurements taken across five time points. These questions will be examined in the sections to follow. In terms of vowel height, as indicated by the F1 values, /æg/ tokens are associated with the greatest standard deviation of all vowels and contexts at 169 Hz. The standard deviations for /ɛg/ and /eyg/ are 131 Hz and 112 Hz, respectively. In general, however, the variation on the front/back dimension is greater than on the height dimension, as indicated by some very large standard deviations for F2. In particular, /æN/ and /eyN/ have huge standard deviations for F2 at 364 Hz and 497 Hz. Again these large numbers may capture to some extent the variation between and within speakers, but are also likely capturing to some extent the degree of movement or vowel-inherent spectral change over the vowel's duration. Pre-nasal realizations of /æN/ and /eyN/ inevitably show more fronting movement over their duration than /æC/ and /eyC/, instance. These comparisons of trajectory will be considered in the following section.

4.2.2 Vancouver

Vancouver Vowels	F1 (Hz)	SD F1 (Hz)	F2 (Hz)	SD F2 (Hz)	Dur (ms)	SD Dur (ms)	Lob. Norm F1	Lob. Norm F2
æC	831	118	1645	228	149	46	1.075	-0.480
æg	630	130	2136	280	160	56	-0.151	0.725
æN	730	93	1867	224	177	42	0.467	0.064
eyC	453	84	2353	332	157	52	-1.218	1.243
eyg	545	124	2156	324	153	59	-0.653	0.745
eyN	489	102	2418	411	178	41	-0.994	1.405
εC	695	101	1855	269	100	31	0.260	0.018
εg	579	106	2195	291	145	39	-0.445	0.854
εN	663	90	1977	211	109	27	0.063	0.320

Table 6. Front vowels before /n/, /g/, and /C/ for Vancouver. Mean of unnormalized F1/F2 values and duration, standard deviations of unnormalized F1/F2 values and duration, plus Lobanov normalized z-scores across all five time-proportional points.

For Vancouver speakers, /æg/ and /æN/ tokens are higher in the vowel space than /æC/ tokens, as evidenced by lower F1 means for the former groups. The mean F1 for /æg/ is lower than for /æN/ indicating that /æg/ tokens are raised higher in the vowel space than /æN/ tokens. This gesture of raising appears to be accompanied by fronting for /æg/ and /æN/. The unnormalized F2 value for /æC/ is 1645 Hz, but /æn/ has a mean F2 value of 1867 Hz, and /æg/ a mean F2 of 2136 Hz. Like /æg/ and /æN/, /εg/ and /εN/ are both raised and fronted in comparison to /εC/, with /εg/ showing by far the highest and frontest position of the three. In comparison to /eyC/, both /eyg/ and /eyN/ involve lowering in the vowel space, with /eyg/ tokens lowering the most. In contrast with /eyN/, /eyg/ tokens are lower and backer in the vowel space, as indicated by a lower mean F2 at 2155 Hz than /eyN/ tokens at 2418 Hz. /eyN/ tokens are lower and fronter than /eyC/; /eyg/ tokens are lower and backer than /eyC/.

For all three vowels /æ/, /ey/, and /ε/, the standard deviations of F1 means are higher than the standard deviations of other allophonic environments within the same vowel class. Pre-velar tokens seem to be associated with more variation or movement over their trajectories than pre-nasal or other tokens. The standard deviation for F1 of /æg/ is the highest of all vowel or following phone categories. In general, the standard deviations are higher for F2 suggesting more variation or movement for the front/back dimension. /æg/ and /ɛg/ have the highest standard deviations of F2 with their vowel group, but /eyN/ has the highest standard deviation for any of the /ey/ allophones at 411Hz.

4.3 Pre-velar Raising

RQ: Are Seattle speakers engaging in the attested raising of /æ/ before /g/? To what extent are Vancouver speakers engaging in pre-velar /æ/ raising?

4.3.1 Descriptive statistics of /æk/ and /æg/ in Seattle relative to front vowels

Unnormalized frequency means in Hertz for /æ/, /ɛ/ and /e/ before /k/ and /g/ are presented in Table 5. Before /k/, /æ/ is realized as [æ] or [æ̠] for Seattle speakers so a word like *back* is pronounced [bæk̚] or [bæ̠k̚]. In contrast, before /g/, many speakers realize /æ/ as [eyg] such that a word like *bag* is pronounced [beyg]. For some speakers, this seemed to be a very regular process affect all words with /æg/ segments, including words like *Bagdad* and *agriculture*, which were realized as [beygdad] and [eygɹɪkl̩tʃɹ̩]. Some speakers do not manifest this strong or consistent pattern of raising, realized words like *tag* as [tæːg], with only an audible length difference as compared to *tack*. The first elliptical plot below focuses on the *onset* of the segment, where a purely coarticulatory effect of the following segment is not expected to occur. A substantial difference present at onset for these allophones provides evidence for exaggeration and phonologization of the following segment's effect beyond what would be expected on the basis of coarticulation. In contrast, little difference at onset between /æ/ in different phonetic environments points to a coarticulatory phonetic effect of the following segment. The following plots show the vowels /e/, /ɛ/, and /æ/ before voiced and voiceless phonemes /g/ and /k/ at onset (20% time proportional point) for Seattle speakers by Sex and Age Group. The first image plots each vowel and following environment as an ellipse by plotting inverted normalized F1 values by normalized F2 values to represent the position of the vowel in the vowel space. Vowel is captured by line color; Following Phone is captured by line type. Older speakers are presented as Group 2 in the panels on the left. The second and third images illustrate the formant trajectories of F2 and F1, respectively, for the same phonemes and groups of speakers.

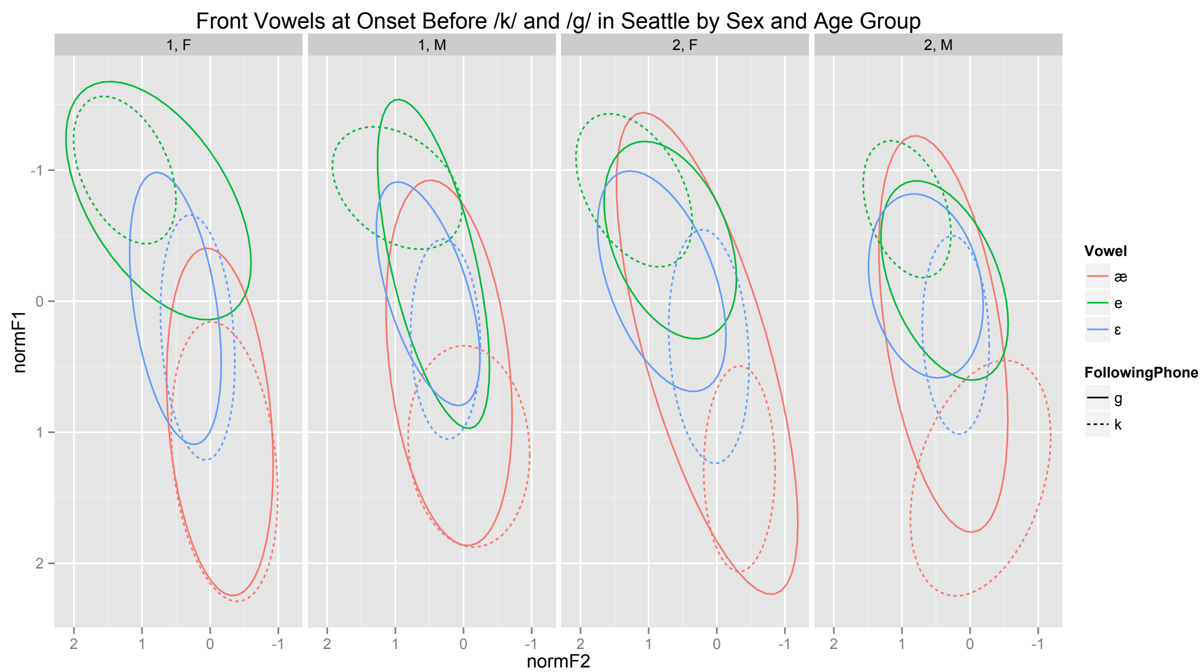

Figure 7. Ellipse plot of /æg/ and front vowels in Seattle /æk/ and /æg/ tokens at onset (20% time-proportional duration) as compared to /e/ and /ɛ/ (Lobanov normalized inverted F2 on x-axis; inverted Lobanov normalized F1 on y-axis) for Seattle speakers by age group (1= Group 1; 2= Group 2) and sex

At onset for the Group 2 male speakers in Seattle, this visualization indicates substantial overlap of /æg/ with /æk/ (shown be the red solid and red dotted ellipses) as well as with /eyg/, and /ɛg/ (as shown by the solid red, green, and blue ellipses). For Group 2 female speakers, /e/ and /ɛ/ overlap considerably before /g/, and /æ/ may also participate in this overlap, though the longer red solid ellipse suggests more variation than among the Group 2 male speakers in whether /æ/ participates in this raising at segment onset. Older speakers, both male and female, also appear to lower /ey/ before /g/ based on the solid green ellipse for /eyg/ overlapping with the solid blue one representing /ɛg/. For Group 1 male speakers, /e/ and /ɛ/ show a high degree of overlap before /g/, and almost no overlap before /k/. Some tokens or speakers raise /æ/ nearly to the height of /ey/ before /g/, but there is considerable variation in the height of /æ/ before /g/. For the youngest female speakers in the leftmost panel, /æg/ (the solid red line) overlaps considerably with /ɛk/ (dashed blue line) at onset, but very little with /eyg/ (solid green line) and not at all with /eyk/ (dashed green line). For this group of the youngest female speakers, as for all male and Group 2 Seattle speakers, /eyg/ lowers in comparison to /eyk/, yet the lack of overlap between /æg/ and /ɛg/ sets young female speakers apart from all other speaker sub-groups.

4.3.2 Mixed-effects regression results for /æk/ ~ /æg/ for Seattle

The table below summarizes the number of observations by speaker sub-group for the Seattle data.

Following Phone	**Age Group 1**		**Age Group 2**		**Total**
	Female	Male	Female	Male	
æk	455	425	505	430	1815
æg	375	350	425	365	1515
GRAND TOTAL			**n=3,330**		

Table 7. Number of observations by age and sex included in mixed-effects linear regression models of pre-velar raising among Seattle speakers

The linear mixed effects regression model used to examine F1 and F2 values for /æ/ before /k/ and /g/ is given below, followed by a table summarizing the effects found to be statistically significant, and a description of the findings. For a complete table providing the results from this model, see Appendix C.

F1

When modeling Seattle speakers' F1 values, a model containing a four-way interaction of Following Phone, Position.ord, Sex and normalized Duration was found to be more predictive than one including Age Group. Age Group did participate in significant three-way interactions with Following Phone and Sex. Preceding Phone information did not significantly improve the model. Post-hoc testing revealed that including speakers' sociocultural survey responses did not significantly improve the model. The significant predictors of F1 values are summarized in the table below. A full output of the model is available in Appendix C.

```
F1.lmerG <- lmer(normF1 ~ FollowingPhone*as.factor(AgeGroup)*Sex +
Position.ord*FollowingPhone*Sex*normdurms + (1 + Position.ord | Name) + (1|Word),
data=SEAae1)
```

	Est.	Std. Er.	t value	p
(Intercept)	0.662	0.12	5.31	< 1e-04
FollowingPhonek	0.487	0.07	7.05	< 1e-04
as.factor(AgeGroup)2	-0.434	0.15	-2.81	0.005
SexM	-0.470	0.17	-2.83	0.005
Position.ord.L	-0.927	0.07	-12.61	< 1e-04
Position.ord.Q	-0.533	0.05	-9.82	< 1e-04
FollowingPhonek:as.factor(AgeGroup)2	0.702	0.05	14.49	< 1e-04
FollowingPhonek:SexM	0.467	0.05	8.65	< 1e-04
FollowingPhonek:Position.ord.L	0.757	0.06	12.69	< 1e-04
FollowingPhonek:Position.ord.Q	0.317	0.06	5.31	< 1e-04
Position.ord.L:normdurms	0.143	0.04	3.84	0.000
Position.ord.Q:normdurms	-0.086	0.04	-2.31	0.021
FollowingPhonek:normdurms	-0.069	0.03	-2.18	0.029
FollowingPhonek:as.factor(AgeGroup)2:SexM	-0.250	0.07	-3.56	0.000
FollowingPhonek:SexM:Position.ord.L	-0.155	0.09	-1.80	0.071
FollowingPhonek:SexM:Position.ord.Q	-0.218	0.09	-2.54	0.011
FollowingPhonek:Position.ord.L:normdurms	-0.222	0.06	-3.54	0.000
SexM:Position.ord.L:normdurms	-0.177	0.05	-3.48	0.001
FollowingPhonek:SexM:normdurms	0.148	0.04	3.35	0.001
FollowingPhonek:SexM:Position.ord.L:normdurms	0.280	0.10	2.89	0.004

Table 8. Statistically significant fixed-effects for linear mixed-effects regression model of F1 for /æk/ ~ /æg/; full model output available in Appendix C

The figure below shows these effects of /k/ and /g/ on /æ/, relative to F1 trajectories for the front vowels /ɛ/, and /e/. Vowel is represented by color; Following Phone is represented by line type.

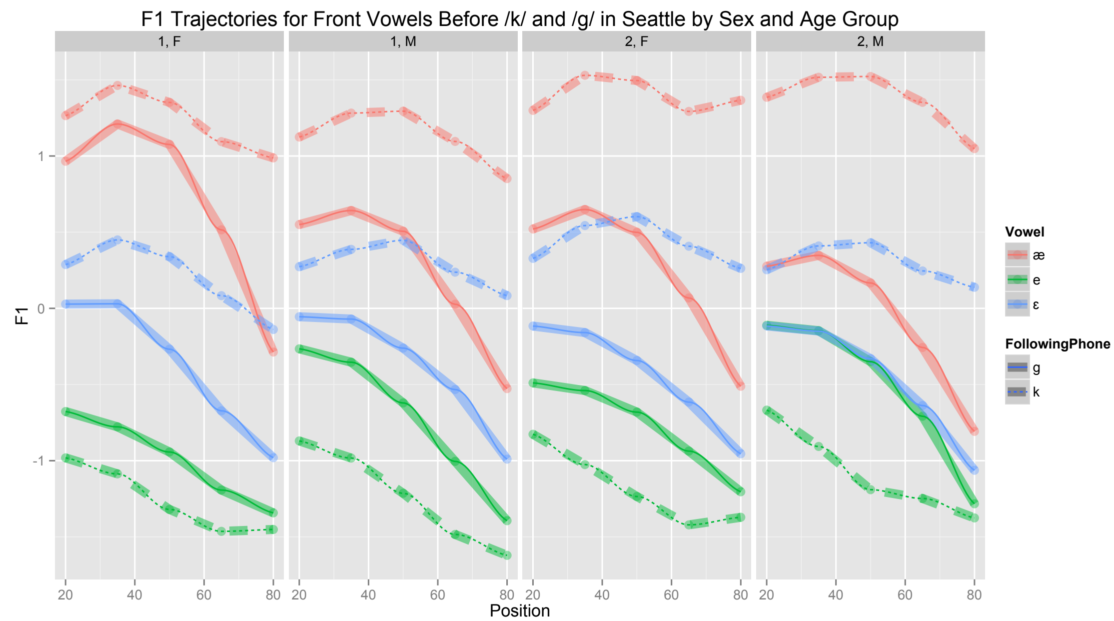

Figure 8. F1 trajectories for /æg/ in Seattle for /æ/, /e/, and /ɛ/ before /g/ (solid line) and /k/ (dashed line) with 5 time-proportional duration points on x-axis; Lobanov normalized F1 on y-axis for Seattle speakers wrapped by age group (1= Group 1; 2 = Group 2) and sex

For Seattle speakers, /k/ as a following phone has a significant effect on normalized F1 values, causing higher normalized F1 values in comparison to /æ/ before /g/. The effect of /g/ on /æ/ raising is significant, and the sizeable interaction of Following Phone and Age Group shows that the effect is much greater for Group 2 speakers than for Group 1 ones. Age Group is a significant factor in predicting normalized F1 values: Group 2 speakers have slightly lower normalized F1 values for æ before /g/ than speakers, meaning that they are engaging in more /g/-triggered raising than Group 1 speakers. This is the largest effect size observed for the model. The interaction between Following Phone and Sex likewise reveals that men have relatively higher F1 values for /æk/ as compared to /æg/, confirming that men also engage in significantly more contextual raising than women. There are significant interactions of Following Phone and F1 trajectory such that speakers show different slopes, parabolic and cubic shapes of their F1 trajectories before /k/ as compared /g/. The positive coefficient for the linear dimension reflects that the slope of F1 before /k/ is more gradually falling than before /g/. The small positive quadratic coefficient suggests that the parabolic shape of the F1 trajectory of /æ/ before /k/ is significantly flatter and less concave than /æ/ before /g/. There are additional interactions that involve the linear (slope) trajectories for these allophones among different sub-groups of speakers. For instance, the interaction between slope and Following Phone is different for men than it is for women. Men show higher F1 values for /æk/ relative to /æg/, which corresponds with greater differentiation of the two types of tokens. Men show less difference in their F1 slopes for /æ/ before /k/ and /g/, than women. (This is a counterintuitive indication that the two types of allophonic tokens are more differentiated more for men than for women, because it relates to the fact that men have lower values for /æg/ from onset and the degree of co-articulatory dropping is less than for women.) Finally, there is a three-way interaction of Age Group, Sex, and Following Phone. For /æk/ relative to /æg/, Group 2 male speakers tend to show lower F1 values compared to women than their Group 1 male counterparts. In other words, the contextual difference between /æk/ and /æg/ is greater for Group 2 male speakers than for young ones. For the Group 2 male speakers (far right panel), the F1 trajectories of /eg/ and /ɛg/ are identical, which is not the case for any other speaker sub-group. In the voiced pre-velar environment, then, F1 for /e/ has gone up and F1 for /ɛ/ has gone down relative to their trajectories before /k/. The F1 of /æg/ tokens for Group 2 male speakers start much lower from onset than /æk/ (approximately where the /ɛk/ tokens begin), suggesting that raising before /g/ is phonologized and not simply a co-articulatory gesture. Over the course of their duration, the F1 trajectory for /æg/ tokens for Group 2 male speakers approaches the nearly uniform /eyg/ - /ɛg/ trajectory. The /æg/ trajectory has a similar trajectory shape, but has a higher F1 value at onset, indicating that /æg/ tokens still start in a lower position in the vowel space than /eyg/ and /ɛg/, and then raise toward /eyg/ and /ɛg/ over the segment duration. The gap between the F1 of /æg/ and /æk/ tokens is greatest for the Group 2 male speakers than for any other sub-group highlighting that /æg/ is, relative to /æk/, the most raised of any speaker sub-group from onset.

With respect to their trajectory shapes, front vowels across all speaker subgroups before /g/ show steeper falling F1 trajectories than front vowels before /k/, and this does continue to manifest among Group 1 female speakers. This steeper trajectory for /Vg/ tokens as compared to /Vk/ tokens, and especially for /æg/ tokens, suggests a greater extent of vowel-inherent spectral change (VISC) for vowels preceding /g/ (Wickham 2009) (Yu 2013) (Yuan and Liberman n.d.). There are additional differences between men and women with respect to the effect of normalized duration on F1 values and trajectories. For Group 2 female speakers, the F1 trajectory of /æg/ more closely overlaps with the /ɛk/ trajectory than either the /eyg/ or /ɛg/ ones, which are not uniform for female as they are for Group 2 male speakers. F1 at onset of /æg/ is slightly higher than /ɛ/, but its trajectory falls sharply over its duration toward /ɛg/, but not reaching it. For Group 1 speakers, /eyg/ and /ɛg/ do not show the identical trajectories that they do among Group 2 male speakers, although there continues to be a lowering of /eyg/ in the vowel space relative to /eyk/ and a raising of /ɛg/ relative to /ɛk/. These changes affect the F1 of /eyg/ and /ɛg/ from onset, and are more extreme for Group 1 male speakers than for Group 1 female speakers. The F1 values at onset for /æg/ are progressively higher for each speaker sub-group moving from Group 2 male speakers to Group 1 female speakers, suggesting that /æg/ tokens are lower in the vowel space. In other words, the onset of /æg/ gets closer to the onset of /æk/ for the progressively Group 1 group. Young female speakers, in particular, show onset values of /æg/ that are very close to /æk/, despite having very different trajectory shapes for the two allophones.

Across all tokens (/æk/ and /æg/), male speakers show steeper F1 slopes accompanying increased duration than women. For /æk/ in comparison to /æg/, however, men show significantly less steep slopes with an increase in duration relative to women. This four-way interaction suggests, again, that the differentiation in the /æk/ and /æg/ tokens is greater for men. Based on the size of their t-values and the coefficients of normalized F1, the largest of the significant effects for Seattle speakers are for the interaction of Following Phone and slope for /k/ in contrast to /g/ and for the interaction of Age Group and Following Phone. The main effect of Following Phone, plus the interaction of Sex and Following Phone also have sizeable impacts on F1 values.

F2 for /æk/ ~ /æg/ in Seattle

The same four-way interaction was used to begin the model construction for F2. Position.ord was found not to participate in any significant interactions with Following Phone, Sex or Age Group, but maintained a strong independent effect on F2 values. The model was significantly improved by modeling normalized duration in an interaction with these terms and a significant four-way interaction was found. Preceding Phone did not significantly improve the model. Speakers' responses about the importance of shopping from their home city were found to improve the model and significantly affect F2 values for Seattle talkers. The final model and significant interactions are given below:

```
F2.lmerH <- lmer(normF2 ~ FollowingPhone*Sex*as.factor(AgeGroup)*normdurms +
Position.ord + Sameness + normImportanceShoppingHomeCity + (1 + Position.ord | Name) +
(1|Word), data=SEAae1)
```

	Estimate	Std.Error	t.value	p
(Intercept)	-0.25	0.08	-3.21	0
SexM	0.21	0.09	2.46	0.01
as.factor(AgeGroup)2	0.48	0.08	5.88	<1e-04
normdurms	0.16	0.02	6.59	<1e-04
Position.ord.L	0.2	0.03	6.3	<1e-04
Position.ord.Q	0.16	0.02	6.95	<1e-04
normImportanceShoppingHomeCity	-0.18	0.03	-5.36	<1e-04
SamenessY	0.27	0.06	4.23	<1e-04
FollowingPhonek:SexM	-0.44	0.05	-8.29	<1e-04
FollowingPhonek:as.factor(AgeGroup)2	-0.49	0.05	-10.73	<1e-04
SexM:normdurms	-0.15	0.03	-4.57	<1e-04
as.factor(AgeGroup)2:normdurms	-0.09	0.03	-2.88	0
FollowingPhonek:SexM:as.factor(AgeGroup)2	0.32	0.07	4.61	<1e-04

Table 9. Statistically significant fixed effects for linear mixed-effects regression model of F2 for /æk/ ~ /æg/ in Seattle; full model output available in Appendix C

The figure below shows these effects of /k/ and /g/ on /æ/, relative to F2 trajectories for the front vowels /ɛ/, and /e/. Vowel is represented by color; Following Phone is represented by line type.

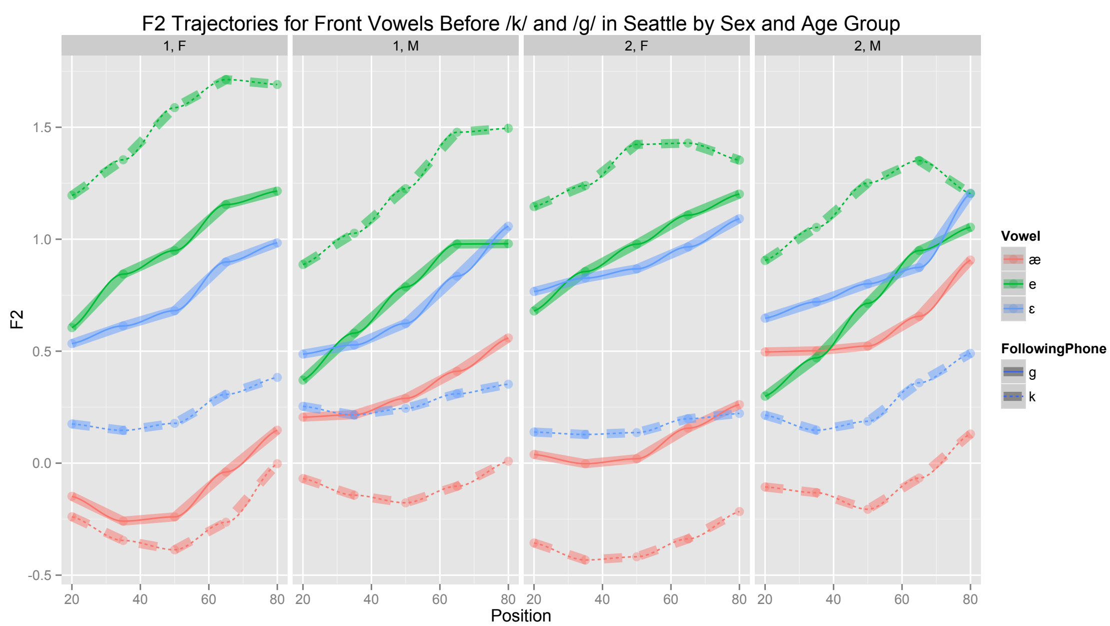

Figure 9. F2 trajectories for /æg/ in Seattle for /æ/, /e/, and /ɛ/ before /g/ (solid line) and /k/ (dashed line) with 5 time-proportional duration points on x-axis; Lobanov normalized F1 on y-axis for Seattle speakers wrapped by age group (1= Group 1; 2 = Group 2) and sex

For Seattle speakers, Following Phone does not have a significant independent effect on normalized F2 values, though it participates in interaction with Age Group and Sex to affect F2 values. In addition to these interactions, Age Group and Sex do have main effects on F2 values. Following Phone and Sex show a significant and large interaction and with male speakers showing lower F2 values for /æk/ as compared to /æg/ than for female speakers. Following Phone and Age Group also show a significant and sizable effect. For Group 2 speakers and men, separately, /æk/ tokens have significantly lower F2 values than /æg/ tokens. This suggests greater fronting of /æg/ as compared to /æk/ for Group 2 speakers and men, which might accompany raising on the F1 dimension. In other words, the differences between male speakers' F2 values for /æk/ and for /æg/ are more extreme than for female speakers, suggesting that male speakers are engaging in raising to a greater extent than female speakers, and the same is true of Group 2 and Group 1 speakers.

There are also differences in the slope and trajectory shape of different /æ/ tokens. There is a significant interaction between Following Phone and ordered Position indicating differences in the slope of F2 trajectories for /æk/ versus /æg/ tokens (note the different slopes of the dashed and solid red lines in Figure 11 above). The interaction shows that the slope of F2 for /æk/ is increasing less over the vowel's duration than the slope increases for /æg/. For Seattle speakers, /æg/ tokens involve more fronting over their trajectory than /æk/ tokens. The F2 trajectories of front vowel tokens before /k/ and /g/ largely correspond with the observed patterns for F1 trajectories, supporting the idea that "raising" actually includes a gesture of fronting. Generally, for all segments and all speaker subgroups, F2 trajectories have a positive slope and are raising (fronting) over the segment's duration. For all speaker subgroups, /eyg/ has a lower F2 at onset than /eyk/ and /ɛg/ has higher F2 at onset than /ɛk/. For the Group 2 female speakers and the

Group 1 male speakers, the F2 trajectories for /eyg/ and /ɛg/ are nearly identical. For the Group 1 female speakers, these are spread farther apart with /eyg/ remaining higher (fronter) than /ɛg/. The F2 trajectories of /æg/ tokens for Group 1 speakers are more back relative to other front vowels than for the Group 2 male speakers. For Group 2 male speakers, /æg/ begins nearly at the same frontness as /eyg/ and /ɛg/. For Group 2 female and Group 1 male speakers, it is less front, with the F2 trajectories of /æg/ backer in the vowel space and closely paralleling those for /ɛk/. For the youngest female speakers, the F2 trajectories of /æg/ are backer still in the vowel space and shows very little difference from /æk/. In fact, they are almost identical in shape, but F2 for /æg/ manifests as slightly higher (more front). The Group 1 female speakers are distinguished by the fact that /æg/ begins much farther back in the vowel space, despite continuing to move more front over the duration of the segment. There is an additional 3-way interaction of Following Phone, Age Group and Sex. The interaction of Following Phone and Age Group is different for male as compared to female speakers. Relative to female speakers, Group 2 male speakers show higher F2 values for /æ/ before /k/ as compared to /æ/ before /g/. While men show a higher degree of contextual raising between /æk/ and /æg/, they also have higher F2 values for both /æk/ and /æg/ than their female counterparts, suggesting a more front realization of /æ/ in both environments than women. Finally, there is a four-way interaction involving Following Phone, Sex, Age Group and normalized Duration. For /æk/ compared to /æg/, increased duration is associated with higher F2 values for Group 2 men than for women, again indicating more a front realization.

Subjects' responses to two of the sociocultural interview questions were also statistically significant as predictors of F2 values for pre-velar /æ/. Speakers who mentioned the sameness or similarity of Seattle and Vancouver in their sociocultural interview had significantly higher F2 values, meaning a more fronted variant of /æ/. Speakers' responses to the sociocultural survey question regarding the importance they placed on shopping from their home city also emerged as a significant predictor of F2 values. Higher ratings about the importance of shopping from Seattle among subjects predicted lower F2 values, which correspond with a backer realization of /æ/. These effects were small in general, and less sizeable than the effects of following phone or of age and sex sub-group, but were nonetheless statistically significant.

4.3.3 Summary of pre-velar raising in Seattle

Seattle speakers are engaging in raising of /æg/ tokens as compared to /æk/ tokens, and these changes are attested on both the F1 and F2 dimensions. The F1 dimension does reflect a greater magnitude of change (raising) than the F2 dimension (fronting). However, while female speakers demonstrate a statistically significant difference in the their F1 and F2 trajectories for /æg/ as compared to /æk/, their contrast between these two phonetic environments differs quantitatively and qualitatively from the same contrast among male speakers. Taking into account corresponding results for the separate F1 and F2 models, Group 2 speakers and male speakers are engaging more raising than Group 1 speakers and female speakers. Young female speakers show the least raising for /æg/ of any age and sex sub-group. While their /æk/ and /æg/ tokens are still significantly different, the differences are not present early in the vowel's duration and manifest toward offset, suggesting that they are due not to phonologized raising before /g/ (which would affect the segment from its onset), but to co-articulatory effects. This will be discussed in more depth in Chapter 6.

4.3.4 Descriptive statistics /æk/ and /æg/ in Vancouver relative to front vowels

Unnormalized frequency means in Hertz for /æ/, /ɛ/ and /e/ before /k/ and /g/ are presented in Table 6. Before /k/, /æ/ is realized as [æ] or [æ̠] for Vancouver speakers so a word like *back* is pronounced [bæk̚] or [bæ̠k̚]. In contrast, before /g/, many speakers realize /æ/ as [eyg], such that a word like *bag* is pronounced [beyg]. The elliptical plot below focuses on the *onset* of the segment, where a purely coarticulatory effect of the following segment is not expected to occur. Substantial differences by following phonetic environment at onset provide evidence for phonologization of the effect beyond what would be expected on the basis of coarticulation. In constrast, little difference at onset between /æ/ in different phonetic environments points to a coarticulatory phonetic effect of the following segment. The following plots show the vowels /e/, /ɛ/, and /æ/ at onset (20% time proporitional duration) before voiced and voiceless phonemes /g/ and /k/ for Vancouver speakers by Sex and Age Group. The first image plots each vowel and following environment as an ellipse by plotting inverted normalized F1 values by normalized F2 values to represent the position of the vowel in the vowel space. Vowel is captured by line color; Following Phone is captured by line type. Older speakers are presented as Group 2 in the panels on the right. The second and third images illustrate the formant trajectories for F2 and F1, respectively for the same phonemes and groups of speakers.

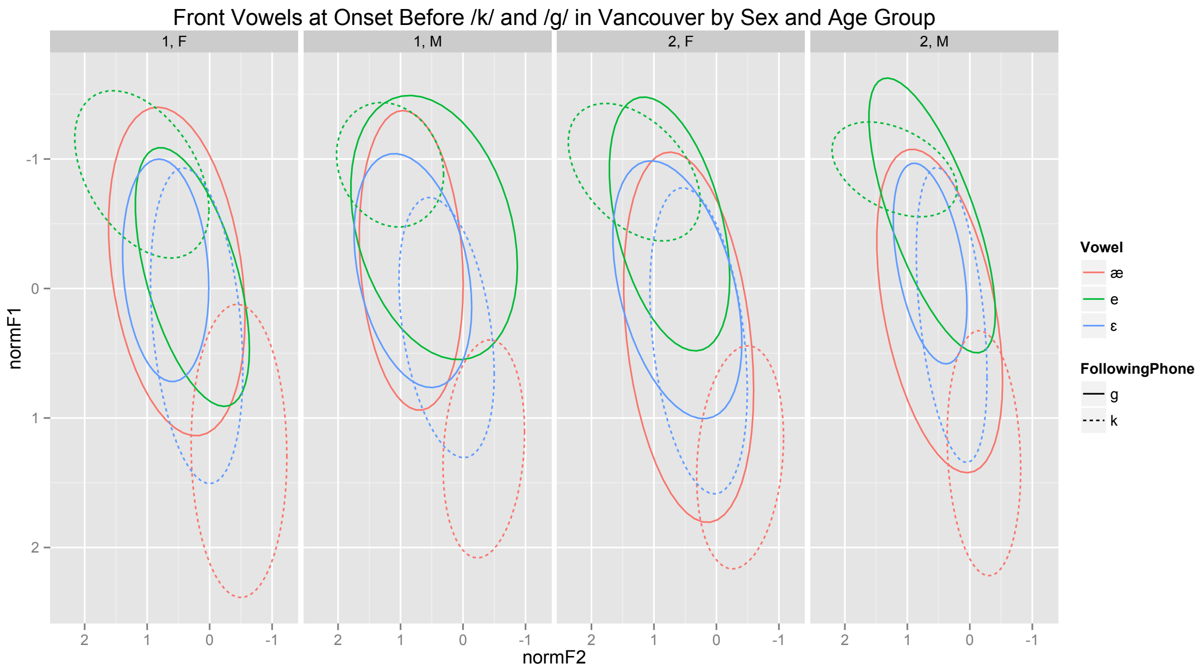

Figure 10. Ellipse plot of /æg/ and front vowels in Vancouver: /æk/ and /æg/ tokens at onset (20% time proportional point) as compared to /e/ and /ɛ/ (Lobanov normalized inverted F2 on x-axis; inverted Lobanov normalized F1 on y-axis) for Vancouver speakers by age group (1= Group 1; 2=Group 2) and sex

For speakers of all age groups, /æk/ and /ɛk/ overlap to a small degree, while /ɛk/ and /eyk/ do not overlap at all. For the oldest speakers, /eyg/, and /ɛg/ overlap almost completely, with /æg/ joining in to a slightly lesser extent. For the Group 1 speakers, and especially females, the overlap between /æg/, /eyg/, and /ɛg/ is even greater than for Group 2 speakers; the three ellipses are nearly identical. In comparison to the Group 2 speakers, Group 1 speakers are raising /æg/ higher and, for Group 1 females, are also lowering /eyg/. The lowering of /eyg/ as compared to /eyk/ appears to increase moving from Group 2 speakers to progressively Group 1 ones (from the two right panels to the two left panels in the figure above).

4.3.5 Mixed-effects regression results for /æk/ ~ /æg/ for Vancouver

The table below summarizes the number of observations included in the regression models:

Following Phone	Age Group 1		Age Group 2		Total
	Female	Male	Female	Male	
æk	415	455	450	355	1675
æg	345	380	370	290	1385
GRAND TOTAL			**n=3,060**		

Table 10. Number of observations (by age and sex) included in mixed-effects linear regressions of /æk/ ~ /æg/ among Vancouver speakers

F1

When modeling Vancouver speakers' F1 values, a model containing a four-way interaction of Following Phone, Position.ord, Age Group and Sex was not found to be significantly better than one modeling the data using a combination of three-way interactions. Age Group was included as a separate interaction with Following Phone because it reduced complexity and did not significantly affect the model's predictive power. Including Preceding Phone did not significantly improve the model, but normalized duration did. Including duration as an interacting term with ordered Position and Following Phone provided a significantly better model than modeling duration as an independent fixed effect. While there were no significant interactions of Position.ord, Following Phone and normalized Duration, there were various significant interactions of two terms, and separating the interaction resulted in a significantly less predictive model. Post-hoc testing identified no significant improvements from including speakers' responses to the sociocultural survey. The most predictive F1 model is:

```
F1.lmerI <- lmer(normF1 ~ Position.ord*FollowingPhone*normdurms + FollowingPhone*Sex +
FollowingPhone*as.factor(AgeGroup) + (1 + Position.ord | Name) + (1|Word), data=VANae1)
```

	Est.	Std. Er.	t value	p
(Intercept)	-0.217	0.07	-2.94	0.003
Position.ord.L	-0.710	0.06	-12.84	<1e-04
Position.ord.Q	-0.356	0.04	-8.83	<1e-04
FollowingPhonek	1.469	0.06	23.99	<1e-04
normdurms	0.082	0.02	5.42	<1e-04
SexM	-0.177	0.07	-2.47	0.014
as.factor(AgeGroup)2	0.233	0.07	3.24	0.001
Position.ord.L:FollowingPhonek	0.487	0.04	11.12	<1e-04
Position.ord.Q:normdurms	-0.061	0.03	-2.33	0.020
FollowingPhonek:normdurms	-0.134	0.02	-5.43	<1e-04
FollowingPhonek:SexM	0.189	0.04	5.36	<1e-04
FollowingPhonek:as.factor(AgeGroup)2	-0.249	0.04	-7.06	<1e-04

Table 11. Statistically significant fixed effects for linear mixed-effects regression model of F1 for pre-velar /æ/ raising in Vancouver; full model output available in Appendix C

The figure below shows these effects of /k/ and /g/ on /æ/, relative to F1 trajectories for the front vowels /ɛ/, and /e/. Vowel is represented by color; Following Phone is represented by line type.

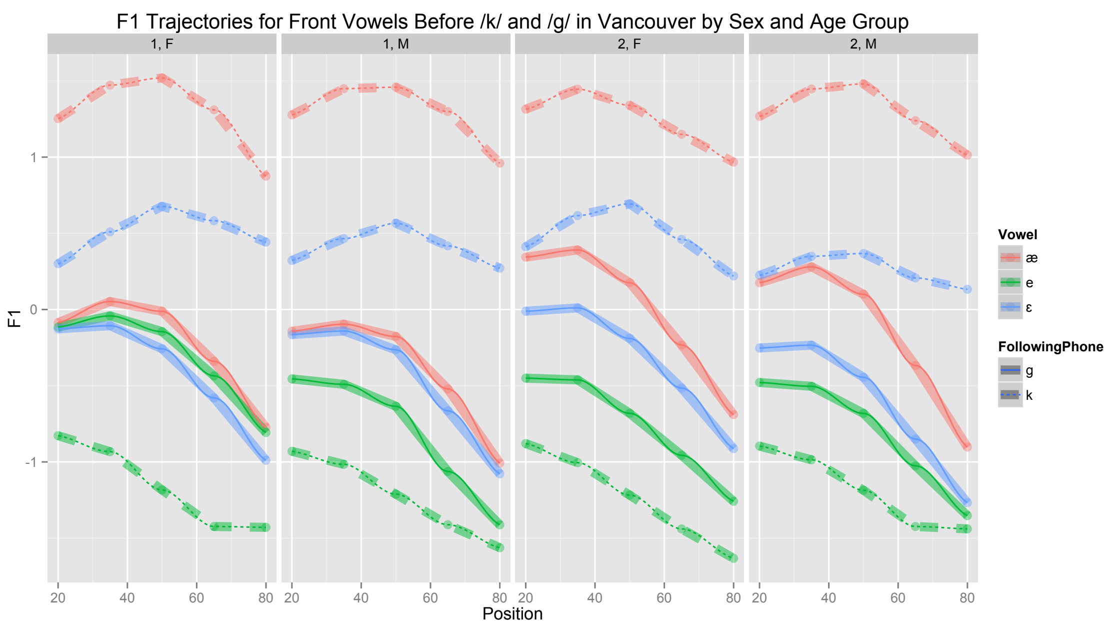

Figure 11. F1 trajectories for /æg/ in Vancouver: F1 trajectories for /æ/, /e/ and /ɛ/ before /g/ (solid line) and /k/ (dashed line) with time point on x-axis; Lobanov normalized F1 on y-axis for Vancouver speakers wrapped by Age Group (1= Group 1; 2=Group 2) and Sex across five proportional time points

Of these statistically significant predictors, Following Phone has the largest effect on F1 values for /æ/. For Vancouver speakers, the normalized F1 values of /æ/ before /k/ are significantly and substantially higher than those of /æ/ before /g/, which suggests that Vancouver speakers are participating in /æg/ raising. There are also significant linear and quadratic differences in the normalized F1 trajectories of /æ/. There are significant differences between Following Phone and Position (F1 trajectory) such that /æ/ has a steeper, more negative slope before /g/ than before /k/. While F1 trajectory was not found to vary significantly for speakers from different, age and sex subgroups, there may still be some indications of variation or change in progress, as the figure shows. For Vancouver speakers, the F1 trajectories of /æk/, /ɛk/, and /eyk/ are very consistent over the sub-groups, but the trajectories of /æg/, /ɛg/, and /eyg/ show more variation and a potential change in apparent time. For the oldest male speakers, the F1 trajectories of /æg/, /ɛg/, and /eyg/ fall between the trajectories of /eyk/ and /ɛk/. The F1 value of /eyg/ at onset is higher than /eyk/, while /ɛg/ is lower than /ɛk/, and /æg/ is considerably lower than /æk/. The F1 trajectories for Group 2 female speakers look largely similar, though /æg/ and /ɛg/ look slightly closer together than /ɛg/ and /eyg/, which were closer for Group 2 male speakers. For Group 1 male speakers the F1 trajectories for /æg/ and /ɛg/ are completely merged and /eyg/ shows a similarly shaped trajectory but has lower F1 values. For Group 1 female speakers all three vowels have almost identical F1 trajectories before /g/. The onset F1 values for /æg/, /ɛg/ and /eyg/ all begin slightly lower (higher in the vowel space) than /ɛk/ and move toward /eyk/ over their duration. For all speaker sub-groups, the trajectories of /æg/ tokens over falling over the duration of the segment, but there the height of F1 onset continues to lower over time for the Group 1 speakers. This suggests increased phonologized raising for Group 1 speakers.

Age Group and Following Phone participate in a significant and sizable interaction to predict F1 values. There is also a significant difference between male and female speakers with respect to normalized F1 values and a significant interaction of Following Phone and Sex that indicates that relative to women, Vancouver men have higher F1 values for /æk/ relative to /æg/. This suggests that across all Age Groups men are differentiating /æk/ and /æg/ tokens to a greater extent than female speakers, though the effect size is relatively small. There is also a significant interaction between Following Phone and Age Group in which Group 2 speakers show less difference in F1 values for /æk/ relative to /æg/ than Group 1 speakers. This indicates greater differentiation of /æk/ and /æg/ tokens among Group 1 speakers. Normalized Duration also plays a significant role in predicting F1 values. For /æk/, longer duration is associated with less difference from /æg/. Overall, the independent effect of Following Phone is the largest effect in the model of F1 values, followed by large effects for Age Group interacting with Following Phone, and by Sex interacting with Following Phone.

F2

A significant four-way interaction was identified for Following Phone, Position.ord, Age Group and Sex. Normalized duration information was found to significantly improve the model, but preceding phone was not. Post-hoc testing revealed that the F2 model was significantly improved by including subjects' ratings of the similarity between Seattle and Vancouver.

```
F2.lmerD <- lmer(normF2 ~ FollowingPhone*Position.ord*Sex*as.factor(AgeGroup) + normdurms + normSeattleVancouverSimilarity + (1 + Position.ord | Name) + (1|Word), data=VANae1)
```

F2 for Vancouver

	Est.	Std. Er.	t value	p
(Intercept)	0.749	0.08	9.90	< 1e-04
FollowingPhonek	-1.288	0.05	-24.86	< 1e-04
Position.ord.L	0.297	0.07	4.33	< 1e-04
SexM	0.226	0.10	2.30	0.021
as.factor(AgeGroup)2	-0.234	0.10	-2.40	0.016
normdurms	-0.035	0.01	-3.60	0.000
normSeattleVancouverSimilarity	0.093	0.04	2.54	0.011
FollowingPhonek:Position.ord.L	-0.283	0.07	-4.34	< 1e-04
FollowingPhonek:Position.ord.Q	0.109	0.07	1.67	0.094
FollowingPhonek:as.factor(AgeGroup)2	0.296	0.04	7.30	< 1e-04
FollowingPhonek:Position.ord.L:SexM:as.factor(AgeGroup)2	-0.314	0.13	-2.40	0.016

Table 12. Statistically significant fixed effects for mixed effects linear regression model of F2 for /æk/ ~ /æg/ in Vancouver; full model output available in Appendix C

The figure below shows these effects of /k/ and /g/ on /æ/, relative to F2 trajectories for the front vowels /ɛ/, and /e/. Vowel is represented by color; Following Phone is represented by line type.

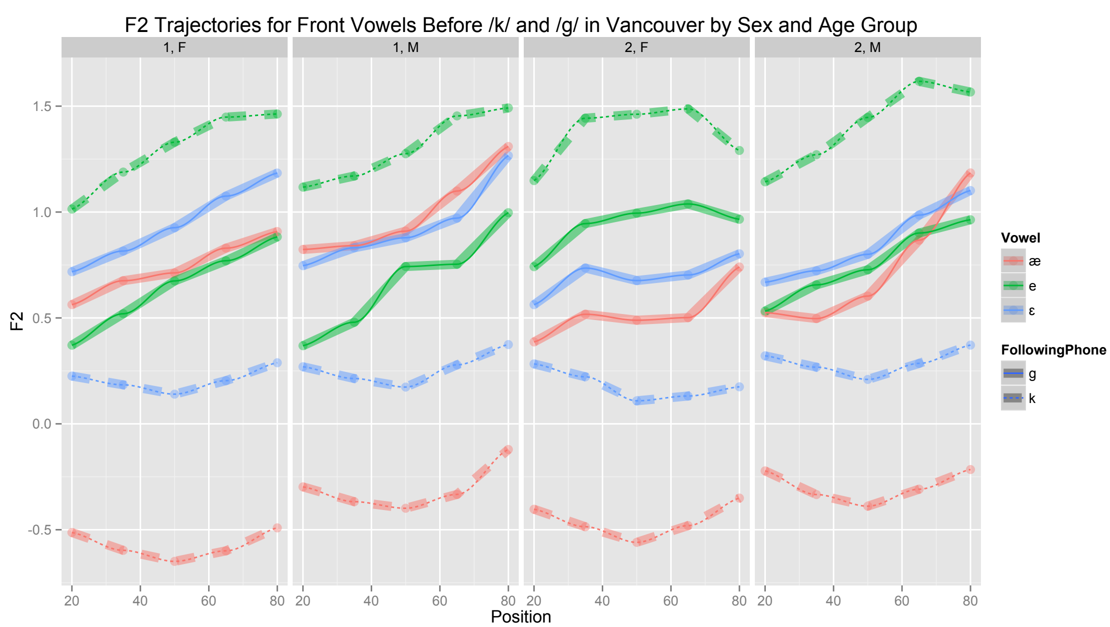

Figure 12. F2 trajectories for /æg/ in Vancouver: F2 trajectories for /æ/, /e/ and /ɛ/ before /g/ (solid line) and /k/ (dashed line) with time point on x-axis; Lobanov normalized F2 on y-axis for Vancouver speakers wrapped by age Group (1= Group 1; 2=Group 2) and sex across five proportional time points

For Vancouver speakers, Following Phone has a main effect on F2 values. The F2 values are significantly and sizably lower for /æk/ tokens than for /æg/ tokens, suggest greater fronting for /æg/ tokens, which would likely accompany raising on the F1 dimension. The effect of Following Phone is by far the largest effect in the model. There are also significant differences in the linear and quadratic shapes of the F2 trajectory for Vancouver speakers. There is a significant main effect of Sex and, independently, Age Group. Older speakers show significantly lower F2 values for /æ/ than Group 1 speakers, suggesting that they engage in less pre-velar fronting. Male speakers, on the other hand, show significantly higher F2 values than female speakers, indicating that their realizations of /æ/ are fronter. There is a significant interaction of Following Phone and Age Group such that Group 2 speakers show significantly greater F2 values for /æk/ as compared to /æg/ than Group 1 speakers. In other words, the difference between /æk/ and /æg/ is larger for Group 1 speakers than for Group 2 speakers suggesting that Group 1 speakers may be engaging in contextual /æg/ fronting to a greater extent than Group 2 speakers. These effects are visible in the figure above. For all speaker sub-groups, F2 trajectories for /æg/, /ɛg/, /eyg/, fall in between those for /eyk/ and /ɛk/, showing that all three vowels are fronted to approximately the same degree before the voiced velar. For Group 1 male and female speakers, the F2 values of /æg/ are higher than for /eyg/, whereas for Group 2 speakers, /eyg/ and /ɛg/ have higher F2 values than /æg/. This visually illustrates the significant finding that /æg/ tokens are progressively fronter and /eyg/ less so for Group 1 Vancouver speakers.

The slope of /æ/'s F2 trajectory before /g/ differs significantly from its F2 trajectory before /k/. The statistical analysis reveals that before /k/, the F2 slope of /æ/ rises less than it does before /g/, suggesting less fronting before /k/. F2 trajectories for Vancouver speakers show trends that correspond with those observed for F1, and this time the variation in F2 trajectory by

Age and Sex subgroup does reach significance. Finally, subjects' ratings of Seattle and Vancouver's similarity were found to have a significant, though very small, main effect on F2 values. Speakers who had higher ratings for the similarity of the two cities had slightly higher F2 values, indicating a more front realization of /æ/. The F2 analysis shows that raising in the vowel space, as indicated by significant contextual effects on F1 values, is accompanied by gestures of fronting.

4.3.6 Summary of Pre-velar Raising in Vancouver

Vancouver speakers are participating in raising and fronting of /æ/ before /g/ as compared to /k/ as defined by significant affects to both F1 and F2 dimensions. This difference of phonetic context is robust for all age and sex subgroups. Nonetheless, significant differences emerge to suggest that male speakers have slightly more contextual raising than female speakers and that Group 1 speakers have significantly more contextual raising than Group 2 speakers. Overall, the analyses suggest very strong phonologized raising of /æg/.

4.3.7 Comparing /æg/ raising in Seattle and Vancouver

The best-fit models for Seattle and Vancouver with the addition of the City variable were used as the starting point for the F1 and F2 models used to compare the cities and identify variation across them. To consider potential variation in formant trajectories across cities, City was modeled as an interactional term with Following Phone and ordered Position. It was also modeled as potentially interacting with Age Group, Sex, and Following Phone to consider whether differences exist among speaker sub-groups in the two cities. For F1, all attempts to remove terms from the three-way and separate four-way interactions resulted in significantly less predictive models than the original one. The inclusion of normalized duration information was found to have a significant effect on the model, but the inclusion of Preceding Phone was not.

Subjects' responses regarding sociocultural questions did not make significant contributions to the model.

```
F1.lmerD <- lmer(normF1 ~ FollowingPhone*Position.ord*normdurms +
City*FollowingPhone*Sex*(as.factor(AgeGroup)) + (1 + Position.ord | Name) + (1|Word),
data=ae1)
```

F1 Comparison Across Cities

	Est.	Std. Er.	t value	p
(Intercept)	0.601	0.10	5.86	< 1e-04
FollowingPhonek	0.527	0.06	8.96	< 1e-04
Position.ord.L	-0.794	0.04	-21.31	< 1e-04
Position.ord.Q	-0.423	0.03	-15.34	< 1e-04
Position.ord.C	0.049	0.02	2.11	0.035
Position.ord^4	0.024	0.02	1.08	0.282
normdurms	0.039	0.01	3.55	0.000
CityVAN	-0.833	0.14	-6.17	< 1e-04
SexM	-0.403	0.13	-2.99	0.003
as.factor(AgeGroup)2	-0.443	0.13	-3.32	0.001
FollowingPhonek:Position.ord.L	0.584	0.03	18.88	< 1e-04
FollowingPhonek:Position.ord.Q	0.114	0.03	3.68	0.000
FollowingPhonek:normdurms	-0.070	0.02	-3.94	< 1e-04
Position.ord.L:normdurms	0.045	0.02	2.44	0.015
Position.ord.Q:normdurms	-0.059	0.02	-3.21	0.001
Position.ord.C:normdurms	-0.045	0.02	-2.47	0.013
FollowingPhonek:CityVAN	0.926	0.05	18.41	< 1e-04
FollowingPhonek:SexM	0.403	0.05	8.05	< 1e-04
CityVAN:as.factor(AgeGroup)2	0.779	0.19	4.10	< 1e-04
FollowingPhonek:as.factor(AgeGroup)2	0.691	0.05	14.43	< 1e-04
FollowingPhonek:Position.ord.C:normdurms	0.066	0.03	1.96	0.050
FollowingPhonek:CityVAN:SexM	-0.206	0.07	-2.91	0.004
FollowingPhonek:CityVAN:as.factor(AgeGroup)2	-0.932	0.07	-13.42	< 1e-04
FollowingPhonek:SexM:as.factor(AgeGroup)2	-0.234	0.07	-3.36	0.001
FollowingPhonek:CityVAN:SexM:as.factor(AgeGroup)2	0.212	0.10	2.10	0.035

Table 13. Statistically significant fixed effects for linear mixed-effects regression model of F1 for /æk/ ~ /æg/ across both Seattle and Vancouver; full model output available in Appendix C

Following Phone emerges as a significant independent predictor of F1 values across Seattle and Vancouver. City also has an independent main effect on F1 values, with Vancouver having lower F1 values than Seattle speakers, though the effect is not large. City also interacts with other variables to impact F1. The interaction between City and Following Phone, for example, produces one of the largest significant effects of any term(s) in the model. For Vancouver speakers, /k/ as a Following Phone produces substantially higher F1 values for /æ/ (relative to /g/) than for Seattle speakers. This suggests greater contextual raising of /æg/ tokens among Vancouver speakers than Seattle speakers. City interacts significantly with Age Group and Following Phone. Older speakers in Vancouver have higher F1 values as compared to Group 1 speakers, showing that Group 2 speaker engage in less contextual raising of /æg/ in Vancouver, where the opposite is true among Seattle speakers. This is one of the largest effects in the model. City interacts similarly with Sex and Following Phone, though the effect is much smaller. For Vancouver men, there is less difference between /æk/ and /æg/ (compared to Vancouver women) than there is for Seattle men.

The three-way interaction of Following Phone, Sex and Age Group indicates that, across both cities, Group 2 men differentiate the /æg/ and /æk/ tokens more than their female counterparts. The subsequent four-way interaction of Following Phone, City, Age Group and Sex reveals, however, that there are relative differences in how this relates to Group 1 speakers. For Group 2 speakers, the interaction of City, Following Phone and Sex works differently than for Group 1 speakers. In the Group 2 speaker group, Vancouver men have lower F1 values for /æk/ relative to /æg/ (more differentiation than women), but they have less differentiation than their Group 1 Vancouver counterparts. In Seattle, similarly, Group 2 men show more differentiation of /æk/ and /æg/ than their Group 2 female counterparts, but in contrast to Vancouver, they show more differentiation than their Group 1 male counterparts. Overall, Following Phone, City, Age Group and Sex are strong predictors of F1 values for pre-velar /æ/ tokens. While Following Phone is an important predictor of F1 in both cities, there is additional variation and complexity among speaker sub-groups with respect to these effects.

F2

To find the best-fitting model for F2 values across both cities in the data set, the models identified as best in each separate city were considered with the addition of City as an interactive term. City was considered in interaction with Following Phone, Duration and ordered Position as well as the interaction of Following Phone, Sex, and Age Group. The model was not significantly different when City was removed from the interaction with Following Phone, Duration and ordered Position, so the model with fewer terms was retained. The inclusion of Preceding Phone did not significantly improve the model. Post-hoc model comparisons identified a statistically significant improvement for only one of the sociocultural survey questions: Municipal Pride. The final model for F2 comparing both cities is as follows:

```
F2.lmerC <- lmer(normF2 ~ FollowingPhone*Position.ord*City*normdurms +
City*FollowingPhone*Sex*(as.factor(AgeGroup)) + normProudOfYourCity + (1 + Position.ord |
Name) + (1|Word), data=ae1)
```

	Est.	Std. Er.	t value	p
(Intercept)	-0.104	0.09	-1.22	0.224
FollowingPhonek	-0.086	0.04	-1.97	0.049
Position.ord.L	0.265	0.03	7.62	< 1e-04
Position.ord.Q	0.121	0.03	4.31	< 1e-04
CityVAN	0.848	0.12	7.31	< 1e-04
normdurms	0.057	0.01	5.15	< 1e-04
SexM	0.374	0.12	3.15	0.002
as.factor(AgeGroup)2	0.259	0.11	2.26	0.024
normProudOfYourCity	-0.073	0.03	-2.28	0.022
FollowingPhonek:Position.ord.L	-0.131	0.04	-3.71	0.000
FollowingPhonek:CityVAN	-1.198	0.04	-27.80	< 1e-04
Position.ord.Q:normdurms	0.050	0.02	2.41	0.016
CityVAN:normdurms	-0.103	0.01	-7.52	< 1e-04
FollowingPhonek:SexM	-0.277	0.04	-6.67	< 1e-04
CityVAN:as.factor(AgeGroup)2	-0.409	0.16	-2.49	0.013
FollowingPhonek:as.factor(AgeGroup)2	-0.400	0.04	-10.06	< 1e-04
FollowingPhonek:Position.ord.L:CityVAN	-0.173	0.05	-3.36	0.001
Position.ord.Q:CityVAN:normdurms	-0.067	0.03	-2.20	0.028
FollowingPhonek:CityVAN:SexM	0.250	0.06	4.26	< 1e-04
FollowingPhonek:CityVAN:as.factor(AgeGroup)2	0.696	0.06	12.08	< 1e-04
FollowingPhonek:SexM:as.factor(AgeGroup)2	0.153	0.06	2.66	0.008
FollowingPhonek:Position.ord.Q:CityVAN:normdurms	0.118	0.06	2.13	0.034

Table 14.Statistically significant fixed effects for linear mixed-effects regression model of F2 for /æk/ ~ /æg/ across both Seattle and Vancouver; full model output available in Appendix C

City has a significant main effect on F2 values and also interacts with other variables to impact F2 values. Vancouver speakers have higher F2 values, suggest more front pre-velar /æ/ variants, though this effect is not the largest in the model. City interacts with Following Phone and, separately, with Age Group to predict F2 values. The interaction of City and Following Phone is the largest in the model. Vancouver speakers have much lower F2 values for /æk/ relative to /æg/ which shows greater differentiation on the fronting dimension than is found among Seattle speakers. There are additional three-way interactions of Following Phone, City and Age Group as well as Following Phone, City, and Sex. The first of these effects is larger, showing that for Group 2 speakers, the interaction of City and Following Phone works differently than for Group

1 speakers. Older speakers in Vancouver have higher F2 values for /æk/ relative to /æg/ than Seattle speakers, showing less differentiation of the allophones and less contextual fronting of /æg/. The interaction between Following Phone and City is also different for female speakers than it is for male speakers. For F2 of /æ/ before /k/ (relative to /æ/ before /g/), Vancouver women have lower F2 values than men suggesting greater contextual raising of /æ/ before /g/, though this effect is much smaller than the one reported for Age Group.

4.3.8 Summary of Pre-Velar Raising Across Seattle and Vancouver

While both Seattle and Vancouver speakers engage in /æg/ raising, distinct trends are evident across gender and sex subgroups. As a whole, Vancouver speakers show a greater degree of raising and fronting than Seattle speakers as evidenced by significant differences in both the F1 and F2 models. The variation across Age and Sex sub-groups within each city populations is complex, however. With respect to Age Group, the two cities display opposite trends: /æg/ raising is more extreme among Group 1 speakers in Vancouver, while it is less extreme among Group 1 speakers in Seattle. Sex subgroups also pattern differently across the two cities. While significant differences are found between /æk/and /æg/ for female speakers, Group 1 female speakers in Seattle engage in less raising. Group 1 female speakers from Vancouver, on the other hand, are leading their male counterparts in raising. While populations from both cities generally appear to engage in phonologized raising, the relatively smaller degree of raising by Group 1 Seattle speakers, and especially females contrasts with dramatically more raising among Group 1 speakers in Vancouver, and especially females.

4.4 Pre-nasal /æ/ Raising

RQ: Are Seattle speakers engaging in the attested raising of /æ/ before /n/? To what extent are Vancouver speakers engaging in pre-velar /æn/ raising?

A notable difference emerges in the trajectories of /æn/ across Seattle and Vancouver speakers. While pre-nasal raising was initially assessed relative to /d/ as both share place and voicing qualities, a comparison of /æn/ and /æg/ trajectories paint a more accurate picture of the variation in types of "raising" that occur across the cities. While the statistical analysis of /æn/ and /æd/ shows significant differences between the phonetic contexts for all sex and age subgroups in both cities, indicating that for all speakers /æ/ was more raised and fronted before /n/ than before /d/, Seattle pre-nasal "raising" and Vancouver pre-nasal "raising" are very different. These qualitative differences between /æn/ raising as compared to /æg/ raising in Seattle and Vancouver are described in this section followed by a statistical analysis.

4.4.1 Descriptive statistics of pre-nasal /æ/ raising in Seattle

For unnormalized and normalized mean values of /æ/ in pre-nasal and pre-velar contexts, refer to Table 5. For Seattle speakers, /æn/ is consistently tensed (raised and fronted) and sounds more diphthongal than /æ/ before non-nasal stops. It is somewhat difficult to transcribe in part due to its rapidly shifting formant structure. At onset, /æn/ has a formant structure that resembles /ej/, but by offset it resembles /æ̝/. The word *fan*, for example, is realized as [fæ̝̃ʲn]. The chart below focuses on the *onset* of the segment, where a purely coarticulatory effect of the following segment is not expected to occur. Substantial differences by following phonetic environment at onset provide evidence for phonologization of the effect beyond what would be expected on the basis of coarticulation. In constrast, little difference at onset between /æ/ in different phonetic environments points to a coarticulatory phonetic effect of the following segment. The following plots show normalized F1 by F2 values for /æ/ at onset (20% time proportional point) before phonemes /g/ and /n/ and /d/ for Seattle speakers by Sex and Age Group. Following Phone is captured by line color; Group 2 speakers are presented as Group 2 in the panels on the left.

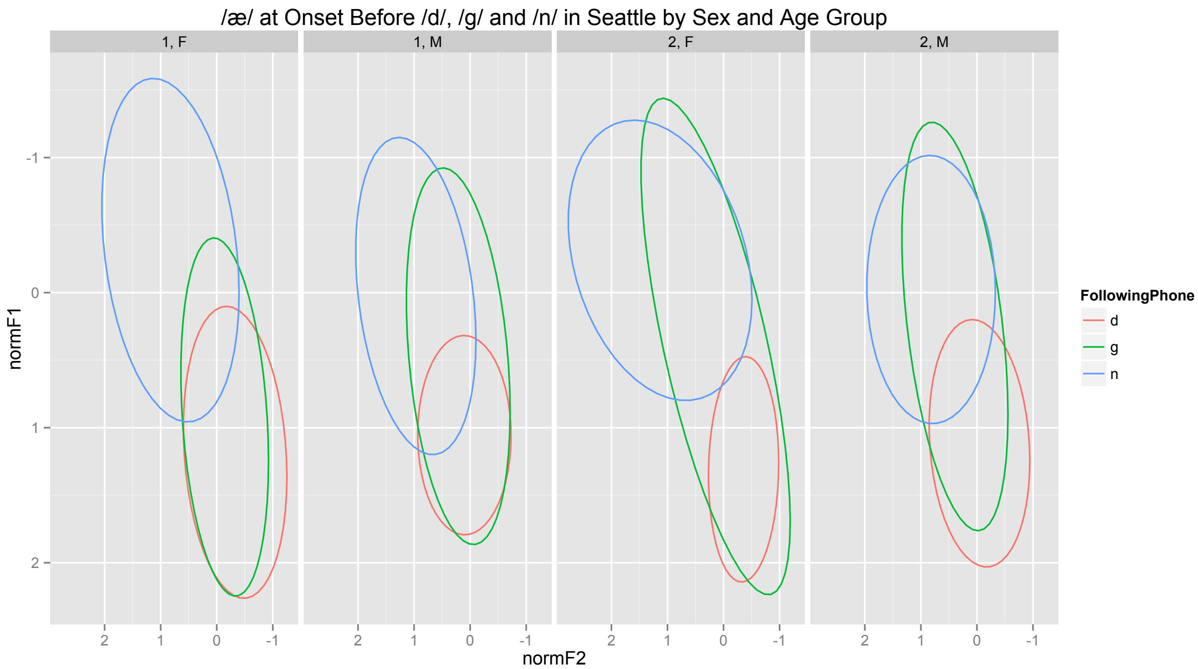

Figure 13. Ellipse plot of /æn/ vs /æd/ in Seattle /æ/ tokens before /d/, /n/, and /g/ at onset (20% time-proportional duration) with Lobanov normalized inverted F2 on x-axis; inverted Lobanov normalized F1 on y-axis for Seattle speakers wrapped by age group (1= Group 1; 2= Group 2) and sex

Relative to /æd/, /æn/ is raised from onset with a similar height and consistency across all speaker sub-groups. From onset, /æn/ tokens make up a nearly separate class than /æd/ tokens as shown by the minimial overlap of the red and blue ellipses across all the panels in the figure above. For Group 2 speakers and Group 1 males, the degree of /æn/ raising overlaps with the degree of raising for /æg/ tokens, though the ellipses for /æn/ are smaller, indicating less variation than for /æg/ raising. For Group 1 female speakers, /æn/ tokens are raised considerably higher than /æg/ tokens.

4.4.2 Mixed-effects linear regression models for /æn/ ~ /æd/ raising in Seattle

The table below summarized the number of observations for the regression analyses in Seattle:

Following Phone	**Age Group 1**		**Age Group 2**		**Total**
	Female	Male	Female	Male	
æd	515	480	595	520	2,110
æN	295	290	345	290	1,220
GRAND TOTAL			**n=3,330**		

Table 15. Number of observations (by age and sex) included in mixed-effects linear regressions of /æd/ ~ /æn/ among Seattle speakers

F1

The F1 model compared /æn/ tokens with /æd/ tokens for Seattle talkers. The first model contained a four-way interaction of Following Phone, Position.ord, Sex, and Age Group, but no significant four-way interactions were found involving Age Group. The model was not significantly affected by removing Age Group. A significant three-way interaction was found for Following Phone, Position.ord, and Sex. The addition of normalized Duration information improved the model, but Preceding Phone did not. Post-hoc testing revealed that speakers' responses to sociocultural questions were not significant predictors of F1 values in pre-nasal raising.

```
F1.lmerC <- lmer(normF1 ~ FollowingPhone*Position.ord*Sex + normdurms + (1 + Position.ord | Name) + (1|Word), data=SEAae2)
```

	Est.	Std. Er.	t value	p
(Intercept)	0.938	0.10	9.17	< 1e-04
FollowingPhonen	-0.981	0.14	-7.20	< 1e-04
Position.ord.L	-0.655	0.06	-11.01	< 1e-04
Position.ord.Q	-0.411	0.04	-9.87	< 1e-04
normdurms	0.040	0.01	3.86	0.000
FollowingPhonen:Position.ord.L	0.922	0.05	17.82	< 1e-04
FollowingPhonen:Position.ord.Q	0.271	0.05	5.24	< 1e-04
FollowingPhonen:SexM	0.115	0.03	3.41	0.001
Position.ord.L:SexM	0.251	0.08	2.97	0.003
FollowingPhonen:Position.ord.L:SexM	-0.372	0.08	-4.95	< 1e-04

Table 16. Statistically significant fixed effects for linear mixed-effects regression model of F1 for /æd/ ~ /æn/ in Seattle; full model output available in Appendix C

The figure below shows the normalized F1 trajectories for the front vowel /æ/ before /g/, /n/ and /d/. Only one vowel is shown, and Following Phone is represented by color.

Figure 14. F1 trajectories for /æn/ in Seattle: F1 trajectories for /æ/ before /d/, /g/, and /n/ with time-proportional duration point on x-axis; Lobanov normalized F1 on y-axis for Seattle speakers wrapped by age group (1= Group 1; 2= Group 2) and sex across five time-proportional points

For Seattle speakers, Following Phone has a significant effect on F1 values in an analysis comparing /æd/ tokens with /æn/ tokens. A following nasal has a sizeable effect in reducing F1 values, indicating a higher vowel, as compared to /æd/. There are also differences in the slope and parabolic shape of F1 trajectories for these allophonic environments, and these are very large effects. Before /n/, the F1 trajectory of /æ/ has a positive slope in comparison to the negative slope it shows before /d/. This is the largest effect in the model. The parabolic shape is also significantly different between the allophonic environments: F1 of /æ/ before /n/ is rising and falling, while it is falling for /æ/ before /d/. This indicates that /æn/ tokens are lowering in the vowel space over their duration, while /æd/ tokens are rising in the vowel space. There is relatively little variation between Age and Sex sub-groups for Seattle speakers with respect to F1 in pre-nasal raising.

These significant effects are also visually represented in the figure above: The F1 values of /æn/ start much lower than /æg/ and /æd/ for all Seattle speakers and rise gently over their duration, indicating that /æn/ starts very high in the vowel space and lowers slightly over its duration. This trajectory contrasts sharply with the falling F1 trajectories for /æg/ and /æd/ over their durations. Even for Group 2 male speakers, who have the highest onset values for /æg/ of any sub-group, the onset of /æg/ is not as high as /æn/ and continues to move higher in the vowel space, while /æn/ lowers. In general, trajectories for /æn/ and /æd/ are more consistent across speaker sub-groups than /æg/. The visual assessment also reveals a very different type of "raising" for /æn/ as compared to /æg/ tokents. While /æg/ tokens "raise" for all speaker sub-groups based on plummeting F1 /æg/ over their duration; /æn/ tokens are "raised" at onset based on very low F1 values, but the tokens actually lower slightly over time.

Age Group shows no effect at all on F1 values, and Sex emerges only in interaction with other terms. These effects, while statistically significant, are not nearly as large as the effect for the following phoneme. For male speakers, F1 values for /æn/ are significantly higher relative to /æd/ as they are for female speakers. This suggests that women are raising /æn/ to a greater extent than men are. The three-way interaction of Following Phone, Position.ord, and Sex also shows that the slope of F1 for /æn/ is not as positive for men as it is for women. This becomes clearer when the trajectory shapes are considered as depicted in the figure above: Group 1 female speakers do not differ much from Group 2 male speakers with respect to their /æn/ onsets, but they do show a slightly different trajectory shape from the other speaker sub-groups. For Group 1 females, F1 of /æn/ rises through 65% of the vowel's duration, and then falls again from 65% to 80%. In other words, the vowel starts high and lowers in the vowel space before taking a short sharp rise at its finish. Overall, Seattle speakers show /æn/ tokens that are strongly differentiated from /æd/ tokens in that they begin much higher in the vowel space and move in the opposite direction over their duration.

F2

The F2 model for pre-nasal raising in Seattle began with a four-way interaction of Following Phone, Position.ord, Sex and Age Group. Age Group had no significant participation in the interaction and was removed from the model. The model was significantly improved by adding information about normalized duration, but Preceding Phone did not make a significant improvement to the model. Post-hoc testing revealed that speakers' responses to one sociocultural survey question were a significant predictor of F2 values, though size of this effect was small.

```
F2.lmerT <- lmer(normF2 ~ FollowingPhone*Position.ord*Sex + normdurms +
normHowOftenShopPNW + (1 + Position.ord | Name) + (1|Word), data=SEAae2)
```

	Est.	Std. Er.	t value	p
(Intercept)	-0.399	0.05	-8.44	<1e-04
FollowingPhonen	0.720	0.06	11.15	<1e-04
SexM	0.243	0.04	5.90	<1e-04
normdurms	0.039	0.01	3.32	0.001
normHowOftenShopPNW	-0.062	0.02	-3.12	0.002
FollowingPhonen:Position.ord.L	-0.925	0.06	-15.18	<1e-04
FollowingPhonen:Position.ord.Q	-0.236	0.06	-3.88	0.000
FollowingPhonen:Position.ord.C	0.127	0.06	2.09	0.037
FollowingPhonen:SexM	-0.192	0.04	-4.87	<1e-04
Position.ord.L:SexM	-0.231	0.09	-2.60	0.009
FollowingPhonen:Position.ord.L:SexM	0.190	0.09	2.15	0.031

Table 17. Statistically significant fixed effects for linear mixed-effects regression model of F2 for /æd/ ~ /æn/ in Seattle; full model output available in Appendix C

The figure below shows the normalized F2 trajectories for the front vowel /æ/ before /g/, /n/ and /d/. Only one vowel is shown, and Following Phone is represented by color.

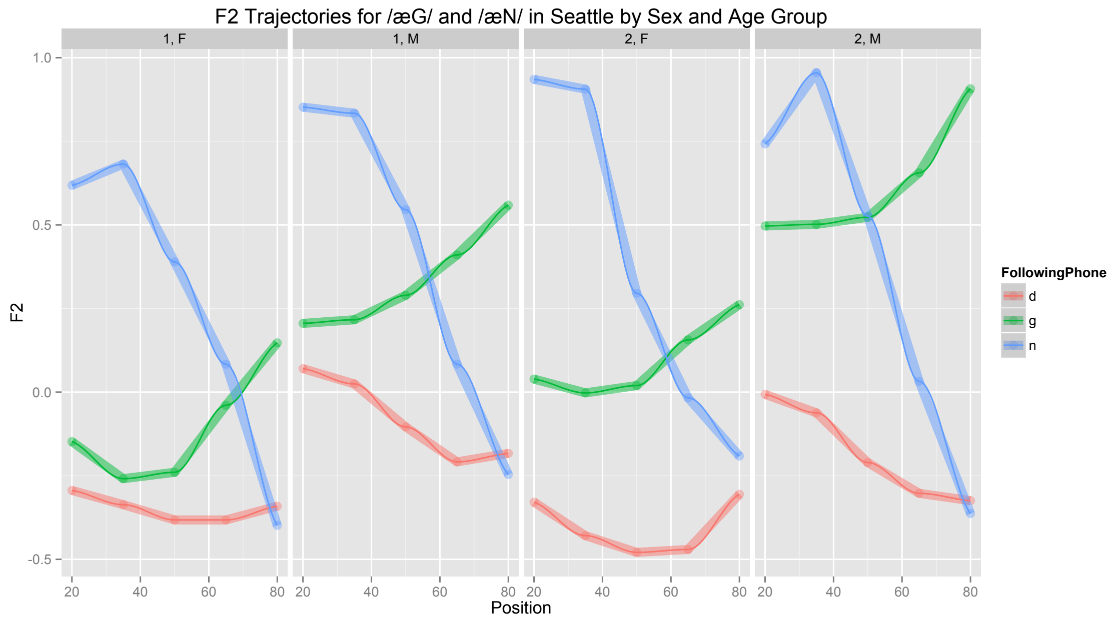

Figure 15. F2 trajectories for /æn/ in Seattle: F2 trajectories for /æ/ before /d/, /g/, and /n/ with time point on x-axis; Lobanov normalized F2 on y-axis for Seattle speakers wrapped by age group (1= Group 1; 2= Group 2) and sex across five proportional time points

Following Phone has a significant and strong effect on F2 values. Differences in the slope, parabolic and cubic shapes of F2 trajectories also emerge for /æ/ before /n/ versus /æ/ before /d/. Before /n/, /æ/ has a substantially higher F2 than before /æd/, indicating that it is much more front in the vowel space. The F2 slope of /æn/ tokens is dropping significantly more than the slope of /æd/. The parabolic shape of F2 before /æn/ is likewise taller and skinnier with a negative coefficient than that of /æd/, which appears like a wide "U" having a positive coefficient. There are differences in the cubic shapes of the F1 trajectories for /æn/ and /æd/, as well. F2 trajectories for /æd/ fall and then rise again whereas /æn/ tokens fall sharply without any rise at offset. The effect of Following Phone and the slope of /æn/ tokens emerge as the largest effects in this model. There is relatively little variation across Age and Sex sub-groups for /æn/ as compared to /æd/, but sex does have a significant main effect on F2 values. Men have higher F2 values than women. Sex also interacts differently with Following Phone differently for men and women. Relative to /æd/ though, men show less differentiation (based on less distance in the F2 values) of their /æn/ tokens than women. This suggests less fronting of /æn/ tokens relative to /æd/ for men than for women. For men, there is also less difference in the slope of /æn/ and /æd/ tokens than for women. Despite some variation between men and women in the sample, pre-nasal fronting affects all Age and Sex sub-groups based on significantly higher F2 values for /æn/ as compared to /æd/.

The illustrations of /æg/, /æd/ and /æn/ trajectories in Figure 15 illustrate the statistically significant differences described between /æd/ and /æn/ and also highlights some qualitative differences in /æg/ and /æn/ raising among Seattle speakers. Here, the F2 trajectories support the same types of differences between /æn/ and /æg/ as their F1 trajectories. Relative to /æd/ and /æg/, the F2 values at onset for /æn/ are very high for all speaker sub-groups, suggesting that /æn/ tokens start much fronter in the vowel space than /æg/ and /æd/. Again, contrasting with /æg/ and /æd/, F2 values for /æn/ fall sharply over the course of their segments, especially after the 35% point. While /æn/ tokens are moving back in the vowel space over their duration, /æg/ and /æd/ are moving forward, as indicated by their rising F2 trajectories. For /æg/ and /æn/, degree of fronting corresponds with degree of raising. For /æg/, tokens raise and front over the course of their duration. For /æn/, on the other hand, tokens start higher and fronter than other /æ/ allophones, and they progressively lower and move back over their duration.

4.4.3 Summary of /æn/ raising in Seattle

Speakers in Seattle show strong and phonologized pre-nasal raising, which is actually accompanied by pre-nasal fronting. This is true across all sex and age subgroups. Based on F1 and F2 formant trajectories, /æn/ begins in a very high and front position for all subgroups, and lowers and backs in the vowel space across its duration. The formant trajectories indicate more dramatic backing of /æn/ over the segment accompanied by more gradual lowering. Considering pre-nasal and pre-velar "raising" finds quantitative and qualitative differences in the two processes across speaker subgroups. Raised /æn/ begin higher and fronter than raised /æg/ tokens, although the difference between the two categories is less for some speaker subgroups than other. For Group 2 speakers and male speakers (who show more phonologized /æg/ raising) there is less difference between /æg/ raising and /æn/ raising than for Group 1 female speakers, who engage less in phonologized /æg/ raising. Furthermore, examining the formant trajectories of /æg/ and /æn/ allows for a richer insight into the qualitative differences between the two types of raising and reveals that while we may label both process "raising," pre-velar and pre-nasal formant trajectories actually follow opposite trends. This will be discussed in more detailed in Chapter 6.

4.4.4 Descriptive statistics for pre-nasal /æ/ raising in Vancouver

Before /n/, Vancouver speakers realize /æ/ as slightly raised and fronted so that the word *fan*, for example, would be realized as [fɛ̃n] in contrast with a word like *add* which would be realized as [æd̚] or [æ̠d̚]. For unnormalized and normalized mean values of /æ/ in pre-nasal and pre-velar contexts, refer to Table 6. The chart below focuses on the *onset* of the segment, where a purely coarticulatory effect of the following segment is not expected to occur. Substantial differences by following phonetic environment at onset provide evidence for phonologization of the effect beyond what would be expected on the basis of coarticulation. In constrast, little difference at onset between /æ/ in different phonetic environments points to a coarticulatory phonetic effect of the following segment. The following plots show the normalized F1 and F2 values for /æ/ before phonemes /g/ and /n/ and /d/ for Vancouver speakers by Sex and Age Group. Following Phone is captured by line color; Group 2 speakers are in the panels on the right.

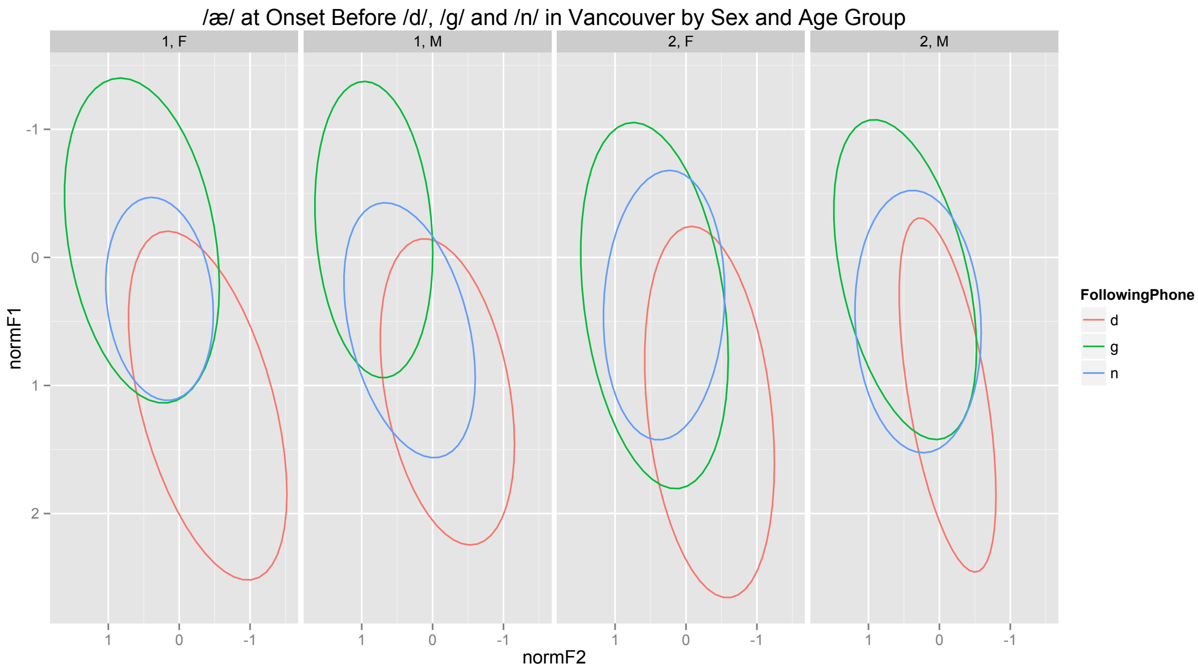

Figure 16. Ellipse plot for /æn/ vs. /æd/ in Vancouver: /æ/ tokens at onset (20% time-proportional point) before /d/, /n/, and /g/ with Lobanov normalized inverted F2 on x-axis; inverted Lobanov normalized F1 on y-axis for Vancouver speakers wrapped by age group (1= Group 1; 2=Group 2) and sex

For Vancouver speakers across all age and sex sub-groups, the ellipse of /æn/ tokens is positioned slightly higher at onset than the /æd/ ellipse, suggesting some degree of allophonic "raising" in the environment of a nasal consonant. The ellipse of /æg/ tokens extends much higher, however, than the /æn/ ellipse. From this figure, /æg/ tokens are raised much higher at onset for Vancouver speakers than /æn/ tokens.

4.4.5 Mixed-effects linear regression models of /æn/ ~ /æd/ raising in Vancouver

The table below summarized the number of observations for the regression analyses in Vancouver:

Following Phone	Age Group 1		Age Group 2		Total
	Female	**Male**	**Female**	**Male**	
æd	560	600	600	480	2,240
æN	280	295	300	235	1,110
GRAND TOTAL			**n=3,350**		

Table 18. Number of observations (by age and sex) included in mixed-effects linear regression models of /æd/ ~ /æn/ among Vancouver speakers

The F1 model for /æn/ and /æd/ showed a four-way interaction of Following, Position.ord, Age Group and Sex. Inclusion of Lobanov normalized duration as an independent predictor was found to have a significant main effect on F1 values and to significantly improve the model. Adding Preceding Phone did not significantly improve the model. Participant responses from one sociocultural survey questions were found to be a significant predictor of F1 values and to significantly improve the F1 model: Subjects' ratings of Seattle and Portland's Similarity were retained in the final model shown below.

```
F1.lmerD <- lmer(normF1 ~ FollowingPhone*Position.ord*(as.factor(AgeGroup))*Sex +
normdurms + normSeattlePortlandSimilarity + (1 + Position.ord | Name) + (1|Word),
data=VANae2)
```

Mixed-Effects Regression for F1 of æn and æd in Vancouver

	Est.	Std. Er.	t value	p
(Intercept)	0.939	0.11	8.24	< 1e-04
FollowingPhonen	-0.638	0.18	-3.53	0.000
Position.ord.L	-0.517	0.06	-8.60	< 1e-04
Position.ord.Q	-0.480	0.04	-11.08	< 1e-04
normdurms	-0.023	0.01	-2.53	0.012
normSeattlePortlandSimilarity	-0.044	0.02	-2.46	0.014
FollowingPhonen:Position.ord.L	0.395	0.07	5.97	< 1e-04
FollowingPhonen:Position.ord.Q	0.331	0.07	5.00	< 1e-04
FollowingPhonen:SexM	0.441	0.04	10.67	< 1e-04
FollowingPhonen:Position.ord.L:as.factor(AgeGroup)2:SexM	-0.379	0.14	-2.71	0.007

Table 19. Statistically significant fixed effects for linear mixed-effects regression model of F1 for /æd/ ~ /æn/ in Vancouver; full model output available in Appendix C

The figure below shows the normalized F1 trajectories for the front vowel /æ/ before /g/, /n/ and /d/ for Vancouver speakers. Only one vowel is shown, and Following Phone is represented by color.

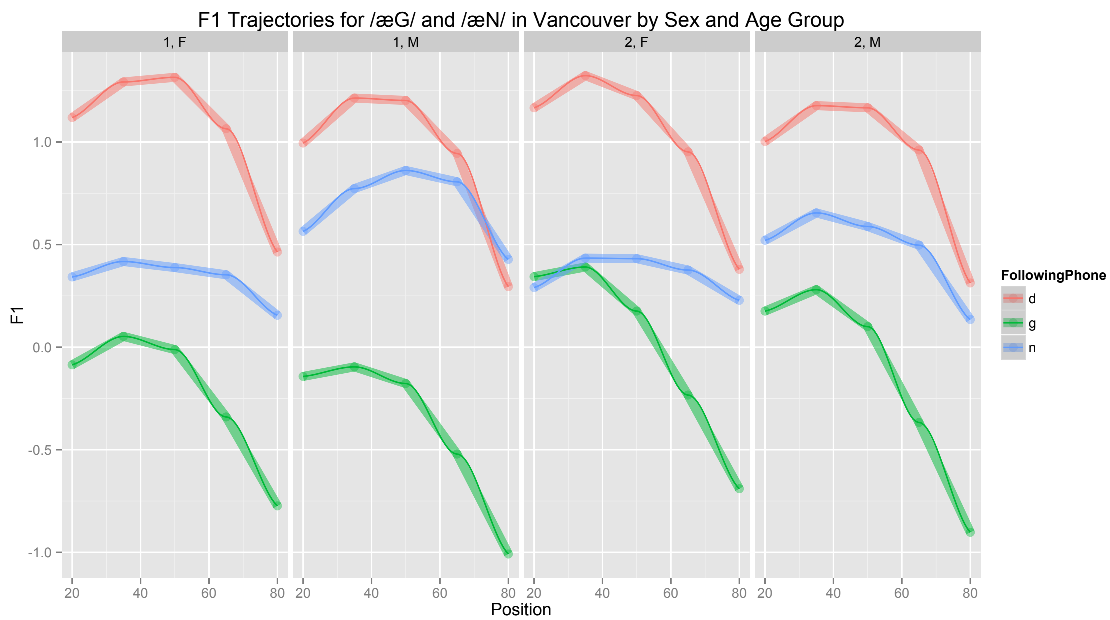

Figure 17. F1 trajectories for /æn/ in Vancouver: F1 trajectories for /æ/ before /d/, /g/, and /n/ with time-proportional point on x-axis; Lobanov normalized F1 on y-axis for Seattle speakers wrapped by age group (1= Group 1; 2= Group 2) and sex across five time-proportional points

Following Phone is a significant predictor of F1 values for Vancouver. F1 values of /æn/ are significantly lower than for /æd/ revealing raising of pre-nasal tokens in the vowel space. There are also significant differences in slope and parabolic shape for F1 trajectories of /æ/ before /d/ and /n/. These differences are among the largest effects in the model. The slope of F1 for /æ/ before /n/ is significantly flatter (less negative) than its slope before /d/. The parabolic shape of F1 for /æn/ is much wider than for /æd/, which has a skinnier and taller parabolic shape. Sex does not have an independent main effect on F1 values, but it participates in significant interactions with other variables. Male speakers have significantly and substantially higher F1 values for /æn/ (compared to /æd/) than their female counterparts. This suggests less difference between /æd/ and /æn/ for men and less raising in the pre-nasal environment as compared with women. Age Group alone is not a significant factor in predicting F1 values, but it does participate in a significant four-way interaction between Age Group, Following Phone, ordered Position, and Sex. For Group 2 men, the F1 slope is more negative for /æn/ than for Group 1 men. (While Group 1 speakers are the baseline of the model, it is actually young male speakers whose F1 trajectories for /æn/ differ from the rest of the speaker sub-groups indicating much less raising of /æn/ tokens than for other Age and Sex sub-groups.) These statistically significant effects manifest in the visual representations of the speakers' F1 trajectories given above. For all Vancouver sub-groups, /æn/ tokens start lower in the vowel space at onset than /æd/, although there is some variation in the shape of the trajectories for /æn/ tokens. For female speakers, the F1 /æn/ trajectories are flatter and fall less sharply than for male talkers. The F1 values of /æn/ tokens also begin lower for female speakers than for males, suggesting that /æn/ is higher at onset and becomes only slightly higher over duration for female speakers. In comparison, male speakers /æn/ tokens are lower in the vowel space, and these vowels rise more sharply in the vowel space after 50% of their duration. Finally, speakers' responses to questions about the similarity of Seattle and Portland acted as a significant predictor of normalized F1 values. A higher rating in response to this question is associated with a lower F1 value, though the effect size is very small.

F2

F2 values for Vancouver were initially modeled as dependent upon a four-way interaction of Following Phone, Position.ord, Age Group and Sex. The model was not significantly improved when normalized Duration was added as an independent term, but was improved when an interaction was added of normalized Duration and Following Phone. Including Preceding Phone did not significantly improve the model and no significant effects were identified. The inclusion of three sociocultural effects resulted in significantly better models and revealed significant effects on F2 values: subjects' years of education, normalized municipal investment, and frequency of reading local publications were included in the final model.

```
F2.lmerN <- lmer(normF2 ~ FollowingPhone*Position.ord*as.factor(AgeGroup)*Sex +
normdurms*FollowingPhone + YearsEducation + normMunicipalInvestment +
normReadLocalPublications + (1 + Position.ord | Name) + (1|Word), data=VANae2)
```

	Est.	Std. Er.	t value	p
(Intercept)	0.201	0.20	1.00	0.320
FollowingPhonen	0.533	0.12	4.41	< 1e-04
Position.ord.Q	0.129	0.04	3.15	0.002
SexM	0.158	0.08	1.92	0.055
YearsEducation	-0.031	0.01	-2.64	0.008
normMunicipalInvestment	0.227	0.04	5.15	< 1e-04
normReadLocalPublications	-0.131	0.04	-3.46	0.001
FollowingPhonen:Position.ord.L	-0.300	0.06	-4.91	< 1e-04
FollowingPhonen:Position.ord.Q	-0.202	0.06	-3.31	0.001
FollowingPhonen:as.factor(AgeGroup)2	-0.213	0.04	-5.59	< 1e-04
FollowingPhonen:SexM	-0.200	0.04	-5.23	< 1e-04
FollowingPhonen:normdurms	0.081	0.02	4.00	< 1e-04
FollowingPhonen:Position.ord.Q:as.factor(AgeGroup)2	0.184	0.09	2.16	0.031
FollowingPhonen:as.factor(AgeGroup)2:SexM	0.237	0.06	4.30	< 1e-04
FollowingPhonen:Position.ord.L:as.factor(AgeGroup)2:SexM	0.271	0.12	2.20	0.028
FollowingPhonen:Position.ord.Q:as.factor(AgeGroup)2:SexM	-0.270	0.12	-2.19	0.028

Table 20. Statistically significant fixed effects for linear mixed-effects regression model of F2 for pre-nasal /æ/ raising in Vancouver; full model output available in Appendix C

The figure below shows the normalized F2 trajectories for the front vowel /æ/ before /g/, /n/ and /d/ for Vancouver speakers. Only one vowel is shown, and Following Phone is represented by color.

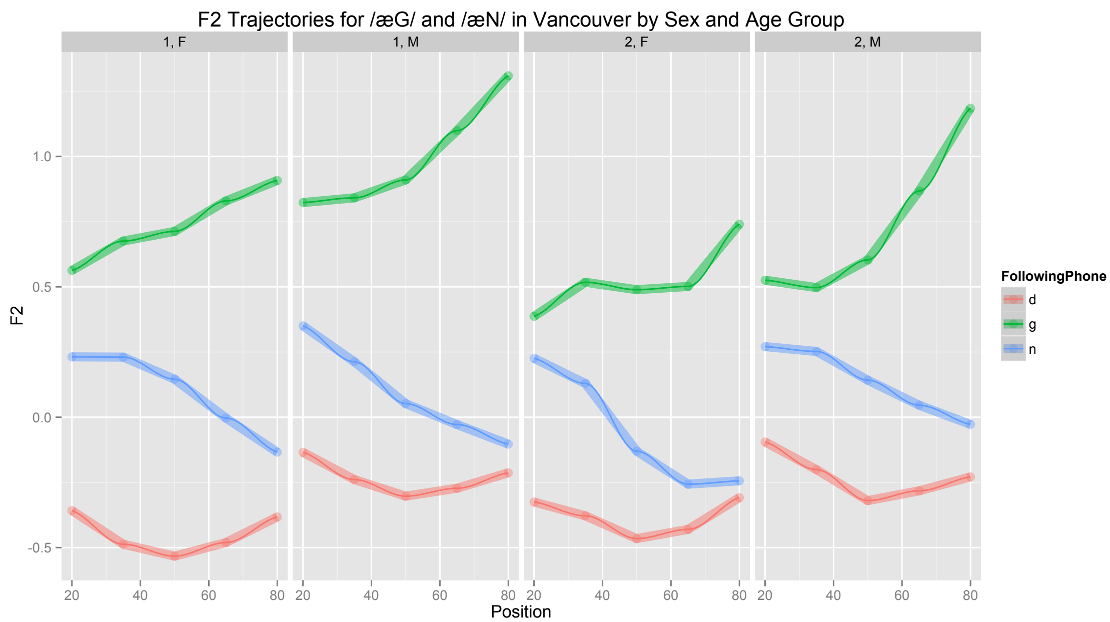

Figure 18. F2 trajectories of /æn/ in Vancouver: F2 trajectories for /æ/ before /d/, /g/, and /n/ with time-proportional point on x-axis; Lobanov normalized F2 on y-axis for Vancouver speakers wrapped by age group (1= Group 1; 2=Group 2) and sex across five time- proportional points

Following Phone has a significant independent effect on F2 values of /æ/ for Vancouver speakers. F2 values for /æN/ are significantly higher for /æN/ than for /æd/. There are also several significant interactions of Following Phone with other variables. For instance, Age Group interacts with Following Phone, as does Sex. Older speakers have lower F2 values for pre-nasal tokens relative to /æd/; male speakers also have lower F2 values for /æN/ relative to /æd/. This suggests that Group 2 Vancouver speakers and men engage in less fronting of pre-nasal /æ/ as compared to Group 1 speakers and women. These effects are among the largest in the model.

The F2 trajectories of pre-nasal /æ/ differ significantly from /æd/ trajectories in terms of their slope and parabolic shape. The slope of F2 for /æ/ before nasals is more negative and steeply falling than before /d/. Its parabolic shape is correspondingly steeper, following a skinnier parabolic shape before nasals as compared to a flatter shape for /æd/. In addition, there are significant three- and four-way interactions illustrating effects on F1 values for Group 2 male speakers. For men as compared to women, the interaction of Age Group and Following Phone have different patterns. Older men show more difference between their /æn/ and /æd/ tokens than Group 1 men. For women, the opposite is true; Group 1 women differentiate /æn/ from /æd/ more than Group 2 women. This suggests that Group 2 men are fronting /æn/ more than Group 1 men, but that Group 1 women are fronting /æn/ more than Group 2 women.

4.4.6 Summary of /æn/ raising in Vancouver

Pre-nasal /æ/ raising in Vancouver appears to be a phonetically driven process by which /æn/ begins in a fronter and higher position than its alveolar counterpart /æd/. F2 trajectories of /æn/ reveal that the segment moves back in the vowel space across its duration, though F1 trajectories show co-articulatory raising. The effect of the pre-nasal environment may affect vowel height to a greater extent than the front/back dimension, though there are significant effects of the pre-nasal environment on F2, as well. The realization of /æn/ does show some significant variation by Age Group and Sex. Women and Group 1 speakers are generally raising and fronting pre-nasal /æ/ tokens to a greater extent than men and Group 2 Vancouver speakers. While these two were not directly compared in a single statistical model, the visual representations of their trajectories and their respective analyses suggest that pre-nasal raising is qualitatively and quantitatively different than pre-velar raising among Vancouver speakers. The degree of phonologization and the effect size of /g/ or /n/ relative to their phonetically proximate neighbors are quite different, with pre-velar raising and fronting far exceeding pre-nasal raising and fronting as are the multi-dimensional acoustic manifestations of this "raising" as will be discussed further in the following Chapter 6.

4.4.7 Comparing /æn/ raising in Seattle and Vancouver

F1

The F1 model comparing pre-nasal raising across cities contained two separate four-way interactions. One significant four-way interaction was found as well as a significant three-way interaction. All attempts to remove terms from these interactions resulted in significantly less predictive models, so the terms were retained. The addition of Preceding Phone as an independent fixed term did not make any significant improvements to the model. Post-hoc testing revealed that speakers' ratings of their national pride significantly improved the model and was a significant predictor of F1 values.

```
F1.lmerH <- lmer(normF1 ~ FollowingPhone*Position.ord*normdurms*City +
City*as.factor(AgeGroup)*Sex*FollowingPhone + normNationalPride + (1 + Position.ord |
Name) + (1|Word), data=ae2)
```

	Est.	Std. Er.	t value	p
(Intercept)	0.683	0.14	4.83	< 1e-04
FollowingPhonen	-0.816	0.21	-3.94	< 1e-04
Position.ord.L	-0.533	0.04	-14.57	< 1e-04
Position.ord.Q	-0.387	0.03	-14.73	< 1e-04
CityVAN	0.184	0.07	2.58	0.010
as.factor(AgeGroup)2	0.196	0.07	2.84	0.005
SexM	0.158	0.07	2.13	0.033
normNationalPride	0.052	0.02	2.22	0.026
FollowingPhonen:Position.ord.L	0.743	0.04	21.14	< 1e-04
FollowingPhonen:Position.ord.Q	0.289	0.04	8.23	< 1e-04
FollowingPhonen:normdurms	0.068	0.02	3.30	0.001
Position.ord.L:normdurms	0.066	0.02	3.42	0.001
Position.ord.C:normdurms	-0.044	0.02	-2.31	0.021
FollowingPhonen:CityVAN	0.244	0.05	5.37	< 1e-04
Position.ord.Q:CityVAN	-0.097	0.04	-2.62	0.009
CityVAN:as.factor(AgeGroup)2	-0.274	0.10	-2.70	0.007
CityVAN:SexM	-0.305	0.10	-2.96	0.003
as.factor(AgeGroup)2:SexM	-0.217	0.10	-2.20	0.028
FollowingPhonen:SexM	0.103	0.05	2.26	0.024
FollowingPhonen:Position.ord.L:CityVAN	-0.324	0.05	-6.45	< 1e-04
FollowingPhonen:normdurms:CityVAN	-0.106	0.03	-3.74	0.000
CityVAN:as.factor(AgeGroup)2:SexM	0.292	0.14	2.04	0.042
FollowingPhonen:CityVAN:SexM	0.338	0.06	5.30	< 1e-04
FollowingPhonen:CityVAN:as.factor(AgeGroup)2:SexM	-0.247	0.09	-2.74	0.006

Table 21. Statistically significant fixed effects for linear mixed-effects regression model of F1 for /æd/ ~ /æn/ across both Seattle and Vancouver; full model output available in Appendix C

City emerges as a significant predictor of F1 values for /æn/ and /æd/. For both allophonic environments, Vancouver speakers have higher F1 values than Seattle speakers, indicating less raising. City also interacts with Following Phone to highlight that Vancouver speakers have higher F1 values for /æn/ relative to /æd/ than Seattle speakers. This confirms that Vancouver speakers are engaging in pre-nasal raising to a lesser extent than Seattle speakers. The slope of F1 for /æ/ is also different in the pre-nasal environment for Seattle as compared to Vancouver speakers. The slope is slightly negative for Vancouver speakers, but positive for Seattle speakers. This indicates that Seattle /æn/ and Vancouver /æn/ are moving quite differently through the vowel space over their duration. For Seattle speakers /æn/ is actually lowering sharply in the vowel space over its duration; for Vancouver speakers, it is rising slightly. There are additional interactions of Age Group and Sex for the F1 model comparing Seattle and Vancouver. For Group 2 speakers, the effect of City is different than for Group 1 speakers. Group 2 Vancouver speakers show lower F1 values overall. The same is true for men as compared to women in Vancouver. An additional three-way interaction reveals that the interaction of Following Phone and City is different for men than women. As compared to women, Vancouver men show less difference in their /æn/ and /æd/ tokens, suggesting less pre-nasal raising for /æn/ than for women. Finally, a significant four-way interaction further clarifies this observation: for men, the interaction of Following Phone, City, and Age Group produces a different effect than for women. Group 2 Vancouver men are raising more for /æn/ relative to /æd/ than Group 1 Vancouver men, whereas the opposite pattern holds true for women.

F2

```
F2.lmerW <- lmer(normF2 ~ Position.ord*City*FollowingPhone +
City*as.factor(AgeGroup)*Sex*FollowingPhone + normdurms + normFollowSports + (1 +
Position.ord | Name) + (1|Word), data=ae2)
```

	Est.	Std. Er.	t value	p
(Intercept)	-0.389	0.08	-4.62	< 1e-04
Position.ord.L	-0.113	0.04	-2.93	0.003
Position.ord.Q	0.059	0.03	2.10	0.036
FollowingPhonen	0.535	0.11	4.98	< 1e-04
SexM	0.401	0.08	4.84	< 1e-04
normdurms	0.021	0.01	2.91	0.004
normFollowSports	0.052	0.02	2.34	0.019
Position.ord.L:FollowingPhonen	-0.835	0.04	-22.04	< 1e-04
Position.ord.Q:FollowingPhonen	-0.274	0.04	-7.23	< 1e-04
Position.ord.C:FollowingPhonen	0.129	0.04	3.41	0.001
CityVAN:SexM	-0.237	0.12	-2.00	0.046
FollowingPhonen:as.factor(AgeGroup)2	0.143	0.05	3.05	0.002
FollowingPhonen:SexM	-0.128	0.05	-2.61	0.009
Position.ord.L:CityVAN:FollowingPhonen	0.542	0.05	10.02	< 1e-04
Position.ord.Q:CityVAN:FollowingPhonen	0.177	0.05	3.27	0.001
CityVAN:FollowingPhonen:as.factor(AgeGroup)2	-0.352	0.07	-5.24	< 1e-04
CityVAN:FollowingPhonen:as.factor(AgeGroup)2:SexM	0.349	0.10	3.59	0.000

Table 22. Statistically significant fixed effects for linear mixed-effects regression model of F2 for /æd/ ~ /æn/ across both Seattle and Vancouver; full model output available in Appendix C

City does not have a main effect on F2 values for /æn/ and /æd/, but it participates in several significant interactions, in particular, related to the differing trajectory shape of F2 for /æn/ between Seattle and Vancouver speakers. Across both cities, Following Phone has the effect of raising F2 values as compared with baseline F2 values observed for /æd/. For all speakers, trajectories for /æn/ and /æd/ differ in terms of their slope, parabolic and cubic shapes, and these are very large effects. The additional three-way interaction of Position.ord, Following Phone and City reveals that the way in which /æn/ trajectories differ from /æd/ trajectories is not the same in both cities. This is one of the largest effects in the model. For Vancouver, the slope of F2 for /æn/ is not as negative relative to the slope of F2 for /æd/, whereas this is not true for Seattle. (Seattle /æn/ has a very steep negative slope; Vancouver /æn/ has a gentle negative slope.) For Vancouver talkers, /æn/ is backing mildly over the course of the segment; for Seattle talkers,

/æn/ is backing dramatically in the vowel space. This is a corresponding and significant difference in the parabolic shape of F2 trajectories for /æn/ across the cities. The sharply dropping slope for Seattle corresponds to a taller and skinnier inverted v-shaped parabola while the Vancouver parabolic shape is much wider and gently sloping.

Sex has an effect on F2 values for Seattle and Vancouver speakers. Across the cities, being male is associated with higher F2 values than for women, suggesting more front variants for both /æn/ and /æd/. For men as compared to women, Vancouver speakers show lower F2 values. Age Group does not have a significant main effect on F2 values, though it does participate in some significant interactions. The interaction between City and Following Phone works differently for Group 2 as compared to Group 1 speakers. For Group 2 speakers, the difference between the cities' respective realizations of /æn/ and /æd/ is significantly greater than for Group 1 speakers. This suggests that Group 1 Vancouver speakers are differentiating /æn/ and /æd/ more in terms of their degree of fronting and Group 1 Seattle speakers are differentiating /æn/ and /æd/ less. Men and women differ in this trend, however, as shown by the interaction of City, Following Phone, Age Group and Sex. The interaction of City, Following Phone, and Age Group also differs for men as compared to women.

4.4.8 Summary of /æn/ raising in Seattle and Vancouver

Both Seattle and Vancouver speakers manifest pre-nasal /æ/ tokens differently than /æ/ before a non-nasal alveolar like /d/, but the cities have very different patterns when it comes to pre-nasal "raising." For both cities, F1 is lower at onset, indicating a higher vowel, before a following nasal consonant than before /d/. This difference is much more extreme, however, for Seattle speakers. For Seattle speakers, a very high pre-nasal /æn/ actually lowers in the vowel space across its duration as illustrated by rising F1 values. In contrast, among Vancouver speakers, a less high /æn/ at onset rises slightly in the vowel space over its duration, as evidenced by gently dropping F1 values. There are additional similarities and differences with respect to the F2 dimension. Both cities begin with higher F2 values for pre-nasal tokens than for /æd/, but the difference is again much more extreme for Seattle. Both cities show falling F2 trajectories over segment duration, but the drop is much sharper for Seattle. For Seattle speakers, then, pre-nasal "raising" means a very high, front onset for /æn/ accompanied by dramatic backing and gradual lowering across duration. For Vancouver speakers, pre-nasal "raising" implies a slightly higher and fronter realization of /æn/ that backs, but continues to rise slightly over its duration. Finally, in both cities, the phenomena labeled as "pre-nasal raising" differ substantially from those labeled as "pre-velar raising." The phenomena may involve different degrees of phonologization and co-articulatory effects as well as distinct accompaniment with changes on the front/back dimension. This raises the importance of precise language and dynamic analyses when describing phonetic or phonological processes as will be discussed further in Chapter 6.

4.5 /æ/ Retraction

RQ: Are Vancouver speakers retracting /æ/? Which environments promote retraction? How does this compare to Seattle speakers?

The following series of analyses considers whether /æ/ is backing in the vowel space of Vancouver and Seattle speakers. Although a change was anticipated on the fronting/backing dimension (affecting F2), regression analyses of F1 were also conducted to rule out any accompanying gestures of raising or lowering. For both Seattle and Vancouver, normalized formant values were modeled as a function of a predictor set including vowel, manner of articulation of the following consonant, time point as an ordered factor, age group and sex.

Random effects were included for lexical item, following phoneme, speaker, and time point as an ordered factor.

For unnormalized formant data, the mean F2 values of both Seattle and Vancouver suggest a more back variant of /æ/, with Vancouver /æ/ appearing very slightly more back (before a following stop) 1724 at Hz than Seattle /æ/ at 1743 Hz, and the subsequent analyses will consider whether there are any statistically significant differences between the two populations. The standard deviations indicate more variation or movement on the back/front dimension than the vowel height dimension. Because the mean values are calculated for each of the 5 time points in the vowels' trajectories, large standard deviations may represent variation between speakers or greater VISC for some vowels than others. For both cities, /u/ has the greatest standard deviation in F2 of the back vowels, and /æ/ also displays substantial variation (235 Hz before stops for Seattle and 296 Hz for Vancouver), though it is less than /u/. An overview of /æ/ in varying manner contexts is summarized in the chart below relative to the back vowels /ɑ/, /ɔ/, and /u/. Three following phonetic manners of articulation are considered: /æ/ preceding stops, fricatives and lateral consonants.

4.5.1 Descriptive statistics for /æ/ retraction in Vancouver

While interspeaker variation exists with respect to /æ/, Vancouver speakers tend to articulate /æ/ as [æ̠] before stop and fricatives. Before laterals, where more retraction is expected the articulation moves closer to [ɐ̹], though not quite reaching this degree of centralization. An overview of /æ/ in varying manner contexts is summarized in the chart below relative to the back vowels /ɑ/, /ɔ/, and /u/. Three following phonetic manners of articulation are considered: /æ/ preceding stops, fricatives and lateral consonants.

Vancouver Vowels	F1 (Hz)	SD F1 (Hz)	F2 (Hz)	SD F2 (Hz)	Dur (ms)	SD Dur (ms)	Lob. Norm F1	Lob. Norm F2
æSTOP	806	140	1752	276	155	46	0.924	-0.219
æFRIC	825	122	1621	218	155	44	1.043	-0.538
æLAT	809	108	1445	216	103	32	0.945	-0.976
ɑ	725	71	1247	186	135	51	0.442	-1.475
ɔ	736	81	1243	210	204	44	0.503	-1.474
u	380	79	1558	356	156	72	-1.671	-0.691

Table 23. Mean of unnormalized F1/F2 values and duration, standard deviations of unnormalized F1/F2 values and duration for /æ/ before stops, fricatives and laterals relative to back vowels, plus Lobanov normalized z-scores across all five time-proportional points for Vancouver speakers

The figure below focuses on the *onset* of the segment, where a purely coarticulatory effect of the following segment is not expected to occur. Substantial differences by following phonetic environment at onset provide evidence for phonologization of the effect beyond what would be expected on the basis of coarticulation. In constrast, little difference at onset between /æ/ in different phonetic environments points to a coarticulatory phonetic effect of the following segment. The figure below shows normalized F1 by F2 plots for /æ/ at onset in three phonetic contexts varying by the manner of articulation of the following consonant as compared to the back vowels /ɑ/ and /ɔ/. Vowel is represented by line color; manner of the following consonant for /æ/ (stop, fricative, or lateral) is represented by line type.

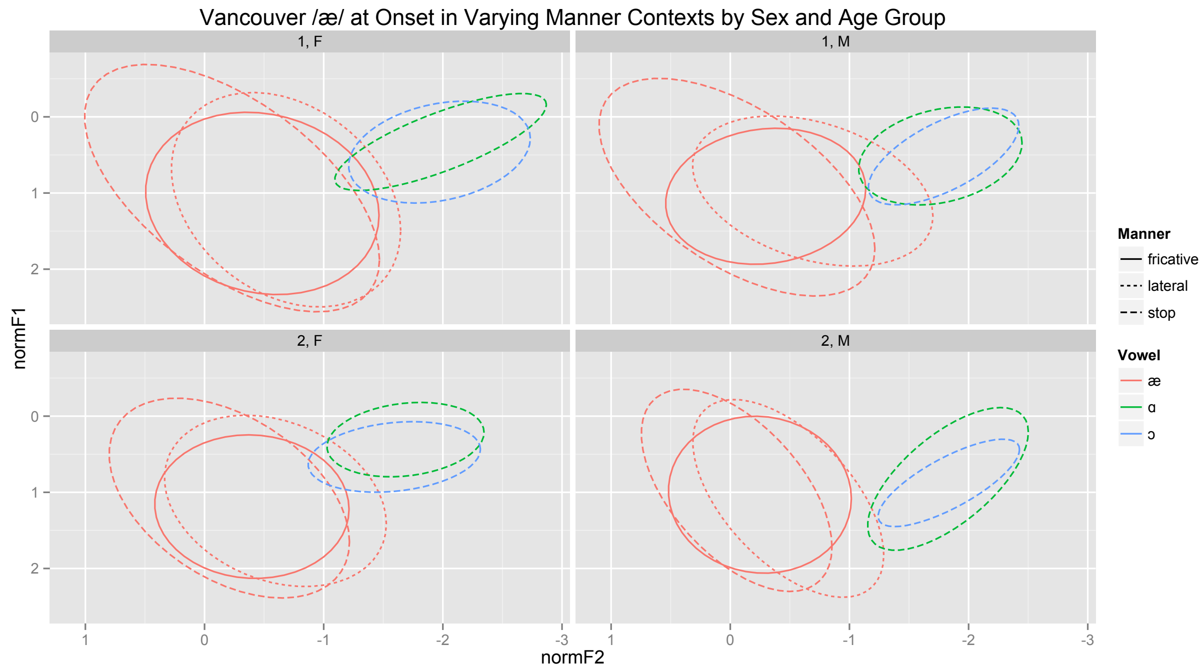

Figure 19. Ellipse plot of /æ/ retraction in Vancouver: /æ/, /ɑ/ and /ɔ/ tokens before various manners of articulation at onset (20% time-proportional duration for Vancouver speakers with Lobanov normalized inverted F2 on x-axis; inverted Lobanov normalized F1 on y-axis for all time five time points wrapped by age group (1= Group 1; 2= Group 2) and sex

For all speaker sub-groups, /æ/ overlaps only slightly with /ɑ/ and /ɔ/ when it precedes a stop (outlined by the wider dashed red line), but shows greater overlap with the back vowels when it is followed by a following fricative or lateral consonant (outlined by the solid red line and the smaller dashed red line, respectively). The overlap with /ɑ/ and /ɔ/ when /æ/ is followed by a lateral consonant, but for Group 1 speakers, /æ/ overlaps nearly as much with /ɑ/ and /ɔ/ when it is followed by a fricative as when it is followed by a lateral. For all /æ/ allophones, there is a wider range of variation than for the back vowels /ɑ/ and /ɔ/ suggesting more variation between individual speakers in the realization of /æ/ than /ɑ/ and /ɔ/.

4.5.2 Mixed-effects linear regression models for /æ/ retraction in Vancouver

The table below summarizes the number of observations for the Vancouver regressions analyzing contextual /æ/ retraction:

Following Manner	**Age Group 1**		**Age Group 2**		**Total**
	Female	Male	Female	Male	
æSTOP	2360	2580	2535	2015	9,490
æFRIC	690	745	750	610	2,795
æLAT	300	330	360	300	1,290
GRAND TOTAL			**n=13,575**		

Table 24. Number of observations (by age and sex) included in mixed-effects linear regression models of /æ/ retraction among Vancouver speakers

F2

In building a model of F2 for Vancouver, a four-way interaction was originally included between Sex, Age Group, Manner of the following consonant, and ordered Position. Because no significant four-way interactions were found, the terms were unpacked to include separate three-way interactions. Age Group was found not to have a significant main effect, but was included in several significant interactions. The addition of normalized duration information to the interaction of Manner and Position.ord did significantly improve the model of F1 values. Vancouver speaker responses for one sociocultural survey question were found to have a significant impact on F2 values. Subjects' perceptions of Seattle and Vancouver similarity was found to significantly affect F2 values. The final model is given below. In this figure, fricative is the baseline value for Manner, as compared to lateral and stop and female is the baseline value for Sex.

F2.lmerG <- lmer(normF2 ~ Manner*as.factor(AgeGroup)*Sex + Manner*Position.ord*normdurms + PrecedingPhone + normSeattleVancouverSimilarity + (1 + Position.ord | Name) + (1|Word), data=VANback3)

	Est.	Std. Er.	t value	p
(Intercept)	-0.152	0.20	-0.77	0.439
as.factor(AgeGroup)2	0.157	0.05	3.06	0.002
SexM	0.133	0.05	2.56	0.010
Position.ord.L	-0.232	0.02	-10.17	< 1e-04
Position.ord.Q	0.067	0.02	3.89	0.000
normdurms	0.081	0.01	7.00	< 1e-04
PrecedingPhoned	-0.538	0.03	-16.46	< 1e-04
PrecedingPhoneeɪ	-0.493	0.17	-2.84	0.005
PrecedingPhonek	-0.589	0.21	-2.80	0.005
PrecedingPhonel	-0.879	0.41	-2.13	0.033
PrecedingPhonep	-0.632	0.21	-2.94	0.003
PrecedingPhoner	-0.961	0.35	-2.76	0.006
PrecedingPhonet	-0.474	0.17	-2.80	0.005
normSeattleVancouverSimilarity	0.058	0.02	2.74	0.006
Mannerstop:as.factor(AgeGroup)2	-0.138	0.02	-5.94	< 1e-04
Mannerlateral:SexM	-0.197	0.04	-5.29	< 1e-04
as.factor(AgeGroup)2:SexM	-0.157	0.07	-2.13	0.033
Mannerlateral:Position.ord.L	-0.496	0.04	-11.38	< 1e-04
Mannerstop:Position.ord.L	0.134	0.02	7.12	< 1e-04
Mannerlateral:normdurms	-0.090	0.02	-4.28	< 1e-04
Mannerstop:normdurms	-0.082	0.01	-6.20	< 1e-04
Position.ord.Q:normdurms	0.064	0.02	3.69	0.000
Mannerlateral:as.factor(AgeGroup)2:SexM	0.104	0.05	1.96	0.050
Mannerstop:as.factor(AgeGroup)2:SexM	0.065	0.03	1.94	0.052
Mannerlateral:Position.ord.L:normdurms	-0.089	0.03	-2.63	0.009
Mannerstop:Position.ord.Q:normdurms	-0.045	0.02	-2.30	0.022

Table 25. Statistically significant fixed effects for linear mixed-effects regression model of F2 for /æ/ retraction in Vancouver; full model output available in Appendix C

The figure below shows the normalized F2 trajectories for /æ/ in three phonetic contexts varying by manner of articulation of the following consonant along with the trajectories for /ɑ/ and /ɔ/.

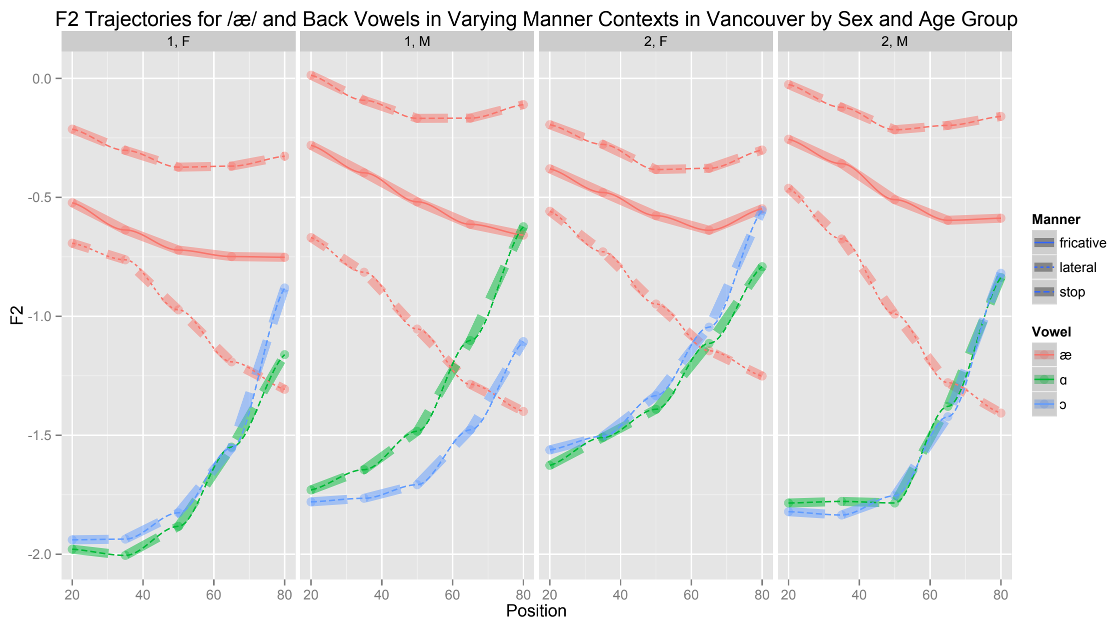

Figure 20. F2 trajectories for /æ/ retraction in Vancouver: F2 trajectories for /æ/ in different following manner contexts relative to /ɑ/ and /ɔ/ (time-proportional point on x-axis; Lobanov normalized F2 on y-axis) for Vancouver speakers wrapped by age group (1= Group 1; 2= Group 2) and sex

Retraction of /æ/ is anticipated to affect the front-back dimension to a greater extent than the F1 dimension. The allophonic environments of /æ/ based on the manner of the following consonant do display differences in F2 values for Vancouver speakers, but manner of the following consonant is not independently a significant predictor of F2 values for /æ/ across the Vancouver sample. This lacking main effect of Manner may be obscured by the variation in F2 values for /æ/ across speaker Age and Sex sub-groups, since Manner does participate in several significant interactions affecting F2 values. Sex is a significant predictor of F2 values for /æ/ with male speakers having slightly higher F2 values than females, suggesting a more front realization for male speakers. The same is true of Group 2 speakers: they have significantly higher F2 values than Group 1 speakers, and this effect is slightly larger than the effect of being male. Among these statistically significant fixed effects, the interaction of Manner and Position has one of the largest effects on normalized F2 values. For lateral following consonants, the slope of normalized F2 is much lower than the baseline (/æ/ before fricatives). This can be seen in the more steeply dropping third line from the top (red line with thin dashes) across all of the panels in Figure 22 above. The statistical model confirms that /æ/ is backing more dramatically before laterals than before fricatives and stops. Another significant interaction, though less sizeable, is found for the slope of /æ/ before stops. Before stops, F2 trajectories for /æ/ are dropping less steeply than before fricatives. This confirms that both fricatives and laterals promote retraction of /æ/ (lower F2 values) in comparison to stops. There are additional differences in the shape of the F2 trajectories depending on the following phoneme. This is clearly shown in the Figure 22 above: the trajectories for /æ/ have negative slopes in all of the following manner contexts, and the F2 values for /æ/ before a lateral consonant are lower than before a fricative, which are lower than before a stop. Based on the elliptical plot in Figure 21, it is clear that these differences for /æ/ before fricatives as compared to stops begin at segment onset and are not just coarticulatory effects caused by the following segment. While /æ/ can be described as "retracting" in the vowel space over the duration of the segment, it does not verge on approaching the backness of neighboring /ɑ/ and /ɔ/, nor does it approximate their height. Finally, there is also a large effect found for Preceding Phone. In particular, several preceding phones have a sizeable effect on F2 values. Preceding /d/, /k/, /p/, /r/, /l/, and /eɪ/ are all associated with lower F2 values for /æ/.

Significant interactions reveal differences for Age and Sex sub-groups. For instance, Group 2 speakers have lower F2 values for /æ/ before stops than Group 1 speakers. Male speakers have lower F2 values before laterals than female speakers. Older male speakers show less difference from women in their F2 values than Group 1 male speakers show from Group 1 women. There are additional three-way interactions of Manner, Age Group and Sex. For male speakers as compared to females, the interaction of a following lateral consonant and Age Group is different. Male speakers show a higher F2 value for /æ/ before a lateral than Group 1 males, but the opposite is true of women. For Group 1 women, F2 values at onset for /æ/ before a fricative and a lateral are close; for Group 1 men, F2 values for /æ/ before a fricative are considerably higher than before a lateral. There is a similar effect found for /æ/ preceding stops, but the effect size is quite small.

There are additional effects involving duration. In general, greater duration for /æ/ is associated with higher F2 values, but this is not the case for /æ/ before laterals. Before laterals, the longer the token, the lower its F2 will be. This may capture the fact that /æ/ is longer when preceding fricatives and stops (and has a higher F2), than preceding laterals (where it has a lower F2). The interaction of Manner, Duration and ordered Position also reveals significant differences in the quadratic shape of F2 before a stop. F2 trajectories for /æ/ before stops have a more parabolic shape than those before laterals and fricatives with F2 falling at onset then rising at offset. Finally, speakers' responses to the sociocultural survey question about the similarity of Seattle and Vancouver emerges as a significant predictor of F2 values for Vancouver. The effect is small, but it indicates that as speakers' ratings of Seattle and Vancouver's similarity increase, F2 values also increase.

F1

Though retraction is anticipated to affect the F2 dimension to a greater extent than the F1 dimension, a mixed-effect linear regression was constructed to check for possible predictors of F1 values. Manner of the following consonant was not a significant independent predictor of F1 values, but it did show interactions with ordered factor Position, Sex and normalized duration. Age Group and Sex also did not reach significance when modeled as independent predictors, but were retained as interactive terms to conservatively assess variation between speaker sub-groups with respect to F1 values. Preceding phone was shown to significantly improve the model for F1, and several preceding phones emerged as significant predictors of F1 values. Post-hoc testing revealed that speakers' ratings of how closely they followed sports teams from their home city significantly improved the model and were a significant predictor of F1 values.

The selected F1 model is:

```
F1.lmerH <- lmer(normF1 ~ Manner*Position.ord*Sex*normdurms +
(as.factor(AgeGroup))*Sex*Manner + PrecedingPhone + Sameness + normFollowSports + (1 +
Position.ord | Name) + (1|Word), data=VANback3)
```

	Estimate	Std..Error	t.value	p
(Intercept)	1.05	0.36	2.88	0.00
Position.ord.L	-0.48	0.05	-9.11	< 1e-04
Position.ord.Q	-0.39	0.03	-11.33	< 1e-04
normdurms	0.05	0.02	2.99	0.00
normFollowSports	0.09	0.02	3.69	0.00
SamenessY	-0.17	0.06	-2.86	0.00
Placevelar	-0.48	0.16	-3.06	0.00
Mannerstop:Position.ord.L	0.15	0.03	4.83	< 1e-04
Mannerstop:SexM	-0.1	0.03	-3.73	0.00
Position.ord.L:SexM	0.18	0.08	2.32	0.02
Mannerlateral:normdurms	-0.07	0.03	-2.21	0.03
Mannerstop:normdurms	-0.04	0.02	-2.14	0.03
Position.ord.Q:normdurms	-0.06	0.03	-2.09	0.04
Mannerstop:Position.ord.L:SexM	-0.15	0.04	-3.39	0.00
Mannerlateral:Position.ord.Q:normdurms	-0.13	0.06	-2.29	0.02
Mannerlateral:SexM:normdurms	0.09	0.04	2.32	0.02
Mannerlateral:SexM:as.factor(AgeGroup)2	0.25	0.06	3.96	< 1e-04
Mannerstop:SexM:as.factor(AgeGroup)2	0.1	0.04	2.53	0.01

Table 26. Statistically significant fixed effects for linear mixed-effects regression model of F1 for /æ/ retraction in Vancouver; full model output available in Appendix C

The figure below shows the normalized F1 trajectories for /æ/ in three phonetic contexts varying by manner of articulation of the following consonant along with the trajectories for /ɑ/ and /ɔ/.

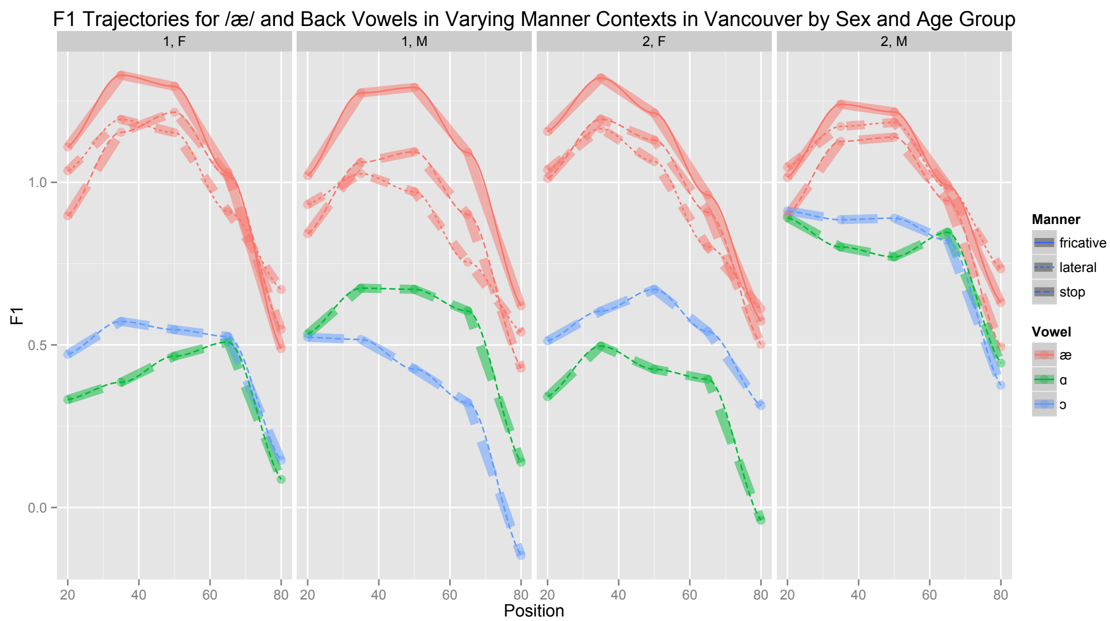

Figure 21. F1 trajectories for /æ/ retraction in Vancouver: F1 trajectories for /æ/ in different following manner contexts relative to /ɑ/ and /ɔ/ (time-proportional point on x-axis; Lobanov normalized F1 on y-axis) for Vancouver speakers wrapped by age group (1= Group 1; 2=Group 2) and sex

No significant differences were found in the F1 values of /æ/ before laterals, fricatives, and stops. This suggests that there is no significant difference in the height of /æ/ in these allophonic environments. There are significant differences in the slope and quadratic shape of the F1 trajectories as well as interactions indicating significant differences in the shape of the F1 trajectory for /æ/ before stops, fricatives, and laterals. The falling slope of F1 before a stop is less steep than before a fricative (see figure above). Tokens of /æ/ before laterals and fricatives do not significantly differ in terms of F1 slope. Preceding Phone is a significant predictor of F1 values. Compared to /æ/ following /b/, several preceding phones have the effect of raising F1 values. Preceding phones producing higher F1 values include a preceding /g/, /d/, /p/, or /eɪ/, and of these, /g/ and /p/ have the largest effect on F1. There are no significant main effects of Age Group or Sex on F1 values, though there are some significant interactions including each. For

Vancouver men, F1 values are lower for /æ/ before a following laterals and stops than for women. This indicates that, relative to women, /æ/ is slightly higher in the vowel space for male speakers before laterals and stops than before fricatives. There is an additional three-way interaction between Age Group, Sex, and Manner of the following consonant. The interaction between manner and age group is different for men as compared to women. As opposed to having slightly lower F1 values before laterals and stops than women, Group 2 men have higher F1 values before laterals and stops than women. In other words, among Group 2 speakers, the F1 values of /æ/ in varying manner contexts are more similar for men than for women. Among Group 1 speakers, however, the women show more consistent F1 values for /æ/ regardless of manner of the following consonant than men.

Two sociocultural survey questions acted as significant predictors of F1 values. Higher ratings for how closely a participant followed sports teams from their home city was linked with higher F1 values, indicating a lower vowel in the vowel space. The row labeled sameness in the preceding table illustrates that subjects who described Seattle and Vancouver as “the same” or “similar” had significantly lower F1 values, indicating a higher /æ/ vowel across all contexts. Despite the significance of these effects, the effect sizes are quite small throughout this model revealing that the height of /æ/ does not vary much across the speaker sub-groups.

4.5.3 Summary of /æ/ retraction in Vancouver

Vancouver speakers are engaging in phonetically-conditioned retraction of /æ/ based on the different slopes and lowering of F2 values before laterals and fricatives. Retraction affects primarily the F2 dimension for Vancouver speakers, and the effect to the F1 dimension is minimal. The manner of the following consonant is a most relevant factor in predicting the degree of /æ/ retraction, but the preceding phone context impacts F2 values. This retraction is most extreme before laterals, but also occurs before fricatives, relative to F2 values position before stops. Some social variation is also evident in /æ/ retraction. Women and Group 1 speakers do show significantly more retraction than men. For Group 1 women, F2 values for /æ/ before fricatives and laterals are similarly low in comparison to /æ/ before stops. For men, and especially Group 2 men, F2 values for /æ/ before fricatives tend to be more similar to those for /æ/ before stops. Vowel height, as indicated by F1 values, is stable across all Age and Sex sub-groups in the study. Finally, speakers' ratings about the similarity of Seattle and Vancouver had a significant effect on F2 values, though the effect size was rather small. This suggests that higher ratings of Seattle and Vancouver's similarities correlated with a less retracted variant of /æ/.

4.5.4 Descriptive statistics for /æ/ retraction in Seattle

Seattle speakers tend to articulate /æ/ consistently in following manner contexts (pre-velar and pre-nasal tokens excluded). Before stops and fricatives, /æ/ manifests as [æ] or [æ̟] for most speakers. Before laterals, it maybe be more retracted and could be transcribed accordingly as [æ̠].

Seattle Vowels	F1 (Hz)	SD F1 (Hz)	F2 (Hz)	SD F2 (Hz)	Dur (ms)	SD Dur (ms)	Lob. Norm F1	Lob. Norm F2
æSTOP	798	154	1768	210	161	55	0.981	-0.198
æFRIC	805	150	1687	209	166	56	1.022	-0.408
æLAT	795	129	1499	246	110	40	0.994	-0.902
ɑ	722	101	1293	211	150	60	0.570	-1.431
ɔ	753	109	1293	198	210	60	0.734	-1.464
u	359	62	1534	328	157	67	-1.665	-0.811

Table 27. Mean of unnormalized F1/F2 values and duration, standard deviations of unnormalized F1/F2 values and duration for /æ/ before stops, fricatives and laterals relative to back vowels plus Lobanov normalized z-scores across all five time-proportional points for Seattle speakers

The figure below focuses on the *onset* of the segment, where a purely coarticulatory effect of the following segment is not expected to occur. Substantial differences by following phonetic environment at onset provide evidence for phonologization of the effect beyond what would be expected on the basis of coarticulation. In constrast, little difference at onset between /æ/ in different phonetic environments points to a coarticulatory phonetic effect of the following segment. The figure below shows normalized F1 by F2 plots for /æ/ at onset (20% time-proportional duration) in three phonetic contexts varying by the manner of articulation of the following consonant as compared to the back vowels /ɑ/ and /ɔ/. Vowel is represented by line color; manner of the following consonant for /æ/ (stop, fricative, or lateral) is represented by line type.

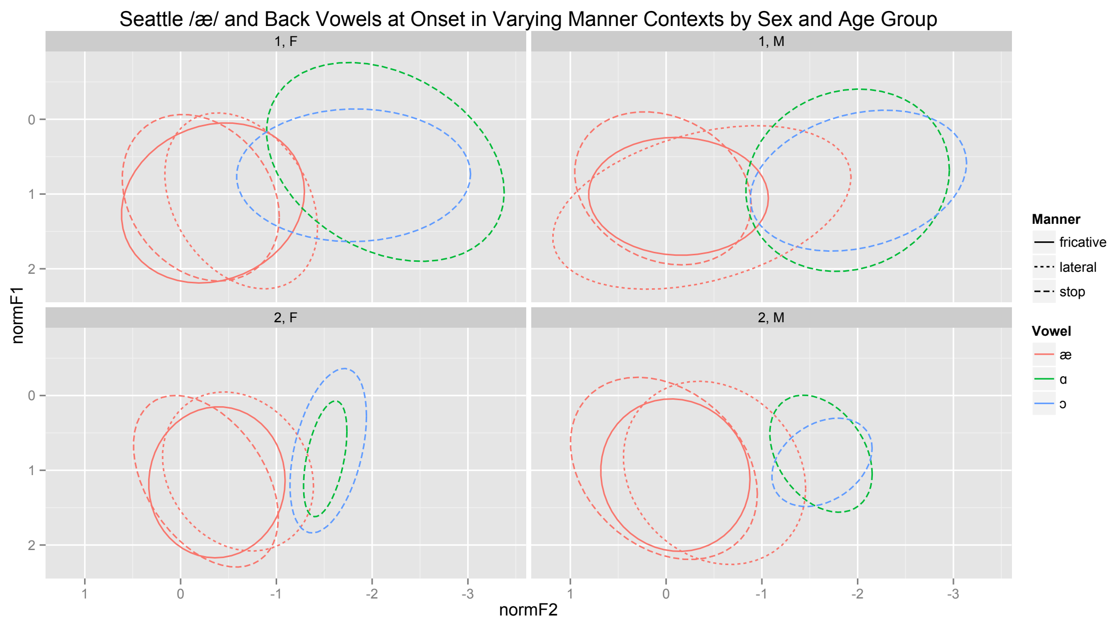

Figure 22. Ellipse plot of /æ/ retraction in Vancouver: /æ/, /ɑ/ and /ɔ/ tokens at onset (20% time-proportional duration) before various manners of articulation for Seattle speakers with Lobanov normalized inverted F2 on x-axis; inverted Lobanov normalized F1 on y-axis wrapped by age group (1= Group 1; 2= Group 2) and sex

For Seattle speakers of all sub-groups, /ɑ/ and /ɔ/ have nearly completely overlapping ellipses. For all speaker sub-groups, /æ/ overlaps minimally with /ɑ/ and /ɔ/ when it is following by a stop or fricative consonant, and slightly more when /æ/ is followed by a lateral.

4.5.5 Mixed-effects linear regression models for /æ/ retraction in Seattle

The following table summarizes the number of observations in the regression models for retraction of /æ/ in Seattle:

Following Manner	Age Group 1		Age Group 2		Total
	Female	Male	Female	Male	
æSTOP	2470	2350	2840	2435	10,095
æFRIC	730	695	845	730	3000
æLAT	360	345	385	350	1440
GRAND TOTAL			**n=14,535**		

Table 28. Number of observations (by age and sex) included in mixed-effects linear regression models of /æ/ retraction among Seattle speakers

F2 in Seattle

The F2 model identified a four-way interaction of Manner, ordered Position, Age Group and Sex. Including normalized duration as an independent fixed effect significantly improved the model. The inclusion of Preceding Phone as an independent fixed term made no significant improvement to the model and was not retained. In the post-hoc consideration of whether speakers' sociocultural survey responses improved the model, the inclusion of subjects' responses regarding the importance of shopping locally from the Pacific Northwest was shown to improve the model. This sociocultural question did have a significant main effect on F2 and was included in the final model shown below:

```
F2.lmerE <- lmer(normF2 ~ Manner*Position.ord*(as.factor(AgeGroup))*Sex +
 normdurms + normImportanceShoppingPNW + (1 + Position.ord | Name) + (1|Word),
 data=SEAback3)
```

	Est.	Std. Er.	t value	p
(Intercept)	-0.397	0.08	-4.70	< 1e-04
Mannerlateral	-0.515	0.12	-4.37	< 1e-04
Mannerstop	0.137	0.08	1.79	0.073
Position.ord.L	-0.099	0.06	-1.57	0.118
Position.ord.Q	0.068	0.04	1.73	0.083
normdurms	0.028	0.01	4.84	< 1e-04
normImportanceShoppingPNW	-0.106	0.03	-3.36	0.001
Mannerlateral:Position.ord.L	-0.530	0.06	-8.33	< 1e-04
Mannerlateral:as.factor(AgeGroup)2	0.102	0.04	2.59	0.010
Mannerstop:as.factor(AgeGroup)2	0.052	0.03	2.05	0.041
Mannerlateral:SexM	0.122	0.04	3.00	0.003
Mannerstop:SexM	0.100	0.03	3.75	0.000
Position.ord.L:SexM	-0.264	0.09	-2.93	0.003
Mannerlateral:Position.ord.L:SexM	0.245	0.09	2.69	0.007
Mannerstop:Position.ord.L:SexM	0.133	0.06	2.23	0.025
Mannerlateral:as.factor(AgeGroup)2:SexM	-0.320	0.06	-5.64	< 1e-04
Mannerlateral:Position.ord.L:as.factor(AgeGroup)2:SexM	-0.259	0.13	-2.04	0.041

Table 29. Statistically significant fixed effects for linear mixed-effects regression model of F2 for /æ/ retraction in Seattle; full model output available in Appendix C

The figure below shows the normalized F2 trajectories for /æ/ in three phonetic contexts varying by manner of articulation of the following consonant along with the trajectories for /ɑ/ and /ɔ/. Vowel is depicted by line color; Following Phone is denoted by line type.

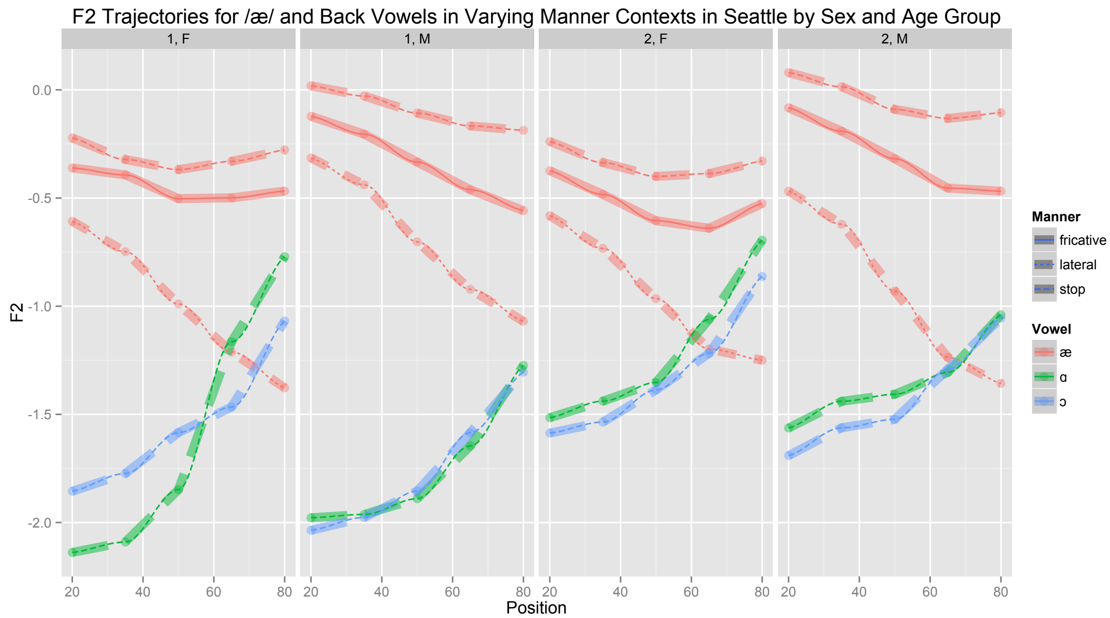

Figure 23. F2 trajectories for /æ/ retraction in Seattle: F2 trajectories for /æ/ in different following manner contexts relative to /ɑ/ and /ɔ/ (time- proportional point on x-axis; Lobanov normalized F2 on y-axis) for Seattle speakers wrapped by age group (1= Group 1; 2= Group 2) and sex

Retraction of /æ/ is expected to manifest primarily on the F2 (front-back dimension). For Seattle speakers, the results of the mixed-effects regression reveal the significant differences in F2 values for /æ/ before a lateral and /æ/ realized in other contexts. Manner of the following consonant is found to be a highly significant predictor of F2 values with /æ/ having lower F2 values before laterals than before fricatives. A following lateral consonant has the largest effect on F2 of /æ/ in this model, though the effect size is not particularly large ($t = -4.37$). Still, the realization of /æ/ before laterals is more back than before fricatives and stops, and this effect is highly significant. This difference can be seen in the elliptical plot in Figure 24 where tokens of /æ/ followed by a lateral consonant (red ellipse outline by smaller dashes) are the most back of the three following manner contexts (all red ellipses) at onset. There is no significant main difference between F2 values for /æ/ before a fricative as compared to a stop. The solid red ellipse denoting /æ/ before fricatives shows virtually no difference with the ellipse for /æ/ before stops (outlined by the wider dashes) in Figure 24. The dynamic view of F2 formant trajectory in Figure 25 reveals a greater difference temporally later in the segment for the /æ/ realizations varying by manner, visible in the increasing distance between the different red line types moving left to right for each panel of Figure 25. There are additional significant interactions between the shape of the F2 trajectory and the manner of the following consonant. F2 trajectories preceding lateral segments drop more sharply than those preceding fricatives, and F2 trajectories preceding stops drop gently and less sharply than fricatives. The illustration of F2 trajectories in the figure above helps to visualize these patterns: For all speaker sub-groups, the F2 values for /ɑ/ and /ɔ/ start very low, indicating they are very back in the vowel space, and move forward over the duration of the segment. F2 values for /æ/ start much higher, indicating that they are more front at onset and decline over the course of the segment. For all age and sex sub-groups, the F2 values of /æ/ are highest before stops, lower before fricatives, and lowest before laterals. Given the relatively small difference at onset between the phonetic environments and the increasing differences over the segment's duration, backing of /æ/ before laterals seems to be motivated primarily by coarticulatory factors, not phonologized retraction.

There are no significant differences by age group or sex, though there are some significant interactions involving each. For Group 2 speakers, F2 values are slightly higher for both /æ/ before a lateral and /æ/ before a stop, suggesting generally more front vowels for Group 2 speakers. Sex and Manner of the following consonant interact similarly to identify higher F2 values for men for /æ/ before a lateral and /æ/ before a stop. This suggests that men generally have more front realizations of /æ/ than women. One of the largest effects in the model though is an interaction for Age Group, Sex and Manner. Among Group 2 speakers, men have significantly lower F2 values for /æ/ before a lateral (relative to before a fricative) than women. For Group 1 speakers, the opposite is true. Finally, there was a significant effect of speakers' responses for the importance of shopping from the Pacific Northwest region. A higher rating for the importance of shopping from the region predicts a lower F2 value, suggesting a more retracted variant of /æ/. Overall, Seattle speakers are retracting /æ/ in the sense that it moves back in the vowel space over its duration, but regardless of following phonetic environment, they are not reaching the backness of neighboring vowels /ɑ/ and /ɔ/.

F1

While retraction is anticipated to affect primarily the F2 domain, a model for F2 was constructed to investigate whether "retraction" involved any raising or lowering of the vowel that would be observable on the F1 dimension. Removing Age Group did not result in a significantly different model. Manner of the following consonant has no main effect on F1 values, but did participate in some significant interactions. The only significant main effects on F1 in this model are found for position (time as an ordered factor) and duration. The trajectories of F1 do differ linearly, quadratically and cubicly reaching significance. Preceding phone was not found to have and effect on normalized F1 values, nor did it significantly improve the model when considered as an interactive terms with Manner. Post-hoc tests revealed that there were no significant improvements to the model with the inclusion of responses from any sociocultural survey questions.

F1.lmerD <- lmer(normF1 ~ Manner*Position.ord*Sex + normdurms +Sameness + (1 + Position.ord | Name) + (1|Word), data=SEAback3)

	Estimate	Std..Error	t.value	p
(Intercept)	0.95	0.13	7.35	< 1e-04
Position.ord.L	-0.51	0.06	-9.22	< 1e-04
Position.ord.Q	-0.37	0.03	-10.99	< 1e-04
Position.ord.C	0.1	0.03	3.63	0
normdurms	0.02	0.01	3.66	0
SamenessY	-0.09	0.04	-2.07	0.04
Mannerstop:Position.ord.L	0.11	0.03	3.71	0
Mannerlateral:Position.ord.Q	0.1	0.05	2.18	0.03
Mannerstop:Position.ord.C	-0.06	0.03	-2.08	0.04
Mannerstop:SexM	-0.1	0.02	-4.92	< 1e-04
Position.ord.L:SexM	0.22	0.08	2.7	0.01
Mannerstop:Position.ord.L:SexM	-0.09	0.05	-2.03	0.04

Table 30. Statistically significant fixed effects for linear mixed-effects regression model of F1 for /æ/ retraction in Seattle; full model output available in Appendix C

The figure below shows the normalized F1 trajectories for /æ/ in three phonetic contexts varying by manner of articulation of the following consonant along with the trajectories for /ɑ/ and /ɔ/. Vowel is depicted by line color; Following Phone is denoted by line type.

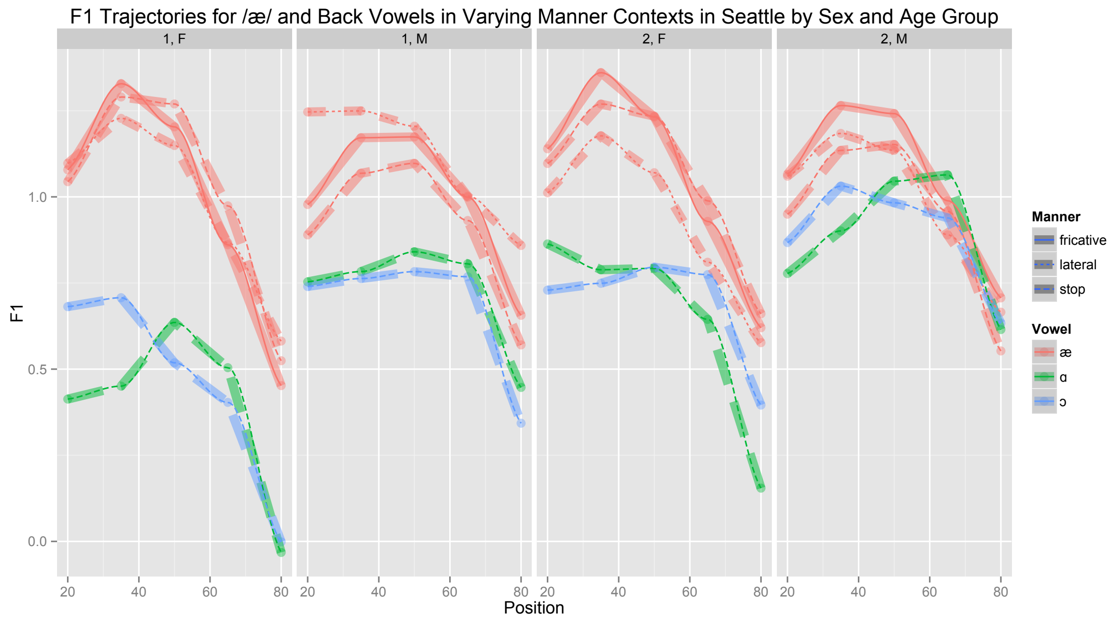

Figure 24. F1 trajectories for /æ/ retraction in Seattle: F1 trajectories for /æ/ in different following manner contexts relative to /ɑ/ and /ɔ/ (proportional time point on x-axis; Lobanov normalized F1 on y-axis) for Seattle speakers wrapped by age group (1= Group 1; 2= Group 2) and sex

Across the F1 model considering predictors of retraction, the effect sizes are very small. Manner of the following consonant does not have a significant effect on normalized F1 values. Normalized duration is a significant predictor of F1 values. This effect is expressed as change in Lobanov normalized F1 values per change in Lobanov normalized duration units. The change is quite small. The F1 values for /æ/ before laterals, fricatives and stops are not significantly different, though there are some significant differences in trajectory shape. Manner does interact with position as an ordered factor; there are significant differences between the linear, quadratic and cubic shapes of F1 trajectories for /æ/ before stops, laterals, and fricatives. In particular, the slope of F1 for /æ/ is significantly different before a stop than before a fricative. The cubic shape of the F1 trajectory also differs significantly between stops and fricatives with the pre-stop environment producing a steeper negative slope associated with a rising vowel in the vowel space. The slope of F1 /æ/ before laterals and fricatives is not significantly different, but F1 trajectories for /æ/ have a different parabolic shape before laterals as compared to before fricatives. This is evident in the figure above based on the differences in the three red lines representing /æ/ in different phonetic environments. From the statistically significant predictors of F1 values, the effect size is greatest for ordered Position, indicating differences in trajectory shape, though these differences are not entirely consistent across speaker sub-groups. There are also significant interactions of Sex and Manner such that relative to women, men have higher F1 values before a lateral and lower F1 values before a stop, though the effect size of these differences is small. Age Group is not a significant independent predictor of normalized F1 values, but it does interact with the manner of the following consonant to produce significantly lower F1 values for Group 2 speakers' realizations of /æ/ before a lateral consonant. This suggests that for Group 2 Seattle speakers /æ/ is higher in the vowel space before a lateral consonant than for Group 1 speakers. Speakers' responses to one of the sociocultural interview questions is a significant predictor of F1 values for Seattle speakers in this analysis of /æ/. The row labeled sameness in the preceding table illustrates that subjects who described Seattle and Vancouver as "the same" or "similar" had significantly lower F1 values, indicating a higher /æ/ vowel across all contexts.

4.5.6 Summary of /æ/ retraction in Seattle

Seattle speakers are engaging in phonetically-conditioned retraction of /æ/, by which /æ/ is more retracted before laterals than fricatives, and retracts more over its duration before a fricative than before a stop. For Seattle speakers, this allophonic retraction affects primarily the F2 dimension, and does not involve substantial or predictable gestures of raising or lowering on the F1 dimension. There is not a significant difference in vowel height for these phonetically conditioned realizations of /æ/, though there are small differences in the trajectories of F1 over the course of the vowel. There is no significant or substantial social variation evident in these patterns, aside from very small differences in vowel height for certain age or sex sub-groups, which may not be perceptible, and which also do not indicate more or less retraction. The analysis indicates that speakers who felt it was more important to shop from the Pacific Northwest also tended to have more retracted realizations of /æ/.

4.5.7 Comparing of /æ/ retraction in Seattle and Vancouver

While the data suggest that retraction of /æ/ is strongly conditioned by phonetic environment, they may also suggest variation between the two cities in terms of the status of /æ/ retraction as a dialect marker.

F2

The F2 model for comparing Seattle and Vancouver was based on the best-fit F2 models for the two cities separately. City was added as a term and tested in a variety of interactions with Age Group, Sex, Manner, and ordered Position. No significant improvement to the model was made by including City as an interacting term with Age Group and Sex, and no significant main effects or interactions of Age Group emerged. The model was simplified in a step-wise fashion to remove insignificant terms, leaving a four-way interaction of City as an interacting term with Manner, Duration and ordered Position and a separate fixed effect of Sex. A significant four-way interaction emerged between Manner, ordered Position, City, and normalized Duration. The inclusion of

Preceding Phone information significantly improved the model. Post-hoc testing was conducted to determine whether the speakers' responses to the sociocultural survey questions were significant predictors of normalized F2 values.

The final model is below:

```
F2.lmerG <- lmer(normF2 ~ Manner*Position.ord*City*normdurms + PrecedingPhone +
normHowOftenShopLocalHomeCity + (1 + Position.ord | Name) + (1|Word),
data=back3)
```

	Est.	Std. Er.	t value	p
(Intercept)	-0.225	0.13	-1.70	0.089
Mannerlateral	-0.419	0.16	-2.62	0.009
Position.ord.L	-0.230	0.03	-7.95	<1e-04
Position.ord.Q	0.059	0.02	3.06	0.002
Position.ord.C	0.037	0.02	2.06	0.040
CityVAN	-0.146	0.04	-3.72	0.000
normdurms	0.047	0.01	4.49	<1e-04
SexM	0.131	0.04	3.61	0.000
PrecedingPhoned	-0.314	0.03	-10.08	<1e-04
PrecedingPhonel	-0.608	0.30	-2.03	0.042
PrecedingPhonep	-0.333	0.15	-2.19	0.028
PrecedingPhoner	-0.667	0.26	-2.61	0.009
normHowOftenShopLocalHomeCity	-0.038	0.02	-2.12	0.034
Mannerlateral:Position.ord.L	-0.420	0.04	-9.54	<1e-04
Mannerstop:Position.ord.L	0.121	0.02	5.95	<1e-04
Mannerstop:CityVAN	0.108	0.01	8.23	<1e-04
Mannerstop:normdurms	-0.038	0.01	-3.15	0.002
CityVAN:normdurms	0.049	0.01	4.19	<1e-04
Mannerlateral:CityVAN:normdurms	-0.101	0.02	-4.37	<1e-04
Mannerstop:CityVAN:normdurms	-0.042	0.01	-3.12	0.002
Mannerlateral:Position.ord.L:CityVAN:normdurms	-0.107	0.05	-2.07	0.039

Table 31. Statistically significant fixed effects for linear mixed-effects regression model of F2 for /æ/ retraction across both Seattle and Vancouver; full model output available in Appendix C

When the data for both cities are compared in a linear regression, Manner of the following consonant continues to emerge as the most influential predictor of F2 values for /æ/. Consistent with the individual city analyses, significant effects are found for the manner of articulation of the following phoneme and for the trajectory slopes and shapes based on time point as an ordered factor. Of the significant effects summarized above, the effect size of the following lateral consonant is one of the largest effects. Before a lateral consonant, /æ/ has a significantly lower F2 value than before a fricative. There is no significant main effect of stops as a following Manner, though there are additional interactions of stop as a Manner of articulation with F2 trajectory. Manner also shows significant interactions with the slope and shape of the F2 trajectory for /æ/ over time. Tokens of /æ/ preceding a lateral consonant have a steeper declining slope for F2 than those before fricatives, and those preceding a fricative have a steeper, more negative slope than tokens of /æ/ before stops. The quadratic functions of F2 trajectories before lateral consonants also differ from those for /æ/ before stops and fricatives. The coefficient is positive, but closer to zero for /æ/ before laterals indicating a wider parabolic shape for the F2 trajectory than before stops and fricatives. Preceding phone is also a significant predictor of F2 values. When compared against a baseline of /b/, various preceding phonemes also significantly affect F2 values. In particular, the effect of preceding liquids /r/ and /l/ is sizeable. F2 values of /æ/ following a liquid (/r/ or /l/) are significantly lower than /æ/ following /b/. Other preceding consonants (/d/, and /p/) also have the effect of lowering F2 values for /æ/, but the effect is smaller than for /r/ and /l/.

City and Sex also emerge as independent significant predictors of normalized F2 values for /æ/, but the effect sizes are smaller than the effect size for the Manner of the following consonants. Vancouver speakers show significantly lower F2 values for /æ/ than Seattle speakers. This suggests that the degree of retraction in Vancouver is significantly greater than the retraction of /æ/ in Seattle, though the difference may be relatively small. Male speakers across the sample show higher F2 values, indicating less retraction. City also interacts with Manner of the following consonant. For Vancouver speakers, /æ/ tokens have even lower F2 values before /l/ than for Seattle speakers. Vancouver speakers also show a greater difference between /æ/ tokens before stops and those before fricatives than Seattle speakers. This suggests that Vancouver speakers are retracting more before fricatives than Seattle speakers. For F2 values, there are no significant effects or interactions of Age Group with Sex or Following Manner. Speakers' responses from one sociocultural survey question were shown to be a significant predictor of F2 values. Speakers' responses about how often they shopped from businesses associated with their home city significantly improved the model and had a significant main effect on F2. Higher ratings about the frequency of local shopping were associated with slightly lower F2 values, indicating more retraction of /æ/.

F1

In fitting the model for F1 values, a four-way interaction of Manner, ordered Position, Age Group and Sex was initially tested. No four-way interactions were found, so the model was simplified in a step-wise fashion. City did not reach significance as an independent predictor, so the term was included only in interactions with Age Group and Sex, as well as with Manner and ordered Position. Preceding Phone was included as an independent predictor, which significantly improved the model, though significant main effects were found for only a few preceding consonant environments. Post-hoc testing revealed that there were no significant improvements to the model when speakers' sociocultural responses were included.

The model for F1 across both Seattle and Vancouver is below:

```
F1.lmerC <- lmer(normF1 ~ Manner*Position.ord*normdurms +
 Manner*(as.factor(AgeGroup))*Sex*City + PrecedingPhone + (1 + Position.ord | Name)
 + (1|Word), data=back3)
```

	Est.	Std. Er.	t value	p
(Intercept)	0.802	0.20	3.93	< 1e-04
Position.ord.L	-0.390	0.03	-14.04	< 1e-04
Position.ord.Q	-0.368	0.02	-20.46	< 1e-04
Position.ord.C	0.044	0.01	3.03	0.002
normdurms	0.038	0.01	3.84	0.000
PrecedingPhoned	0.127	0.03	3.71	0.000
PrecedingPhoneg	0.458	0.23	1.95	0.051
Mannerstop:Position.ord.L	0.065	0.02	4.10	< 1e-04
Mannerstop:Position.ord.C	-0.041	0.02	-2.58	0.010
Mannerlateral:normdurms	-0.037	0.02	-2.09	0.036
Mannerstop:normdurms	-0.034	0.01	-3.00	0.003
Position.ord.L:normdurms	-0.066	0.01	-4.64	< 1e-04
Position.ord.Q:normdurms	-0.044	0.01	-3.09	0.002
Mannerlateral:as.factor(AgeGroup)2	-0.166	0.04	-3.95	< 1e-04
Mannerstop:as.factor(AgeGroup)2	-0.058	0.03	-2.13	0.033
Mannerlateral:SexM	0.091	0.04	2.10	0.036
Mannerstop:SexM	-0.116	0.03	-4.07	< 1e-04
Mannerlateral:CityVAN	-0.096	0.04	-2.16	0.031
Mannerstop:CityVAN	-0.116	0.03	-4.08	< 1e-04
Mannerlateral:Position.ord.Q:normdurms	-0.090	0.03	-3.20	0.001
Mannerstop:Position.ord.Q:normdurms	-0.042	0.02	-2.57	0.010
Mannerlateral:as.factor(AgeGroup)2:CityVAN	0.139	0.06	2.26	0.024
Mannerlateral:SexM:CityVAN	-0.203	0.06	-3.24	0.001
Mannerlateral:as.factor(AgeGroup)2:SexM:CityVAN	0.236	0.09	2.66	0.008

Table 32. Statistically significant fixed effects for linear mixed-effects regression model of F1 for /æ/ retraction across both Seattle and Vancouver; full model output available in Appendix C

Results from the model confirm that the phonetically-conditioned process of retraction affect F1 values to a much lesser extent than F2 values. The effect sizes across this model are generally small. The manner of the following consonant had no significant independent effect on F1 values. Across Seattle and Vancouver, F1 values for /æ/ do not differ significantly before laterals, fricatives, or stops, though Manner does participate in several significant interactions as described below. The F1 trajectory shapes do vary in different environments. In particular, the slope of F1 before a stop is not as steep as before a fricative, and the cubic shape of the F1 trajectory is also different before a stop than before a fricative. City does not emerge as an independent predictor of F1 values, confirming that the vowel height of /æ/ does not differ significantly between Seattle and Vancouver talkers, though it does participate in interactions with Manner, Sex, and Age Group that affect F1 values. Namely, Vancouver talkers have less high F1 values for stops (as compared to fricatives) than Seattle talkers. Sex was not a significant independent predictor of F1 values, though Sex interacts with Manner and ordered Position to reveal some significant differences. Across the sample, men have lower F1 values for /æ/ than women, and they also have steeper slopes for F1 than women. Age Group also does not reach significance as an independent predictor of F1 values for Seattle and Vancouver speakers, but there are significant interactions involving Age Group and Manner. For Group 2 speakers, /æ/ has lower F1 values before a lateral consonant (relative to /æ/ before fricatives) than for Group 1 speakers. This suggests that Group 2 speakers have higher realizations in the vowel space of /æ/ before laterals than Group 1 speakers and are differentiating /æ/ before laterals and fricatives to a greater extent than Group 1 speakers. The small effect sizes observed in this model as compared to those in the F2 model of retraction in different allophonic environments suggest that there is not substantial variation in vowel height concurrent with /æ/ retraction.

4.5.8 Summary of /æ/ retraction in Seattle and Vancouver

Both Seattle and Vancouver speakers are engaging in phonetically-conditioned retraction of /æ/ as defined by significantly lower F2 values for /æ/ when followed by a lateral consonant. Retraction manifests as a change to the F2 dimension and shows little change to the F1 dimension. Vancouver and Seattle speakers, as broader groups, do not show any difference in vowel height. Vancouver speakers do engage in significantly more retraction than Seattle speakers, especially for laterals and fricatives, and they also display more socially-structured variation than Seattle speakers. Vancouver females show more retraction than Vancouver men; no significant differences emerge between Seattle men and women with respect to retraction. While Vancouver speakers do not vary significantly by Age Group; the variation between men and women may suggest a change in progress or a social status associated with retraction. Across the sample, subjects' ratings for the importance of shopping from their home city also corresponded with significantly lower F2 values (and more retracted variants of /æ/). The findings suggest that while retracted /æ/ has been observed throughout the West coast (from Canada to California), the degree of retraction is significantly greater in some areas than others. Furthermore, retracted /æ/ may have a distinct localized socioindexical value in these various speech communities.

4.6 /aʊ/ Raising

RQ: Are Vancouver speakers participating in raising of /aʊ/? How do Seattle speakers compare?

4.6.1 Descriptive statistics of /aʊ/ raising in Vancouver

Table 31 below gives descriptive statistics for /aʊ/ tokens before voiceless and voiced consonants in Vancouver. The realizations of /aʊT/ in Vancouver is consistent with previous observations that suggest it may differ in quality from the /aʊT/ overheard in regions of Eastern Canada. For Vancovuer speakers, /aʊT/ in words with tautosyllabic voiceless codas sounds more like [ɐʊ] so that *stout* would be [stʰɐʊt̚]. There is a range of pronunciations across speakers, and speakers who engage in more raising may articulate something closer to [stʰʌʊt̚].

Vancouver Vowels	F1 (Hz)	SD F1 (Hz)	F2 (Hz)	SD F2 (Hz)	Dur (ms)	SD Dur (ms)	Lob. Norm F1	Lob. Norm F2
aʊVCD	736	129	1416	241	181	49	0.505	-1.052
aʊVCLS	646	109	1454	268	147	34	-0.037	-0.958
ʌ	686	101	1671	221	115	24	0.202	-0.435
o	499	68	1162	204	145	55	-0.935	-1.676
ʊ	530	67	1601	231	121	30	-0.762	-0.597

Table 33. Mean of unnormalized F1/F2 values and duration, standard deviations of unnormalized F1/F2 values and duration for /aʊ/ before voiceless and voiced consonants relative to back vowels, plus Lobanov normalized z-scores across all five time-proportional points for Vancouver speakers

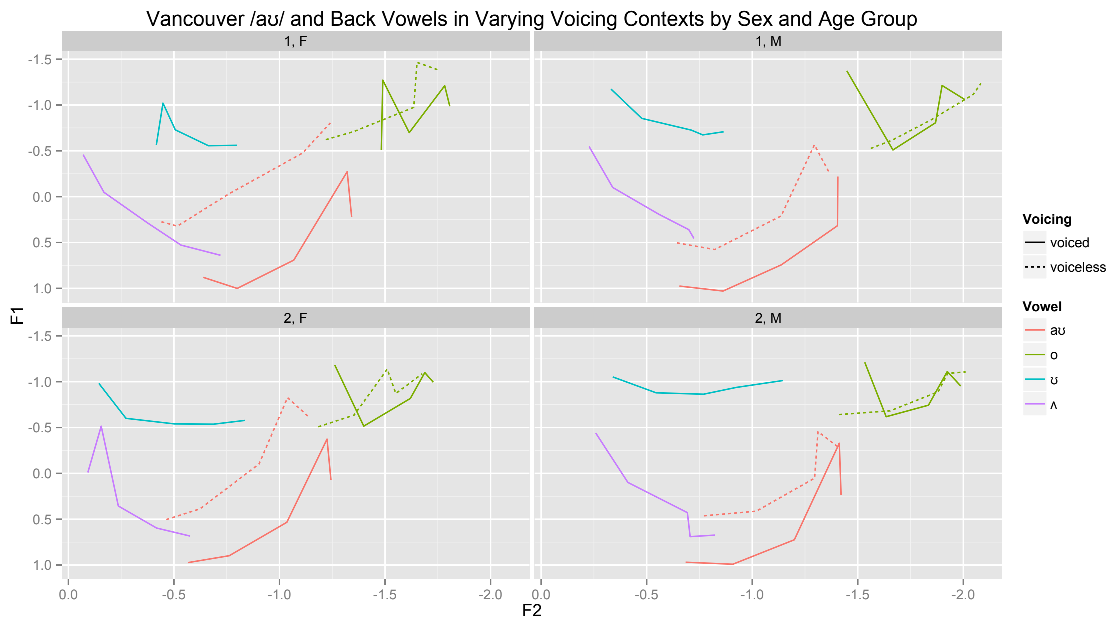

Figure 25. F1 and F2 trajectories across the vowel space for /aʊ/ in Vancouver: /aʊ/ trajectories before voiced and voiceless consonants relative to /ʌ/ and /o/ (Lobanov normalized inverted F2 on x-axis; inverted Lobanov normalized F1 on y-axis for all time five time points) for Vancouver speakers wrapped by age group (1= Group 1; 2= Group 2) and sex

4.6.2 Mixed-effects linear regression models for /aʊT/ ~ /aʊD/ in Vancouver

The table below summarizes the number of observations for Vancouver speakers' realizations of /aʊ/:

Following Voicing	Age Group 1		Age Group 2		Total
	Female	Male	Female	Male	
aʊVCLS	695	745	745	585	2,770
aʊVCD	1300	1380	1390	1105	5,175
GRAND TOTAL	**n=7,945**				

Table 34. Number of observations (by age and sex) included in mixed-effects linear regression models of /aʊT/ ~ /aʊD/ among Vancouver speakers

F1

The model including a 4-way interaction was significantly more predictive than any model unpacking the terms of the 4-way interaction into smaller pieces. The inclusion of normalized Duration and Preceding Phone information also significantly improved the model. The inclusion of speaker responses to one sociocultural survey question was found to yield significantly different results from the original model containing the four-way interaction. The inclusion of speakers' ratings of their National Pride acted as a significant predictor of F1 values for Vancouver speakers. The final model selected was:

```
F1.lmerM <- lmer(normF1 ~ Position.ord*as.factor(AgeGroup)*Sex*Voicing +
 PrecedingPhone + normdurms + normNationalPride + (1 + Position.ord | Name) +
 (1|Word), data=VANau)
```

	Est.	Std.Error	t value	p
(Intercept)	0.650	0.08	8.30	< 1e-04
Position.ord.L	-0.974	0.07	-14.34	< 1e-04
Position.ord.Q	-0.370	0.04	-8.55	< 1e-04
Position.ord.C	0.128	0.03	4.38	< 1e-04
as.factor(AgeGroup)2	-0.122	0.05	-2.42	0.016
Voicingvoiceless	-0.762	0.07	-10.55	< 1e-04
PrecedingPhoneg	-0.436	0.16	-2.72	0.007
PrecedingPhoneh	-0.594	0.14	-4.18	< 1e-04
PrecedingPhoner	-0.263	0.10	-2.74	0.006
normdurms	-0.019	0.01	-3.20	0.001
normNationalPride	0.039	0.02	2.20	0.028
Position.ord.Q:as.factor(AgeGroup)2	0.145	0.06	2.38	0.017
Position.ord.Q:Voicingvoiceless	0.136	0.05	2.95	0.003
as.factor(AgeGroup)2:Voicingvoiceless	0.104	0.03	3.63	0.000
SexM:Voicingvoiceless	0.177	0.03	6.18	< 1e-04
as.factor(AgeGroup)2:SexM:Voicingvoiceless	-0.104	0.04	-2.52	0.012
Position.ord.L:as.factor(AgeGroup)2:SexM:Voicingvoiceless	0.295	0.09	3.19	0.001

Table 35. Statistically significant fixed effects for linear mixed-effects regression model of F1 for /aʊT/ ~ /aʊD/ in Vancouver; full model output available in Appendix C

The figure below shows F1 trajectories for the front vowels /aʊ/ before voiceless and voiced following consonants along with /ʌ/, /ʊ/, and /o/. Vowel is represented by color; Following Phone is represented by line type.

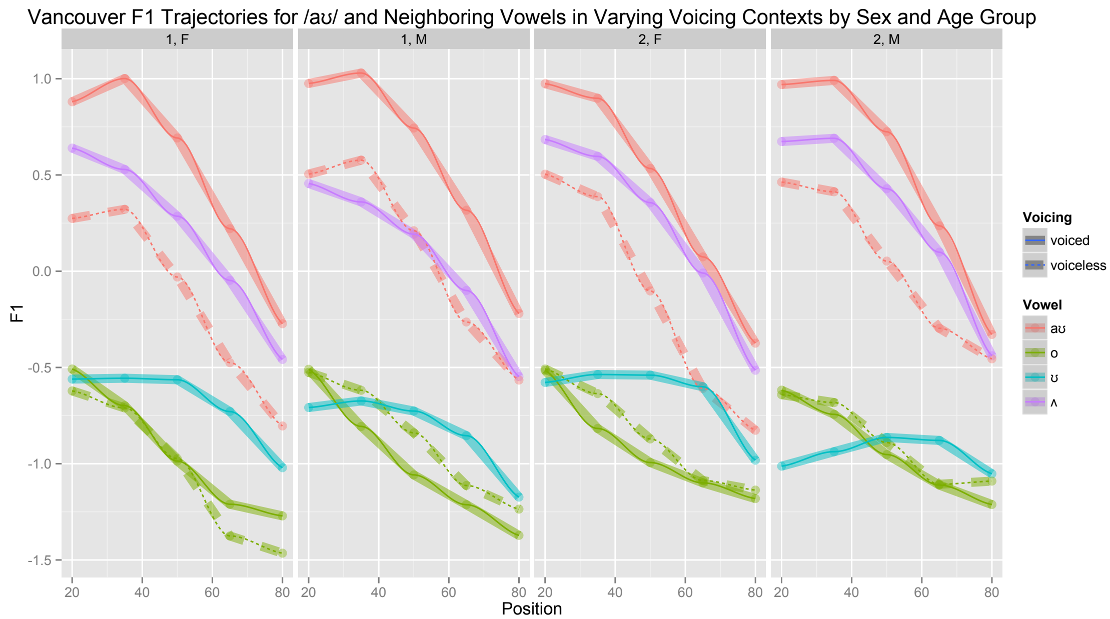

Figure 26. F1 trajectories for /aʊ/ in Vancouver: F1 trajectory for /aʊ/ in different following voicing contexts relative to /o/, /ʌ/, and /ʊ/ (proportional time point on x-axis; Lobanov normalized F1 on y-axis) for Vancouver speakers wrapped by Age Group (1= Group 1; 2=Group 2) and Sex

"Canadian" Raising predicts lower F1 values from onset for /ɑʊ/ before voiceless consonants, approaching those for /ʌ/. Voicing of the following consonant has a significant and large effect as an independent predictor of F1 values for /aʊ/. Tokens of /aʊ/ before voiceless consonants have significantly and sizably lower F1 values for Vancouver speakers, and as the dynamic visualization reveals, this occurs from onset. As the figure above shows, for all speaker sub-groups in Vancouver, F1 values for /ɑʊT/ are about 0.5 z-score units lower before a voiceless consonant than before a voiced one. With the exception of one sub-group (Group 1 male speakers) F1 values for /ɑʊT/ are lower at onset (indicating a higher vowel) than for /ʌ/, as shown by the purple /ʌ/ line above the dashed red one for /ɑʊT/.

Voicing of the following consonant also interacts significantly with other predictors to affect F1 values. Older speakers have significantly lower F1 values than Group 1 speakers, though the effect is relatively small. Older speakers have relatively higher F1 values for pre-voiceless tokens of /aʊ/ than Group 1 speakers. In other words, there is less difference between the pre-voiceless and pre-voiced F1 values of /aʊ/ for Group 2 speakers than for Group 1. The same is true of men as compared to women: men have relatively higher F1 values for pre-voiceless tokens as compared to pre-voiced tokens, suggesting less difference in their pre-voiceless and pre-voiced realizations of /aʊ/. There are differences between men and women in the F1 values of pre-voiceless /aʊ/ across the Age Groups. The three-way interaction of Voicing, Age Group, and Sex illustrates this difference. For Group 1 speakers, women show significantly lower pre-voiceless F1 values than men do (as evidenced by the broader distance between the solid red and dashed red lines in the figure), but for Group 2 speakers, it is the men and not the women who show lower F1 values for pre-voiceless tokens relative to pre-voiced ones. There are also significant differences in the slope, quadratic and cubic shapes of the F1 trajectories of /aʊ/ for Vancouver speakers. There are differences in the linear shape of pre-voiceless /aʊ/ tokens across speaker sub-groups, and there are also differences in the quadratic shape of /aʊ/ trajectories for Group 2 speakers. For Group 2 male speakers, the slopes of F1 for /aʊ/ in pre-voiceless environments as compared to pre-voiced slopes are less steep than for women. (While men and women both show lower F1 values at onset for pre-voiceless /aʊ/, women also continue to lower F1 values through offset to a greater extent than men, resulting in overall steeper slopes for pre-voiceless /aʊ/ for women as compared to men.) For Group 2 speakers, the parabolic shape of the F1 trajectory is also wider. Preceding Phone was found to be a significant predictor of F1 values. Relative to /b/, /g/, /r/, and /h/ are associated with significantly lower F1 values for /aʊ/. National Pride was also found to be a significant predictor of F1 values. Higher ratings of National Pride were associated with higher F1 values for /aʊ/, though this effect is very small.

F2

The inclusion of duration significantly improved the model for F2. Preceding Phone did not, nor were any sociocultural survey responses found to significantly improve the model. Two sets of three-way interactions significantly improved the model and produced significant effects. Overall, the effects in this model are small and might be considered secondary to the larger effects observed for F1 values. The table below summarizes the statistically significant effects on F2 /aʊ/:

```
F2.lmerH <- lmer(normF2 ~ Position.ord*Voicing*Sex +
as.factor(AgeGroup)*Position.ord*Voicing + normdurms + (1 + Position.ord | Name) +
(1|Word), data=VANau)
```

	Est.	Std.Error	t value	p
(Intercept)	-0.950	0.07	-14.12	< 1e-04
Position.ord.L	-0.598	0.06	-10.63	< 1e-04
Position.ord.Q	0.099	0.03	3.66	0.000
Position.ord.C	0.120	0.02	4.87	< 1e-04
Voicingvoiceless	0.142	0.08	1.76	0.078
normdurms	-0.030	0.01	-5.42	< 1e-04
Position.ord.L:Voicingvoiceless	-0.100	0.04	-2.71	0.007
Position.ord.Q:Voicingvoiceless	-0.132	0.04	-3.58	0.000
Voicingvoiceless:SexM	-0.178	0.02	-9.34	< 1e-04
Voicingvoiceless:as.factor(AgeGroup)2	-0.081	0.02	-4.23	< 1e-04
Position.ord.L:Voicingvoiceless:SexM	0.149	0.04	3.51	0.000
Position.ord.Q:Voicingvoiceless:SexM	0.141	0.04	3.32	0.001
Position.ord.L:Voicingvoiceless:as.factor(AgeGroup)2	0.128	0.04	3.01	0.003
Position.ord.Q:Voicingvoiceless:as.factor(AgeGroup)2	0.118	0.04	2.77	0.006

Table 36. Statistically significant fixed effects for linear mixed-effects regression model of F2 for /aʊT/ ~ /aʊD/ in Vancouver; full model output available in Appendix C

The figure below shows F2 trajectories for the front vowels /aʊ/ before voiceless and voiced following consonants along with /ʌ/, /ʊ/, and /o/. Vowel is represented by color; Following Phone is represented by line type.

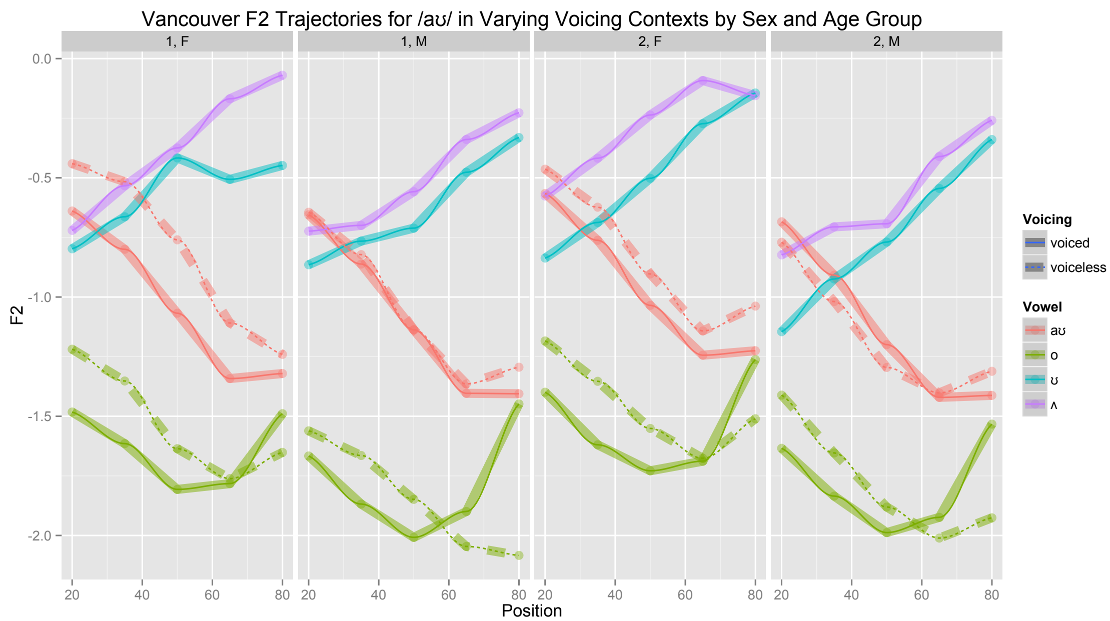

Figure 27. F2 trajectories for /aʊ/ in Vancouver: F2 trajectory for /aʊ/ in before voiceless and voiced consonants relative to /o/, /ʌ/, and /ʊ/ (time- proportional point on x-axis; Lobanov normalized F2 on y-axis) for Vancouver speakers wrapped by age group (1= Group 1; 2= Group 2) and sex

Pre-voiceless /ɑʊ/ raising is anticipated to affect both F1 values and F2 values. Voicing does not have a significant independent effect on F2 for /aʊ/, but it does interact with other variables to produce significant effects. There are linear and quadratic differences between the F2 trajectories of pre-voiceless /aʊ/ and pre-voiced /aʊ/. Pre-voiceless tokens of /aʊ/ have a steeper more negative F2 slope than pre-voiced ones. Older speakers have lower F2 values for /aʊ/ in the pre-voiceless environment than Group 1 speakers, as shown by the lower dashed red line in comparison to the solid one. Men also have lower F2 values for /aʊ/ in the pre-voiceless environment than women. The slope of F2 /aʊ/ before voiceless consonants is steeper than before voiced ones. The parabolic shape of F2 trajectories before voiceless consonants is also taller and skinnier than before voiced consonants. The effect sizes and corresponding visualization of /ɑʊ/ F2 trajectories for

Vancouver speakers do not suggest large or regular patterns of variation between Age and Sex subgroups. For female speakers, pre-voiceless /ɑʊT/ shows higher F2 values than /ɑʊD/, revealing that it starts in a fronter position. Men may begin /ɑʊT/ with a slightly lower F2 value than for /ɑʊD/ (associated with a more retracted pre-voiceless variant), but no other extreme differences emerge in comparing the trajectories by age group or sex.

4.6.3 Summary of /aʊ/ raising in Vancouver

Vancouver speakers show a strong degree of consistency with respect to their F1 values for /aʊ/ before voiceless and voiced environments. The descriptive and inferential statistics reveal substantial and significant differences for /aʊ/ before voiceless consonants. This effect of the pre-voiceless environment is likely large enough to be auditorily perceptible. Women and Group 1 speakers, in general, show characteristics of greater pre-voiceless /aʊ/ raising and greater differentiation of their pre-voiceless and pre-voiced /aʊ/ tokens. On the other hand, Group 2 men show greater differentiation of their /aʊT/ and /aʊD/ tokens than Group 1 men. While there are some significant and small effects across Age Group and Sex, all sub-groups appear to be participating in phonologized raising of /aʊ/ in pre-voiceless environment. The role of F2 in /aʊ/ raising is less clear and may be subject to greater variation between speakers and speaker sub-groups than F1. Based on significantly higher F2 values for women and Group 1 speakers, it seems that /aʊ/ raising is also accompanied by a degree of fronting. Not all speaker sub-groups show differentiation in terms of F2 for /aʊ/ before voiced and voiceless tokens, however, which may indicate that the involvement of F2 in "raising" is an articulatory strategy used differently by different speakers.

4.6.4 Descriptive statistics of /aʊ/ raising in Seattle

Table 35 below shows the descriptive statistics for /aʊ/ in Seattle. Among some Seattle speakers, there is a slight degree of discernible raising before voiceless consonants. Some speakers realize *stout* as [stʰɐʊt˺]. For most Seattle speakers, the difference between /aʊT/ and /aʊD/ is not perceptible or salient. In these cases, *stout* would be realized as [stʰa̠ʊt˺].

Seattle Vowels	F1 (Hz)	SD F1 (Hz)	F2 (Hz)	SD F2 (Hz)	Dur (ms)	SD Dur (ms)	Lob. Norm F1	Lob. Norm F2
aʊVCD	719	168	1420	280	192	54	0.498	-1.121
aʊVCLS	698	158	1465	263	164	41	0.379	-0.998
ʌ	630	113	1638	215	137	46	-0.072	-0.582
o	484	87	1299	226	153	60	-0.890	-1.445
ʊ	501	100	1623	252	146	49	-0.816	-0.550

Table 37. Mean of unnormalized F1/F2 values and duration, standard deviations of unnormalized F1/F2 values and duration for /aʊ/ before voiceless and voiced consonants relative to back vowels, plus Lobanov normalized z-scores across all five time-proportional points for Seattle speakers

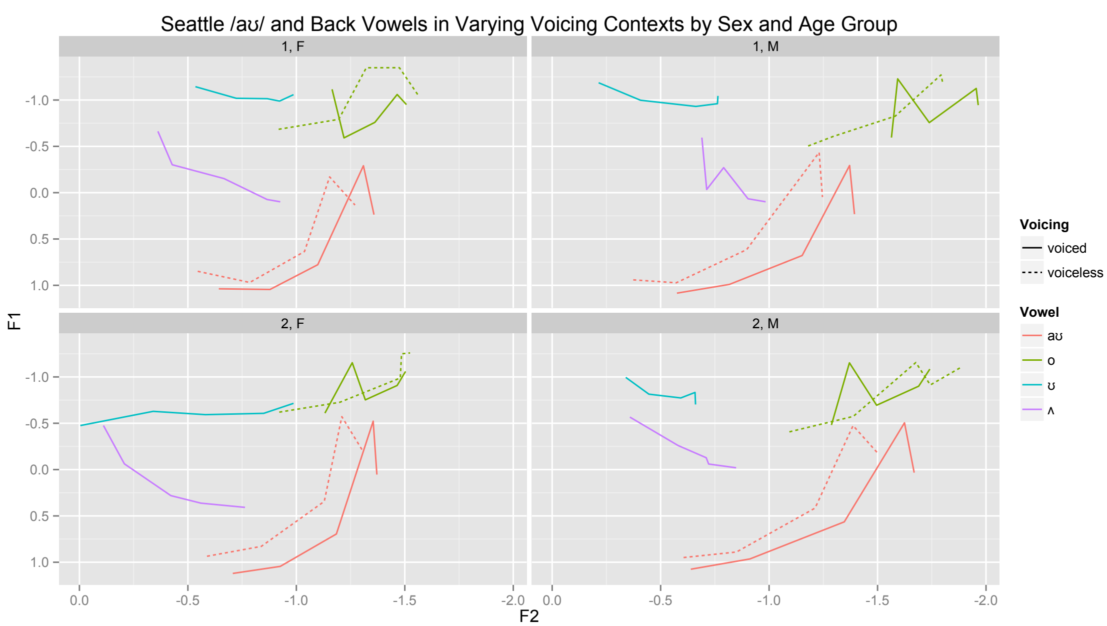

Figure 28. F1 and F2 trajectories across the vowel space for Seattle: /aʊ/ trajectories before voiced and voiceless consonants relative to /ʌ/ and /o/ (Lobanov normalized inverted F2 on x-axis; inverted Lobanov normalized F1 on y-axis for all time five time points) for Seattle speakers wrapped by age group (1= Group 1; 2= Group 2) and sex

4.6.5 Mixed-effects regression models of /aʊT/ ~ /aʊD/ raising in Seattle

The table below summarizes the number of observations for the regression models of /aʊ/ among Seattle speakers:

Following Voicing	Age Group 1		Age Group 2		Total
	Female	Male	Female	Male	
aʊVCLS	755	690	850	725	3,020
aʊVCD	1410	1270	1555	1345	5,580
GRAND TOTAL			**n=8,600**		

Table 38. Number of observations (by age and sex) included in mixed-effect linear regression models of /aʊT/ ~ /aʊD/ raising among Seattle speakers

Results for Linear Regression Model for Seattle

F1

The model of F1 for /aʊ/ among Seattle speakers includes a four-way interaction of Voicing, Position as an ordered factor, Age Group and Sex. This four-way interaction was retained because it produced a significantly more predictive model in model comparisons and because there were statistically significant four-way interactions to report. In addition, normalized Duration interacted with Voicing and Position.ord to significant effect F1 values and to improve the model. The addition of speaker responses from the sociocultural survey was not found to significantly improve the model.

```
F1.lmerH <- lmer(normF1 ~ Voicing*Position.ord*as.factor(AgeGroup)*Sex +
PrecedingPhone + normdurms*Voicing*Position.ord + (1 + Position.ord | Name) +
(1|Word), data=SEAau)
```

	Est.	Std. Er.	t value	p
(Intercept)	0.613	0.11	5.58	< 1e-04
Voicingvoiceless	-0.223	0.09	-2.59	0.010
Position.ord.L	-1.084	0.08	-13.75	< 1e-04
Position.ord.Q	-0.358	0.05	-7.16	< 1e-04
Position.ord.C	0.089	0.03	2.72	0.006
PrecedingPhoneh	-0.410	0.16	-2.57	0.010
Voicingvoiceless:Position.ord.L	0.154	0.05	3.06	0.002
Voicingvoiceless:Position.ord.Q	0.098	0.05	1.95	0.051
Voicingvoiceless:Position.ord.C	0.125	0.05	2.50	0.013
Voicingvoiceless:as.factor(AgeGroup)2	-0.120	0.03	-3.87	0.000
Position.ord.L:as.factor(AgeGroup)2	-0.241	0.11	-2.17	0.030
Voicingvoiceless:normdurms	-0.044	0.01	-2.94	0.003
Position.ord.L:normdurms	-0.144	0.01	-9.79	< 1e-04
Voicingvoiceless:Position.ord.L:as.factor(AgeGroup)2	-0.147	0.07	-2.13	0.034
Voicingvoiceless:Position.ord.L:SexM	-0.317	0.07	-4.33	< 1e-04
Voicingvoiceless:as.factor(AgeGroup)2:SexM	0.105	0.05	2.32	0.020
Voicingvoiceless:Position.ord.Q:normdurms	0.089	0.03	3.04	0.002
Voicingvoiceless:Position.ord.L:as.factor(AgeGroup)2:SexM	0.236	0.10	2.35	0.019

Table 39. Statistically significant fixed effects for linear mixed-effects regression model of F1 for /aʊT/ ~ /aʊD/ in Seattle; full model output available in Appendix C

The figure below shows the F1 trajectories for the front vowels /aʊ/ before voiceless and voiced following consonants along with the trajectories for the back vowel /ʌ/, /ʊ/, and /o/. Vowel is represented by color; Following Phone is represented by line type.

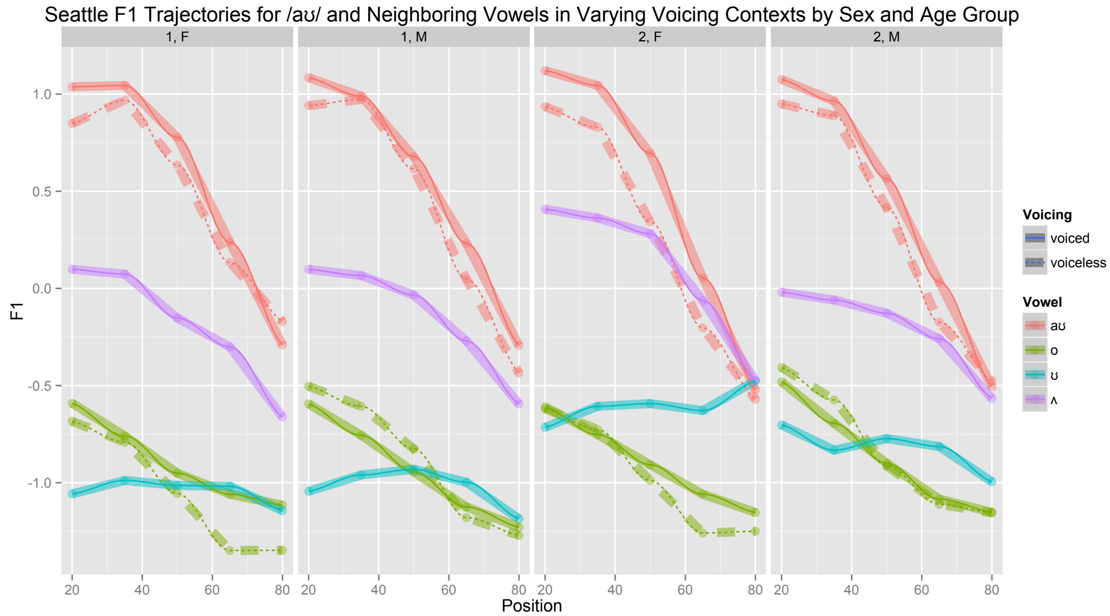

Figure 29. F1 trajectory for /aʊ/ in Seattle: F1 trajectory for /aʊ/ in different following voicing contexts relative to /o/, /ʌ/, and /ʊ/ (proportional time point on x-axis; Lobanov normalized F1 on y-axis) for Seattle speakers wrapped by age group (1= Group 1; 2= Group 2) and sex

If Seattle speakers were engaging in some degree of phonologized /aʊ/ raising, F1 values would be lower at onset and throughout the trajectory preceding voiceless consonants than before voiced consonants. F1 values for /aʊ/ in the pre-voiceless context might even approach those for /ʌ/. Across all sub-groups of Seattle speakers, there is very little difference in the onset values or trajectories for /aʊ/ in the pre-voiceless environment as compared to /aʊ/ in the pre-voiced environment. (This is evident in the nearly identical red lines in the figure above, where the dashed red line representing the F1 trajectory of /aʊ/ before a voiceless consonant is nearly identical to the solid one representing the F1 of /aʊ/ before a voiced one.) For female speakers, young and old, /aʊ/ is minimally lower at onset before voiceless consonants than voiced ones, but the F1 values for /aʊ/ at onset do not come close to approaching those for /ʌ/. For male speakers, there is even less difference between the different allophones of /aʊ/.

While descriptive observations of the F1 and F2 trajectories do not reveal substantial differences between /aʊ/ in different phonetic contexts or for different sub-groups, the inferential statistics reveal some small differences. Across the significant effects in this model, though, the effect sizes are very small. Voicing was found to have an independent effect on F1 values for Seattle speakers, although the effect size is small. In particular, the pre-voiceless context predicts lower F1 values. Voicing also participates in several significant interactions affecting F1 values. Voicing interacts with Position as an ordered factor to reveal differences in the linear, quadratic and cubic shapes of F1 trajectories for /aʊ/ in the pre-voiceless environment as compared to the pre-voiced environment. Voicing also interacts significantly with normalized duration. For /aʊ/ before a voiceless consonant as compared to /aʊ/ before a voiced consonant, longer duration is associated with lower F1 values. This suggests that longer tokens of /aʊ/ before a voiceless consonant see more raising of the diphthong in the vowel space than longer tokens of /aʊ/ before a voiced consonant. While the coefficient for this change appears to be small, the coefficient expresses the change in z-score normalized duration in milliseconds per millisecond of the vowel's duration. Older speakers have lower F1 values for pre-voiceless /aʊ/ than Group 1 speakers, which suggests that Group 2 speakers are raising /aʊ/ in pre-voiceless position to a greater extent than Group 1 speakers, but there are additional differences to consider between men and women. Voicing, Position, and Age Group have a significant three-way interaction, as do Voicing, Position, and Sex. Across all age groups, the slope of F1 for /aʊ/ before voiceless consonants is steeper (dropping more) for men than for women, and this is one of the largest effects in this model. This may be related to the onset value of /aʊ/ for men and women. (From onset, women show lower F1 values before a voiceless consonant, meaning that their slopes are not as steep.) For Group 2 speakers as compared to Group 1 ones, the negative F1 slope for /aʊ/ before a voiceless consonant is steeper. For men, the interaction of the pre-voiceless environment, Position and Age Group is different than for women. Compared to Group 1 women, Group 2 women have a steeper slope, but this is different for men. Older men show a less steep slope relative to Group 1 men than Group 2 women do relative to Group 1 women. Finally, one preceding Phone was found to have a significant effect on F1 values for /aʊ/. Having /h/ as a preceding phone (as compared to /b/) is associated with a lower F1 value for /aʊ/ tokens.

F2

The model for F2 of /aʊ/ in Seattle includes a four-way interaction and two separate two-way interactions. Voicing is not an independent predictor of F2 values for Seattle speakers, but it does interact significantly with other terms to affect F2. Neither Preceding Phone nor normalized Duration reach significance as independent predictors of F2 values, but Duration does participate in significant interactions that are significant in predicting F2. This model did not show any significant improvement when subject responses to sociocultural survey questions were included in post-hoc testing.

```
F2.lmerJ <- lmer(normF2 ~ Voicing*Position.ord*as.factor(AgeGroup)*Sex +
 normdurms*Position.ord + normdurms*Voicing + (1 + Position.ord | Name) + (1|Word),
 data=SEAau)
```

	Est.	Std. Er.	t value	p
(Intercept)	-1.018	0.09	-11.55	< 1e-04
Position.ord.L	-0.571	0.08	-7.06	< 1e-04
Position.ord.Q	0.137	0.04	3.52	0.000
Position.ord.C	0.091	0.04	2.58	0.010
Position.ord.Q:normdurms	0.049	0.01	3.66	0.000
Voicingvoiceless:normdurms	-0.053	0.02	-3.37	0.001
Voicingvoiceless:Position.ord.L:as.factor(AgeGroup)2:SexM	0.243	0.11	2.26	0.024

Table 40. Statistically significant fixed effects for linear mixed-effects regression model of F2 for /aʊT/ ~ /aʊD/ in Seattle; full model output available in Appendix C

The figure below shows the F2 trajectories for the front vowels /aʊ/ before voiceless and voiced following consonants along with /ʌ/, /ʊ/, and /o/. Vowel is represented by color; Following Phone is represented by line type.

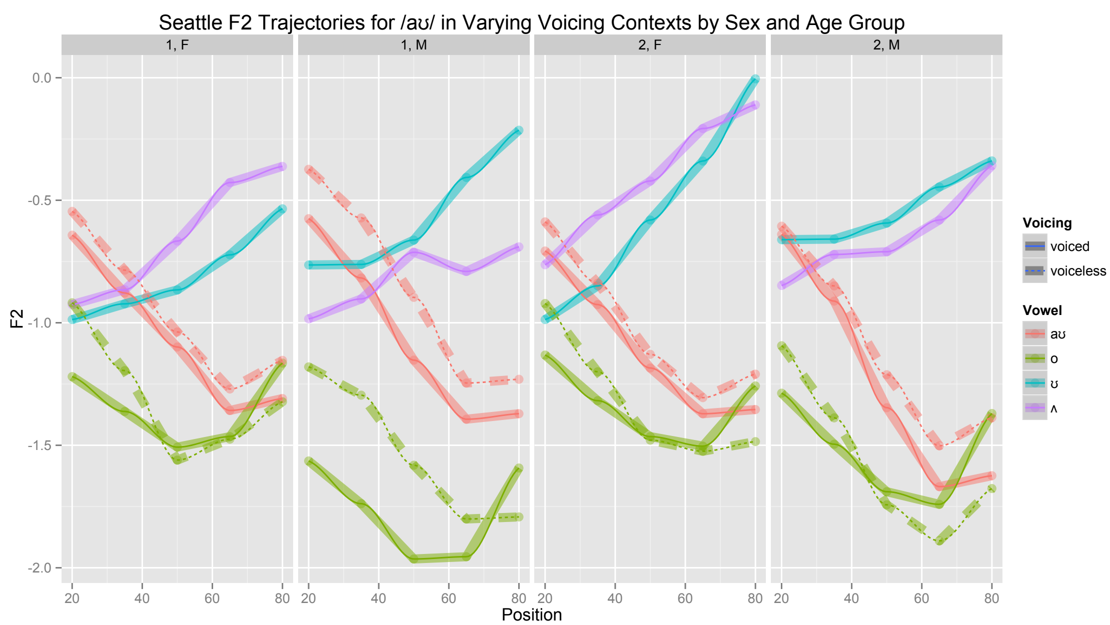

Figure 30. F2 trajectories for /aʊ/ in Seattle: F2 trajectory for /ɑʊ/ before voiceless and voiced consonants relative to /o/, /ʌ/, and /ʊ/ (time-proportional point on x-axis; Lobanov normalized F2 on y-axis) for Seattle speakers wrapped by age group (1= Group 1; 2= Group 2) and sex

Although the phonologized raising of /aʊ/ is expected to affect the F1 height dimension to a greater extent than the F2 dimension, there might be a correlation between the movements of F1 and F2 such that, if Seattle speakers were participating in phonologized raising of /aʊ/, F2 values for /aʊ/ might also be lower in the pre-voiceless environment than the pre-voiced one. This is not the case. Voicing as an independent fixed factor does not significantly effect F2 values of /ɑʊ/. Voicing does interact with other factors as a significant predictor of F2 values. As compared to pre-voiced tokens, pre-voiceless tokens with a longer duration have significantly lower F2 value, meaning they are moving further back in the vowel space. There are significant differences between the linear, quadratic and cubic shapes of F2 trajectories in this model. There are no significant independent effects of Age Group or Sex, but there is a significant four-way interaction. As compared to women, men show a different interaction of Voicing, ordered Position, and Age Group. For men, Group 2 speakers have less steep (negative) slopes for F2 than Group 2 females do relative to Group 1 females. As the figures in this section show, for Seattle speakers, the diphthong /aʊ/ is raising and backing in the vowel space over its duration as indicated by falling F1 values and falling F2 values. It shows very little difference conditioned by voicing of the following consonant in either its raising or backing.

4.6.6 Summary of /ɑʊ/ raising in Seattle

If F1 values are used as the primary consideration in determining /ɑʊ/ raising, then Seattle speakers may be described as participating in some "raising" before voiceless consonants. This raising, however, is physiologically and co-articulatorily driven and may not be sufficient to label as phonologized raising. While statistical differences do emerge in the F1 values of /ɑʊ/ before voiced and voiceless consonants, the auditory effect is very nuanced and likely to go undetected by the average listener. Furthermore, as the descriptive and inferential statistics indicate, the difference between pre-voiceless and pre-voiced /ɑʊ/ for Seattle speakers is quite small. In addition, there may be variation among sub-groups of speakers with respect to the realization of the "raising" that does occur. Women show greater difference than men in terms of F1 values for pre-voiced and pre-voiceless tokens of /ɑʊ/, and men show greater difference than women in terms of the F2 values of pre-voiced and pre-voiceless tokens.

4.6.7 Comparing /aʊ/ raising across Seattle and Vancouver speakers

Two additional mixed-effect regression models were constructed to compare F1 and F2 of /aʊ/ before voiced and voiceless consonants across Seattle and Vancouver. These models are meant to discern differences in the patterns of the cities in question.

F1

The model for F1 values of /aʊ/ across cities is highly complex containing two four-way interactions both of which were found to significantly improve the model and produce significant effects. The inclusion of Preceding Phone was also found to make a more predictive model. No sociocultural responses were significant predictors of F1 values.

```
F1.lmerH <- lmer(normF1 ~ Voicing*Position.ord*Sex*as.factor(AgeGroup) +
City*Voicing*normdurms + City*Voicing*as.factor(AgeGroup)*Sex + PrecedingPhone
+ (1 + Position.ord | Name) + (1|Word), data=BOTHau)
```

	Est.	Std. Er.	t value	p
(Intercept)	0.700	0.09	7.46	< 1e-04
Voicingvoiceless	-0.217	0.08	-2.63	0.009
Position.ord.L	-1.037	0.06	-17.55	< 1e-04
Position.ord.Q	-0.364	0.03	-11.14	< 1e-04
Position.ord.C	0.109	0.02	5.09	< 1e-04
PrecedingPhoneh	-0.504	0.14	-3.58	0.000
PrecedingPhoner	-0.227	0.11	-2.14	0.032
Voicingvoiceless:Position.ord.L	0.116	0.03	3.36	0.001
Voicingvoiceless:Position.ord.Q	0.111	0.03	3.21	0.001
Voicingvoiceless:Position.ord.C	0.076	0.03	2.21	0.027
Voicingvoiceless:as.factor(AgeGroup)2	-0.121	0.03	-4.10	< 1e-04
Position.ord.L:as.factor(AgeGroup)2	-0.197	0.08	-2.37	0.018
Voicingvoiceless:CityVAN	-0.589	0.03	-18.44	< 1e-04
Voicingvoiceless:normdurms	-0.048	0.01	-3.55	0.000
Voicingvoiceless:Position.ord.L:SexM	-0.118	0.05	-2.41	0.016
Voicingvoiceless:Position.ord.L:as.factor(AgeGroup)2	-0.094	0.05	-1.98	0.048
Voicingvoiceless:SexM:as.factor(AgeGroup)2	0.107	0.04	2.50	0.012
Voicingvoiceless:as.factor(AgeGroup)2:CityVAN	0.226	0.04	5.28	< 1e-04
Voicingvoiceless:SexM:CityVAN	0.207	0.04	4.69	< 1e-04
Voicingvoiceless:Position.ord.L:SexM:as.factor(AgeGroup)2	0.242	0.07	3.49	0.000
Voicingvoiceless:SexM:as.factor(AgeGroup)2:CityVAN	-0.213	0.06	-3.43	0.001

Table 41. Statistically significant fixed effects for linear mixed-effects regression model of F1 for /aʊT/ ~ /aʊD/ raising across both Seattle and Vancouver; full model output available in Appendix C

The interaction between City and Voicing was found to have the largest effect on F1 values. For Vancouver speakers as compared to Seattle speakers, tokens of /aʊ/ before a voiceless consonant showed substantially lower F1 values. A pre-voiceless context was an independent predictor of lower F1 values across both cities. Longer duration in the pre-voiceless context was also associated with lower F1 values. Outside of the large effect of Vancouver and /aʊT/ tokens, the other significant effects are small and may indicate small-scale variation between the age and sex sub-groups in the different cities. Older speakers have lower F1 values and steeper negative slopes for /aʊ/ before voiceless consonants than Group 1 speakers. Older men, on the other hand, have higher F1 values for /aʊT/ (relative to /aʊD/) than Group 1 men. For Vancouver, the interaction of Age Group, Sex and Voicing is different than for Seattle speakers. In particular, Group 2 Vancouver men have relatively lower F1 values for /aʊT/ compared to Group 1 speakers. Across the data set, Group 2 male speakers show a less steep negative slope of F1 for /aʊT/ tokens than females.

F2

For F2 values across both Seattle and Vancouver, several complex interactions were found to significantly improve the model and produce significant effects. In general, the effect sizes for the F2 model of /aʊ/ across the cities were smaller than those found for the F1 model. Preceding Phone was not found to be significant predictor of F2 values. No sociocultural responses were found to significantly improve the model or have a significant effect on F2 values.

```
F2.lmerJ <- lmer(normF2 ~ Voicing*Position.ord*Sex*City + normdurms*Voicing*City
+ (1 + Position.ord | Name) + (1|Word), data=BOTHau)
```

	Est.	Std. Er.	t value	p
(Intercept)	-1.013	0.06	-15.68	< 1e-04
Position.ord.L	-0.563	0.05	-11.13	< 1e-04
Position.ord.Q	0.142	0.03	5.64	< 1e-04
Position.ord.C	0.086	0.02	3.90	< 1e-04
Position.ord.L:SexM	-0.212	0.07	-2.94	0.003
Voicingvoiceless:CityVAN	0.062	0.02	2.73	0.006
Voicingvoiceless:normdurms	-0.051	0.01	-3.76	0.000
CityVAN:normdurms	-0.032	0.01	-3.41	0.001
Voicingvoiceless:Position.ord.Q:CityVAN	-0.132	0.05	-2.77	0.006
Voicingvoiceless:SexM:CityVAN	-0.215	0.03	-6.87	< 1e-04
Voicingvoiceless:CityVAN:normdurms	0.043	0.02	2.22	0.027
Voicingvoiceless:Position.ord.Q:SexM:CityVAN	0.215	0.07	3.10	0.002

Table 42. Statistically significant fixed effects for linear mixed-effects regression model of F2 for /aʊT/ ~ /aʊD/ across both Seattle and Vancouver; full model output available in Appendix C

City and Voicing interact to have a significant effect on F2 values for Vancouver speakers. Vancouver speakers had slightly higher F2 values than Seattle speakers for /aʊT/ tokens as compared to /aʊD/. In addition, Vancouver men have substantially lower F2 values for /aʊT/ tokens. Across the data set, men have steeper negative slope for F2 than women. For Vancouver speakers, longer duration for the tokens of /aʊ/ preceding voiceless consonants are also associated with higher F2 values. The coefficient for this effect appears small at 0.043, but this refers to the change in Lobanov normalized F2 values per each additional unit of Lobanov normalized duration in milliseconds. There are also differences in the parabolic shapes of the F2 trajectories of /aʊT/ tokens for Vancouver as compared to Seattle speakers.

4.6.8 Summary of /aʊ/ raising in Seattle and Vancouver

While both Seattle and Vancouver speakers show lower F1 values for /aʊ/ before voiceless tokens as compared to voiced ones, the two cities participate very differently in phonologized /aʊ/ raising. For Vancouver speakers, the differentiation of /aʊT/ and /aʊD/ tokens on the F1 dimension is much more extreme than for Seattle speakers. For Vancouver talkers, this more extreme F1 dimension is accompanied by significant differences between the voicing environments on the F2 dimension, though this is more variable and smaller even for Vancouver speakers than the effects observed on the F1 dimension. There are additional differences within the cities with respect to age and sex sub-groups. Overall, Group 1 Vancouver females are strong participants in phonologized raising. For these speakers, the change on the F1 dimension is accompanied by a fronter realization on the F2 dimension. Seattle women, relative to their male counterparts, are likewise showing more raising based on F1 values, though the degree of their raising by no means approaches that of their Vancouver counterparts.

4.7 /aɪ/ Raising

RQ: Are Vancouver speakers participating in raising of /aɪ/? How do Seattle speakers compare?

4.7.1 Descriptive statistics for /ɑɪ/ raising in Vancouver

Table 41 below provides descriptive statistics for /aɪ/ before voiceless and voiced consonants in Vancouver. Before a tautosyllabic voiced consonant in a word like *hide*, /aɪ/ is realized much backer like [hɑɪːd], while *tyke* sounds more like [tʰaɪk].

Vancouver Vowels	F1 (Hz)	SD F1 (Hz)	F2 (Hz)	SD F2 (Hz)	Dur (ms)	SD Dur (ms)	Norm F1 (Lob)	Norm F2 (Lob)
aɪVCD	745	129	1611	241	190	56	0.562	-0.571
aɪVCLS	609	109	1922	268	120	27	-0.257	0.192
ʌ	686	101	1671	221	115	24	0.202	-0.435
ɪ	497	98	2050	281	86	35	-0.946	0.509
e	464	93	2344	345	156	53	-1.151	1.220

Table 43. Mean of unnormalized F1/F2 values and duration, standard deviations of unnormalized F1/F2 values and duration for /aɪ/ before voiceless and voiced consonants for Vancouver speakers relative to front vowels, plus Lobanov normalized z-scores across all five time-proportional points

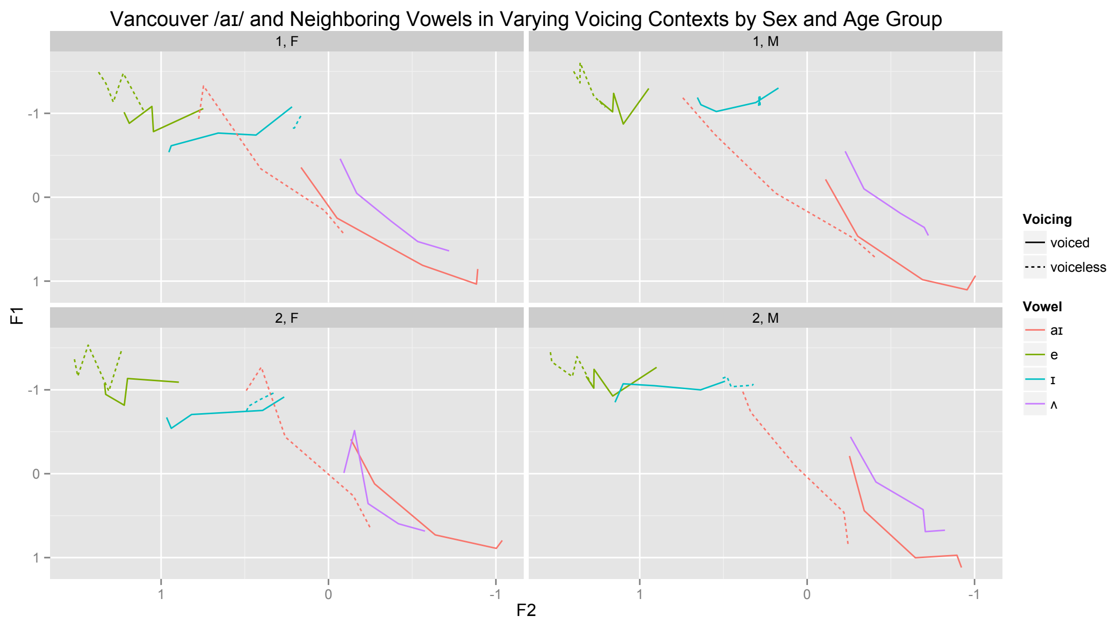

Figure 31. F1 and F2 trajectories for /aɪ/ across the vowel space in Vancouver: /aɪ/ trajectories before voiced and voiceless consonants relative to /ʌ/, /ɪ/ and /e/ (Lobanov normalized inverted F2 on x-axis; inverted Lobanov normalized F1 on y-axis for all five time-proportional points) for Vancouver speakers wrapped by age group (1= Group 1; 2= Group 2) and sex

4.7.2 Mixed-effects linear regressions models of /aɪT/ ~ /aɪD/ in Vancouver

The following table summarizes the number of observations for the regression models of

/ aɪ/ in Vancouver:

Following Voicing	**Age Group 1**		**Age Group 2**		**Total**
	Female	Male	Female	Male	
aɪVCLS	1625	1775	1790	1430	6,620
aɪVCD	1890	2010	2025	1630	7,555
GRAND TOTAL			**n=14,175**		

Table 44. Number of observations (by age and sex) included in linear regression models of /aɪT/ ~ /aɪD/ among Vancouver speakers

Results of Linear Regression Model for Vancouver

F1

The model of F1 for Vancouver identified a significant four-way interaction as well as a separate three-way interaction. The inclusion of information about the Preceding Phone did not make a significant improvement to the model and was not retained. Post-hoc testing found that speakers' responses to four sociocultural survey questions significantly improved the model and were significant predictors of F1 values, though their effects were very small. For thoroughness, speakers' ratings of Toronto and Vancouver's similarity, their ratings of how interested they were in moving, and two questions about their importance and frequency of shopping from Pacific Northwest businesses were included in the final model:

```
F1.lmerR <- lmer(normF1 ~ Voicing*Position.ord*as.factor(AgeGroup)*Sex +
normdurms*Voicing*Position.ord + normInterestedInMoving +
normTorontoVancouverSimilarity +  normHowOftenShopPNW +
normImportanceShoppingPNW + (1 + Position.ord | Name) + (1|Word), data=VANaI)
```

	Est.	Std. Er.	t value	p
(Intercept)	0.505	0.04	11.84	< 1e-04
Voicingvoiceless	-0.931	0.05	-19.47	< 1e-04
Position.ord.L	-0.959	0.08	-12.38	< 1e-04
Position.ord.Q	-0.460	0.06	-8.03	< 1e-04
Position.ord.C	0.096	0.04	2.73	0.006
normdurms	-0.069	0.01	-7.95	< 1e-04
normInterestedInMoving	0.054	0.01	4.08	< 1e-04
normTorontoVancouverSimilarity	0.019	0.01	1.95	0.051
normHowOftenShopPNW	0.057	0.02	3.82	0.000
normImportanceShoppingPNW	-0.047	0.02	-2.87	0.004
Voicingvoiceless:Position.ord.L	-0.500	0.04	-11.79	< 1e-04
Voicingvoiceless:Position.ord.Q	0.197	0.04	4.66	< 1e-04
Voicingvoiceless:Position.ord.C	0.159	0.04	3.76	0.000
Voicingvoiceless:as.factor(AgeGroup)2	0.141	0.02	6.39	< 1e-04
Voicingvoiceless:SexM	0.080	0.02	3.41	0.001
as.factor(AgeGroup)2:SexM	0.174	0.06	2.68	0.007
Voicingvoiceless:normdurms	0.050	0.02	2.63	0.009
Position.ord.L:normdurms	-0.076	0.01	-5.61	< 1e-04
Position.ord.Q:normdurms	-0.083	0.01	-6.10	< 1e-04
Position.ord.C:normdurms	0.028	0.01	2.08	0.038
Voicingvoiceless:Position.ord.L:as.factor(AgeGroup)2	-0.144	0.05	-2.92	0.004
Voicingvoiceless:Position.ord.Q:as.factor(AgeGroup)2	0.126	0.05	2.55	0.011
Voicingvoiceless:Position.ord^4:as.factor(AgeGroup)2	-0.124	0.05	-2.51	0.012
Voicingvoiceless:Position.ord.L:SexM	-0.278	0.05	-5.31	< 1e-04
Voicingvoiceless:Position.ord.C:SexM	0.115	0.05	2.19	0.029
Voicingvoiceless:as.factor(AgeGroup)2:SexM	-0.070	0.03	-2.13	0.033
Voicingvoiceless:Position.ord.L:normdurms	0.103	0.03	3.18	0.001
Voicingvoiceless:Position.ord.Q:normdurms	-0.171	0.03	-5.27	< 1e-04
Voicingvoiceless:Position.ord.C:normdurms	0.147	0.03	4.55	< 1e-04
Voicingvoiceless:Position.ord.L:as.factor(AgeGroup)2:SexM	0.333	0.07	4.54	< 1e-04

Table 45. Statistically significant fixed effects for linear mixed-effects regression model of F1 for /aɪT/ ~ /aɪD/ in Vancouver; full model output available in Appendix C

The figure below shows the F1 trajectories for the front vowels /aɪ/ before voiceless and voiced following consonants along with /ʌ/, /ɪ/, and /e/. Vowel is represented by color; Following Phone is represented by line type.

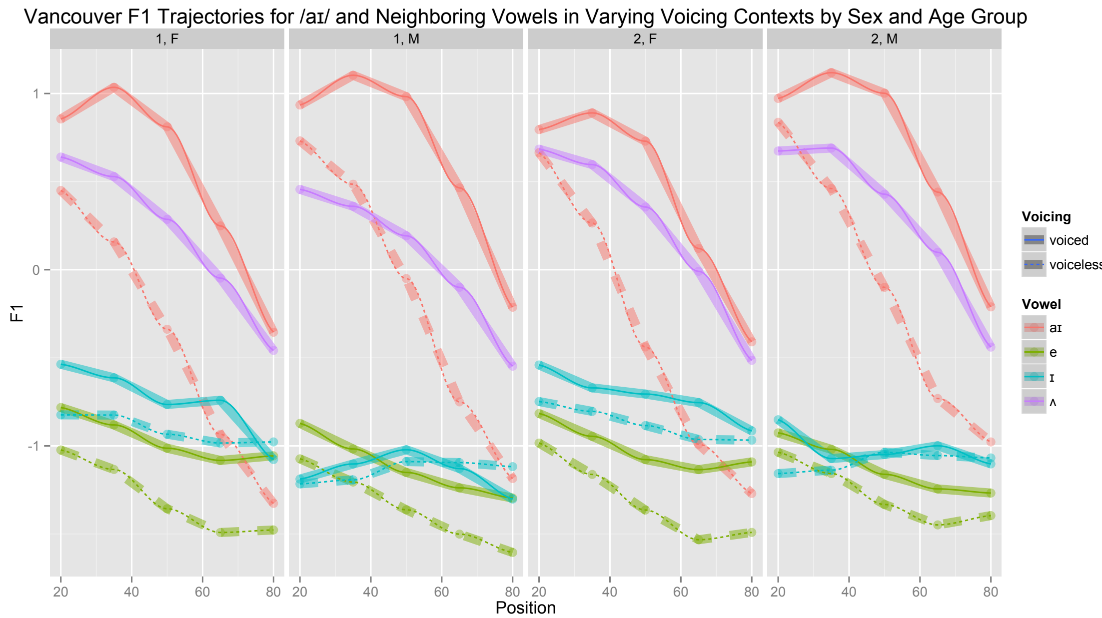

Figure 32. F1 trajectories for /aɪ/ in Vancouver: F1 trajectory for /aɪ/ before voiceless and voiced consonants relative to /e/, /ʌ/, and /ɪ/ (time-proportional point on x-axis; Lobanov normalized F1 on y-axis) for Seattle speakers wrapped by age group (1= Group 1; 2= Group 2) and sex

Based on the contrasting dashed red and solid red lines in the figure above, phonologized differences are evident for both F1 and F2 of /aɪT/ and /aɪD/ for all Vancouver speaker sub-groups. Phonologized raising predicts lower F1 values from onset for /aɪT/ as compared to /aɪD/. All Vancouver speaker sub-groups do show lower onset F1 values for /aɪT/ than /aɪD/ although the differences are not large for some speaker sub-groups. There is a large and significant main effect of voicing, which lowers F1 values for /aɪ/ before voiceless consonants than before voiced ones. This is the largest effect in the model. The slope, parabolic and cubic shapes of the F1 trajectory for /aɪ/ also differ depending on voicing of the following consonant. The following voiceless environment is associated with a steeper, more negative slope for F1 as well as a steeper parabolic shape (see steeper dashed red line as compared to solid red line in the figure above). The cubic shapes of F1 for /aɪT/ and /aɪD/ are also significantly different: for /aɪT/, the shape is closer to a rise-fall-rise shape, while for /aɪD/ it is closer to a fall-rise-fall shape.

Men have significantly higher F1 values for /aɪT/ tokens relative to /aɪD/ than women, which suggests that they may be engaging in less raising (visible in the figure above based on less distance between the dashed and solid red lines for men than for women). This effect size is much smaller than the effect sizes associated with purely phonetic factors like the voicing of the following consonant, but it is one of the largest effect sizes illustrating variation between speakers of different age and sex sub-groups. Age Group is not a significant independent predictor of F1 values for /aɪ/ but it is a participant in several significant interactions. Older speakers, like men, show higher F1 values for /aɪT/ tokens relative to /aɪD/ than Group 1 speakers suggesting that Group 2 speakers may differentiate the allophonic environments to a lesser extent than Group 1 speakers. In the figure above, the two panels on the right have less distance between the dashed and solid lines than the two panels on the left. For men as compared to women, F1 trajectories are also linearly and quadratically different before a voiceless counterpart. The slope of F1 is steeper for men in /aɪT/ tokens relative to /aɪD/ than for women. The interaction of Voicing, Position.ord, and Age Group illustrates that same is true for Group 2 speakers in comparison to Group 1 ones. (This may be due in part to the smaller degree of differentiation these groups show between different allophonic environments at onset.) The four-way interaction of Voicing, Position.ord, Age Group and Sex highlights that for men the interaction of Voicing, Position.ord and Age Group produces a difference effect than for women. For men, the slope of F1 of /aɪT/ is less steep (relative to /aɪD/) for Group 2 speakers than for Group 1 speakers, and the opposite is true for women. This also manifests in the visual presentation because for Group 1 female speakers, in particular, /aɪT/ is higher in the vowel space from onset than /ʌ/. For the other three sub-groups, /aɪT/ begins at the same height as /ʌ/ or slightly lower in the vowel space.

There are additional interactions of normalized Duration, Position.ord and Voicing revealing differences in the slope, parabolic and cubic shapes of F1 for /aɪT/ tokens relative to /aɪD/ dependent on duration. Longer durations for /aɪT/ are associated with a less negative slope and a wider, more gently sloping parabola. Across the Vancouver sample, F1 values and trajectories of /aɪT/ differ significantly from /aɪD/, and these differences may be greater among women and Group 1 speakers.

F2

In the F2 model of /aɪ/ for Vancouver, a significant four-way interaction and a separate significant three-way interaction were found. A four-way of Position.ord, Voicing Sex, and Age Group was retained as well as a three-way interaction of Position.ord, normalized Duration, and Voicing. The inclusion of information about Preceding Phone was found to significantly improve the model. Post-hoc tests indicated no significant improvement with the inclusion of speakers' responses from the sociocultural survey. The final model is:

```
F2.lmerB <- lmer(normF2 ~ Voicing*Position.ord*normdurms +
Voicing*Position.ord*as.factor(AgeGroup)*Sex + PrecedingPhone + (1 + Position.ord |
Name) + (1|Word), data=VANaI)
```

	Est.	Std. Er.	t value	p
(Intercept)	-0.562	0.07	-7.79	< 1e-04
Voicingvoiceless	0.774	0.04	21.63	< 1e-04
Position.ord.L	0.820	0.09	9.21	< 1e-04
Position.ord.Q	0.112	0.05	2.07	0.039
Position.ord.C	-0.205	0.04	-5.86	< 1e-04
as.factor(AgeGroup)2	-0.169	0.09	-1.97	0.049
SexM	-0.163	0.09	-1.91	0.056
PrecedingPhoned	0.240	0.08	3.07	0.002
PrecedingPhoneeɪ	0.152	0.06	2.35	0.019
PrecedingPhoneg	0.247	0.10	2.46	0.014
PrecedingPhoneh	0.259	0.06	4.48	< 1e-04
PrecedingPhonek	0.183	0.07	2.78	0.005
PrecedingPhonen	0.320	0.07	4.83	< 1e-04
PrecedingPhones	0.204	0.06	3.36	0.001
PrecedingPhonet	0.121	0.05	2.51	0.012
PrecedingPhonew	-0.198	0.10	-1.94	0.052
Voicingvoiceless:Position.ord.L	0.150	0.05	3.04	0.002
Voicingvoiceless:Position.ord.Q	-0.186	0.05	-3.78	0.000
Voicingvoiceless:normdurms	-0.053	0.02	-2.49	0.013
Position.ord.L:normdurms	0.180	0.02	11.57	< 1e-04
Position.ord.Q:normdurms	0.078	0.02	5.01	< 1e-04
Voicingvoiceless:as.factor(AgeGroup)2	-0.056	0.03	-2.15	0.031
Voicingvoiceless:SexM	-0.050	0.03	-1.94	0.053
Voicingvoiceless:Position.ord.L:normdurms	0.093	0.04	2.51	0.012
Voicingvoiceless:Position.ord.Q:normdurms	-0.068	0.04	-1.84	0.066
Voicingvoiceless:Position.ord.C:as.factor(AgeGroup)2	-0.014	0.06	-0.25	0.804
Voicingvoiceless:Position.ord^4:as.factor(AgeGroup)2	-0.008	0.06	-0.13	0.894
Voicingvoiceless:Position.ord.L:SexM	0.375	0.06	6.46	< 1e-04
Voicingvoiceless:Position.ord.Q:SexM	0.133	0.06	2.30	0.022
Voicingvoiceless:Position.ord.L:as.factor(AgeGroup)2:SexM	-0.207	0.08	-2.47	0.013

Table 46. Statistically significant fixed effects for linear mixed-effects regression model of F2 for /aɪT/ ~ /aɪD/ in Vancouver; full model output available in Appendix C

The figure below shows the F2 trajectories for the front vowels /aɪ/ before voiceless and voiced following consonants along with /ʌ/, /ɪ/, and /e/. Vowel is represented by color; Following Phone is represented by line type.

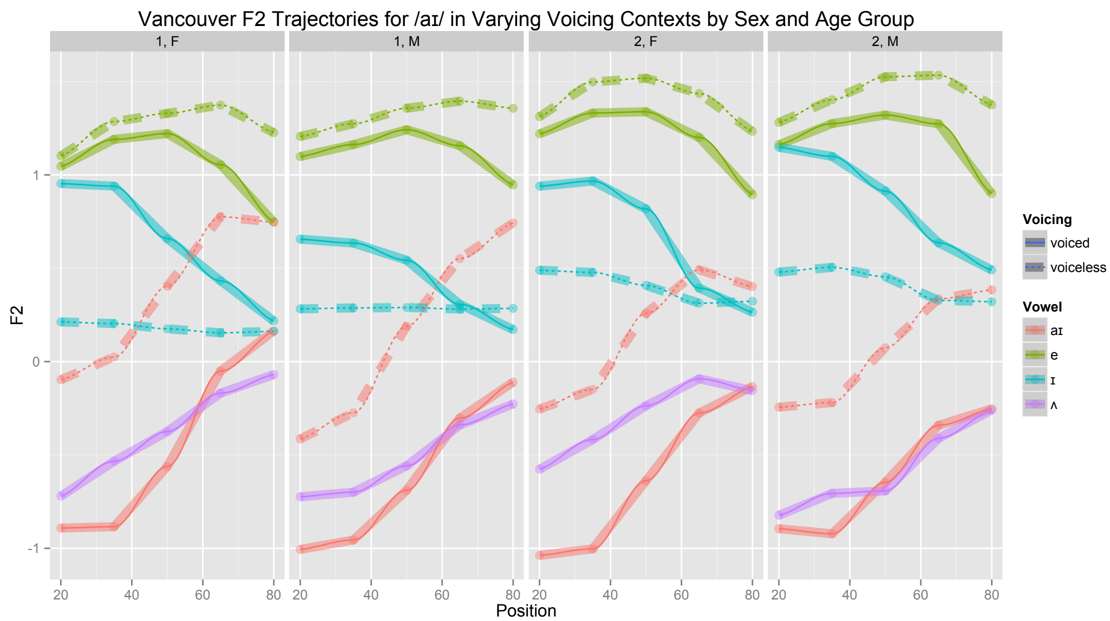

Figure 33. F2 trajectories for /aɪ/ in Vancouver: F2 trajectory for /aɪ/ before voiceless and voiced consonants relative to /e/, /ʌ/, and /ɪ/ (proportional time point on x-axis; Lobanov normalized F1 on y-axis) for Seattle speakers wrapped by age group (1= Group 1; 2= Group 2) and sex

Voicing of the following consonant is a significant predictor of F2 values of /aɪ/ for Vancouver speakers. This effect is by far the largest in the model. Voicing is also associated with significant differences in the trajectory shapes of F2 for /aɪ/. Before voiceless consonants, the slope of F2 rises more steeply than before voiced ones (the dashed red line in the figure above climbs more steeply than the solid one). Normalized segmental duration also interacts with Voicing to produce another large effect. An increase in duration for voiceless tokens is associated with lower F2 values as well as significant steeper (more positive) slope and sharper parabolic shape. Preceding Phone has an additional effect on F2 values for /aɪ/. Compared to /b/, F2 values for /aɪ/ are higher after /eɪ/, /d/, /g/, /h/, /k/, /n/, /s/, /t/ and /w/, though the effect size for Preceding Phone is smaller than for voicing of the following phone.

There are additional social variables predicting F2 values for /aɪ/. Age Group is a significant independent predictor of F2 values for /aɪ/ and also participates in significant interactions to reveal contrasts between Group 2 and Group 1 Vancouver speakers with respect to /aɪT/ raising. Sex is not a significant main predictor of F2 values, but does interact with Voicing and Position.ord to identify differences between men and women with respect to pre-voiceless raising. Older speakers (represented in the right-most panels) have lower F2 values for /aɪT/ relative to /aɪD/ than Group 1 speakers, which suggests that /aɪT/ tokens are relatively less front for Group 2 speakers. As compared to Group 1 speakers, Group 2 speakers do not show any significant differences in the shapes of their F2 trajectories for /aɪT/ and /aɪD/. Men, on the other hand, have significant steeper, more positive F2 slopes for /aɪT/ relative to /aɪD/. This effect is smaller than the purely phonetic effects, but is the largest effect observed indicating variation between social groupings of speakers. The significant four-way interaction of Position.ord, Voicing, Age Group and Sex displays that the interaction of Position.ord, Voicing, and Age Group is different for men than for women. For Group 2 men, the F2 trajectory is significantly less steep for /aɪT/ relative to /aɪD/ than for Group 1 men, while for women this is not true.

4.7.3 Summary of /aɪ/ raising for Vancouver

Vancouver speakers display significant differences between pre-voiceless and pre-voiced tokens of /aɪ/ that affect both the height and front/back dimensions of the allophones. Across all Vancouver speakers, /aɪT/ tokens are significantly more front and higher than /aɪD/ tokens, and these differences are evident from onset, suggesting a phonologized difference prior to co-articulatory effects later in the segment's duration. While all speakers display substantial and significant differences between their /aɪT/ and /aɪD/ tokens, there are differences by age and sex sub-group in the degree of differentiation between the allophonic environments. Younger speakers and female speakers tend to show more differentiated allophonic realizations both in terms of height and frontness than Group 2 or male speakers.

4.7.4 Descriptive statistics for /aɪ/ raising in Seattle

Table 47 below displays the descriptive statistics for /aɪ/ before voiceless and voiced consonants in Seattle. Seattle and Vancouver realizations of /aɪ/ generally seem less perceptibly different than their realizations of /aʊ/. For Seattle speakers, /aɪ/ manifests as much more front before words with a tautosyllabic voiceless consonant meaning that *hide* is realized as [hɑɪːd], while *tyke* sounds more like [tʰaɪk].

Seattle Vowels	F1 (Hz)	SD F1 (Hz)	F2 (Hz)	SD F2 (Hz)	Dur (ms)	SD Dur (ms)	Lob. Norm F1	Lob. Norm F2
aɪVCD	706	168	1690	280	202	67	0.436	-0.420
aɪVCLS	601	158	1933	263	133	35	-0.192	0.202
ʌ	630	113	1638	215	137	46	-0.072	-0.582
ɪ	478	88	2023	259	91	42	-0.939	0.443
e	443	85	2318	353	173	62	-0.072	-0.582

Table 47. Mean of unnormalized F1/F2 values and duration, standard deviations of unnormalized F1/F2 values and duration for /aɪ/ before voiceless and voiced consonants relative to front vowels for Seattle speakers, plus Lobanov normalized z-scores across all five time-proportional points

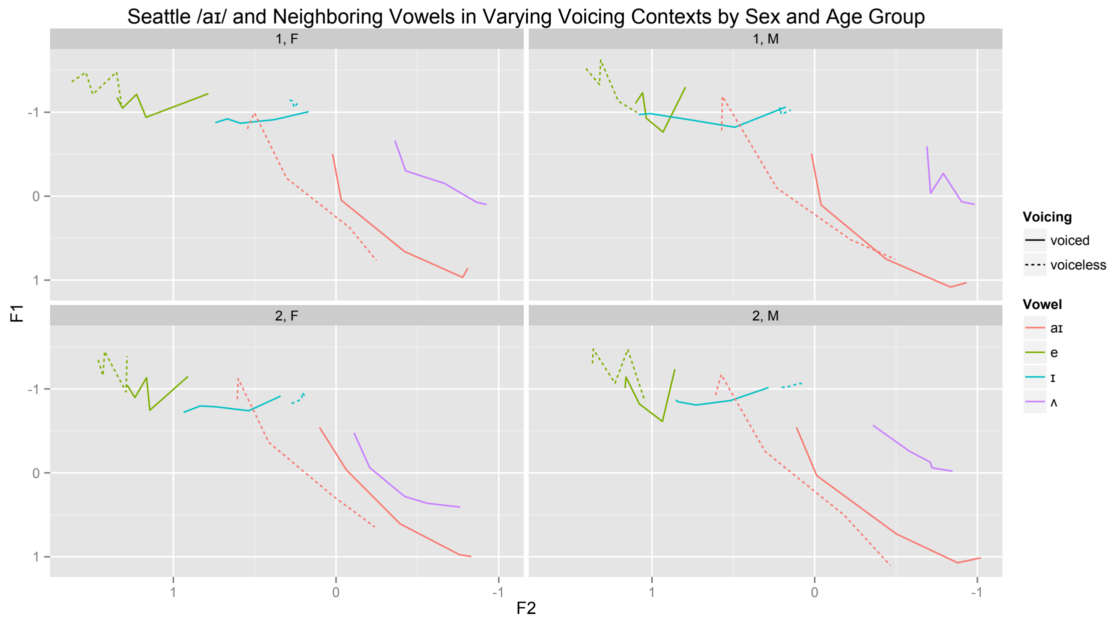

Figure 34. F1 and F2 trajectories for /aɪ/ in Seattle: /aɪ/ trajectories before voiced and voiceless consonants relative to /ʌ/, /ɪ/ and /e/ (Lobanov normalized inverted F2 on x-axis; inverted Lobanov normalized F1 on y-axis for all time five time points) for Seattle speakers wrapped by age group (1= Group 1; 2= Group 2) and sex

4.7.5 Mixed-effects linear regression models for /aɪT/ ~ /aɪD/ raising in Seattle

The table below summarizes the number of observations for the regression models of /aɪ/ in Seattle:

Following Voicing	**Age Group 1**		**Age Group 2**		**Total**
	Female	Male	Female	Male	
aɪVCLS	1790	1640	1995	1725	7,150
aɪVCD	2120	1955	2390	2065	8,530
GRAND TOTAL			**n=15,680**		

Table 48. Number of observations (by age and sex) included in mixed-effects linear regression models of /aɪT/ ~ /aɪD/ among Seattle speakers

F1

In modeling F1 values for /aɪ/ among Seattle speakers, a significant four-way interaction was found for Voicing, Position.ord, Age Group and Sex. A separate three-way interaction was identified for Voicing, Position.ord, and normalized Duration. Attempts to remove terms from these interactions resulted in significantly less predictive models, so the complex interactions were retained. Preceding Phone was found to significantly improve the model and to be a significant predictor of F1 values for /aɪ/. Post-hoc testing revealed that responses from one sociocultural survey question also significantly improved the model and significantly affected F1 values. Subjects' perceptions of Seattle and Vancouver's similarity were included as an independent fixed effect. The final model is below:

```
F1.lmerK <- lmer(normF1 ~ Voicing*Position.ord*as.factor(AgeGroup)*Sex + normdurms*Voicing*Position.ord + PrecedingPhone + normSeattleVancouverSimilarity + (1 + Position.ord | Name) + (1|Word), data=SEAaI)
```

	Est.	Std. Er.	t value	p
(Intercept)	0.405	0.07	5.77	< 1e-04
Voicingvoiceless	-0.579	0.04	-13.00	< 1e-04
Position.ord.L	-1.104	0.07	-15.50	< 1e-04
Position.ord.Q	-0.364	0.06	-6.49	< 1e-04
Position.ord.C	0.141	0.03	5.24	< 1e-04
PrecedingPhoneeɪ	0.275	0.09	3.00	0.003
PrecedingPhoner	-0.163	0.08	-1.98	0.048
normSeattleVancouverSimilarity	0.039	0.01	3.27	0.001
Voicingvoiceless:Position.ord.L	-0.447	0.04	-11.84	< 1e-04
Voicingvoiceless:Position.ord.Q	0.402	0.04	10.65	< 1e-04
Voicingvoiceless:Position.ord.C	0.131	0.04	3.47	0.001
Voicingvoiceless:as.factor(AgeGroup)2	-0.106	0.02	-5.03	< 1e-04
Voicingvoiceless:normdurms	-0.035	0.02	-2.32	0.021
Position.ord.L:normdurms	-0.094	0.01	-7.79	< 1e-04
Position.ord.Q:normdurms	-0.134	0.01	-11.18	< 1e-04
Voicingvoiceless:Position.ord.L:as.factor(AgeGroup)2	0.137	0.05	2.91	0.004
Voicingvoiceless:Position.ord.Q:as.factor(AgeGroup)2	-0.131	0.05	-2.79	0.005
Voicingvoiceless:Position.ord.Q:SexM	-0.263	0.05	-4.97	< 1e-04
Voicingvoiceless:as.factor(AgeGroup)2:SexM	0.124	0.03	3.90	< 1e-04
Voicingvoiceless:Position.ord.C:normdurms	0.126	0.03	4.59	< 1e-04
Voicingvoiceless:Position.ord^4:normdurms	-0.063	0.03	-2.29	0.022
Voicingvoiceless:Position.ord.L:as.factor(AgeGroup)2:SexM	-0.397	0.07	-5.59	< 1e-04
Voicingvoiceless:Position.ord.Q:as.factor(AgeGroup)2:SexM	0.480	0.07	6.74	< 1e-04

Table 49. Statistically significant fixed effects for linear mixed-effects regression model of F1 for /aɪT/ ~ /aɪD/ in Seattle; full model output available in Appendix C

The figure below shows the F1 trajectories for the front vowels /aɪ/ before voiceless and voiced following consonants along with /ʌ/, /ɪ/, and /e/. Vowel is represented by color; Following Phone is represented by line type.

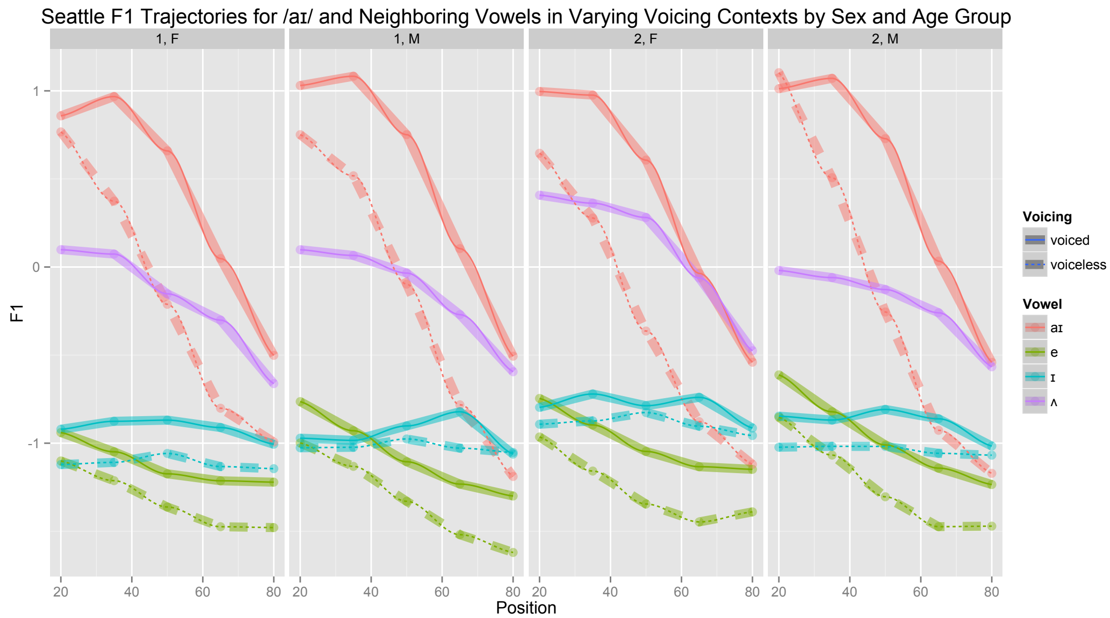

Figure 35. F1 trajectories for /aɪ/ in Seattle: F1 trajectory for /aɪ/ before voiceless and voiced consonants relative to /e/, /ʌ/, and /ɪ/ (proportional time point on x-axis; Lobanov normalized F1 on y-axis) for Seattle speakers wrapped by age group (1= Group 1; 2= Group 2) and sex

Phonologized raising is associated with lower F1 values for /aɪ/ from onset before voiceless consonant than before a voiced one. If speakers are "raising," their F1 values might be as low as those for /ʌ/. Voicing of the following phoneme is a significant predictor of F1 values for /aɪ/ among Seattle speakers. The pre-voiceless environment predicts significantly lower F1 values for /aɪ/ as compared to the pre-voiced environment, and this is the largest effect identified by the model, next to slope difference for F1 trajectories of /aɪT/ and /aɪD/. This is visible in the figure above based on the distance between the dashed and solid red lines across all panels. The slope of F1 for /aɪT/ is significantly steeper than for /aɪD/ (note that the dashed red line is more steeply dropping in the figure than the solid one). The two allophones also differ quadratically in terms of their parabolic shapes. Preceding Phone is also a significant predictor of F1 values, though only two preceding phones differed significantly from the baseline, /b/. As compared to /b/ as a preceding phone, /aɪ/ has lower F1 values when it is preceded by /r/ or /eɪ/.

There is additional variation across speaker sub-groups with respect to F1 values for /aɪT/ and /aɪD/. Age Group interacts significantly with Voicing to identify significantly lower F1 values for /aɪT/ relative to /aɪD/. This would suggest that Group 2 speakers are differentiating the allophonic environments to a greater extent than Group 1 speakers, although there are additional differences between men and women on this point. As compared to women, the interaction of Voicing and Age Group is different for men because they have higher F1 values for /aɪT/ relative to /aɪD/ and not lower ones. The three-way interaction of Position.ord, Voicing, and Age Group also reveals significant differences of slope and parabolic shape for F1 trajectories of /aɪT/ among Group 2 Seattle speakers. For Group 2 speakers, /aɪT/ trajectories are not as steep (less negative) relative to /aɪD/ as for Group 1 speakers. (This may be due to lower F1 values and phonologized raising at onset for Group 2 speakers.) The significant four-way interaction of Voicing, Position.ord, Age Group and Sex confirms that the interaction of Voicing, Position.ord and Age Group is different among men and women. For Group 2 men, the slope of F1 for /aɪT/ is steeper relative to /aɪD/ than for Group 1 men, but the opposite is true for women. While this is a significant effect, the effect size is extremely small. The underlying observation is that the Age Groups pattern differently with respect to Sex and Voicing: among Group 1 speakers, men differentiate /aɪT/ and /aɪD/ more than women, but among Group 2 speakers, men differentiate /aɪT/ and /aɪD/ less than their female counterparts.

Finally, there is a small, but statistically significant effect of speakers' ratings about the similarity of Seattle and Vancouver on their F1 values for /aɪ/. Speakers who had a higher rating of Seattle and Vancouver's similarities had higher F1 values, indicating a lower vowel. This suggests that, for Seattle speakers, those who envision more similarity between Seattle and Vancouver participate to a less extent in /aɪ/ raising.

F2

In modeling F2 values for /aɪ/ among Seattle speakers, a significant four-way interaction was found for Voicing, Position.ord, Age Group and Sex. A separate three-way interaction of Position.ord, normalized Duration, and Voicing was identified. These interactions were retained in the final model. The model was significantly improved with the addition of information about the Preceding Phone. Post-hoc testing revealed one significant improvement to the model with the inclusion of data about speakers' responses to the importance of shopping from businesses originating in their home city.

```
F2.lmerP <- lmer(normF2 ~ Voicing*Position.ord*normdurms +
Voicing*Position.ord*as.factor(AgeGroup)*Sex + PrecedingPhone +
normImportanceShoppingHomeCity + (1 + Position.ord | Name) + (1|Word),
data=SEAaI)
```

	Est.	Std. Er.	t value	p
(Intercept)	-0.436	0.08	-5.60	<1e-04
Voicingvoiceless	0.570	0.04	13.18	<1e-04
Position.ord.L	0.675	0.08	7.96	<1e-04
Position.ord.C	-0.200	0.03	-5.95	<1e-04
PrecedingPhoneg	0.279	0.14	2.01	0.045
PrecedingPhonen	0.248	0.09	2.72	0.007
normImportanceShoppingHomeCity	0.064	0.03	2.38	0.017
Voicingvoiceless:Position.ord.L	0.105	0.05	2.19	0.029
Voicingvoiceless:Position.ord.Q	-0.136	0.05	-2.83	0.005
Position.ord.L:normdurms	0.172	0.02	11.41	<1e-04
Position.ord.Q:normdurms	0.122	0.02	8.08	<1e-04
Voicingvoiceless:as.factor(AgeGroup)2	0.076	0.03	2.82	0.005
Voicingvoiceless:Position.ord.Q:normdurms	-0.170	0.03	-4.91	<1e-04
Voicingvoiceless:Position.ord.L:SexM	0.205	0.06	3.24	0.001
Voicingvoiceless:Position.ord.L:as.factor(AgeGroup)2:SexM	-0.207	0.09	-2.36	0.018

Table 50. Statistically significant fixed effects for linear mixed-effects regression model of F2 for /aɪT/ ~ /aɪD/ in Seattle; full model output available in Appendix C

The figure below shows the F2 trajectories for the front vowels /aɪ/ before voiceless and voiced following consonants along with /ʌ/, /ɪ/, and /e/. Vowel is represented by color; Following Phone is represented by line type.

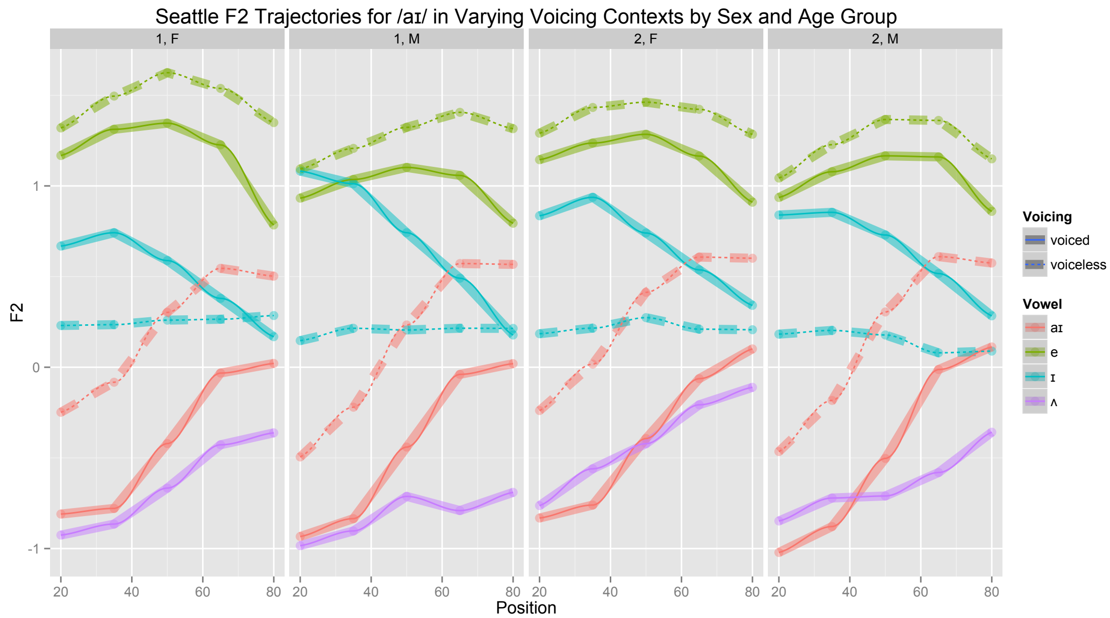

Figure 36. F2 trajectories for /aɪ/ in Seattle: F2 trajectory for /aɪ/ before voiceless and voiced consonants relative to /e/, /ʌ/, and /ɪ/ (time-proportional point on x-axis; Lobanov normalized F1 on y-axis) for Seattle speakers wrapped by age group (1= Group 1; 2= Group 2) and sex

Raising is anticipated to affect the F1 dimension to a greater extent than the F2 dimension, but the allophonic variation between /aɪT/ and /aɪD/ may also be evident on the F2 dimension. If /aɪT/ tokens are allophonically raised in comparison to /aɪD/, their F2 values from onset may be higher than those for /aɪD/. Voicing of the following phone is a significant predictor of F2 values for /aɪ/ tokens among Seattle speakers. In particular, a following voiceless consonant is associated with a higher F2 value than a voiced one, and this is the largest effect in the model. Notice that in Figure 38 above, for all sub-groups of Seattle speakers, F2 values for /aɪT/ are more than 0.60 units higher than for /aɪD/, indicating that they are considerably more front in the vowel space from onset. The pre-voiceless environment is also associated with a significantly different F2 slope and parabolic shape for /aɪ/ than the pre-voiced environment. For /aɪT/ tokens, the slope of F2 is significantly steeper (more positive) than for /aɪD/. The parabolic shape is taller and skinnier for /aɪT/ as compared to /aɪD/. Normalized Duration plays an additional role in predicting F2 values for /aɪ/. Compared to /aɪD/, longer /aɪT/ tokens are associated with a different parabolic shape. Preceding phone also acts as a significant predictor of F2 values for /aɪ/, though this effect is much smaller than the effect of following voicing. Compared to /b/as a preceding phone, both /g/ and /n/ are associated with significantly higher F2 values, indicating more fronting of /aɪ/.

Neither Age Group nor Sex reach significance as main predictors, but they are participants in several significant interactions. There is a two-way interaction of Voicing and Age Group. For Group 2 speakers, the pre-voiceless environment is associated with higher F2 values for /aɪT/ relative to /aɪD/. This suggests more differentiation among Group 2 speakers, but there are additional differences between men and women to consider. The four-way interaction of Voicing, Position.ord, Age Group, and Sex, on the other hand, reveals that the effect of Voicing, slope, and Age Group is different for men than for women. The F2 trajectory for /aɪT/ is less steep (less positive relative to /aɪD) for Group 2 men than for Group 1 men, but the opposite is true for women. Overall, men do show significant differences in F2 slope for /aɪT/ relative to women. For men, the slope of F2 for /aɪT/ (as compared to /aɪD/) is steeper than for women, but the effect size is relatively small. At first glance this may seem to indicate greater differentiation for men between /aɪT/ and /aɪD/, but it is more likely the result of less raising phonologized raising of /aɪT/ at onset than for women. Men have a steeper slope for /aɪT/ and more co-articulatory raising occurs over the segment's duration, whereas women have a slightly less steep slope because their tokens have a higher F2 value at onset. Finally, a small but significant effect was identified for speakers' responses to the sociocultural survey question about the importance of shopping from their home city. Having a higher rating for the importance of local shopping was associated with higher F2 values, indicating more fronting.

4.7.6 Summary of /aɪ/ raising in Seattle

Seattle speakers show significant differences on both the height and front/back dimensions for /aɪ/ tokens before voiceless consonants as compared to voiced ones. For all Age and Sex sub-groups of speakers, /aɪT/ tokens are significantly higher and more front at onset than /aɪD/ tokens, suggesting that Seattle speakers participate to some extent in phonologized /aɪ/ raising in pre-voiceless contexts. There are smaller, but significant differences with respect to Age Group and Sex. In general, women show more fronting and raising of /aɪT/ tokens at onset than men, and less change dramatic change in raising or fronting over the course of the segment than men. Likewise, Group 2 speakers generally show more differentiation of their /aɪT/ and /aɪD/ tokens than Group 1 ones. Looking more closely, though, men and women pattern differently within their respective Age Groups. Different types of social variation for F1 and F2 suggest that speakers or sub-groups of speakers may use different articulatory strategies to realize /aɪT/ "raising." For instance, Group 1 females show less F1 differentiation of their /aɪT/ and /aɪD/ tokens than other sub-groups, but they show more differentiation on the F2 dimension than other sub-groups, suggesting that they differentiate /aɪT/ and /aɪD/ more on the basis of fronting rather than raising. Across the population, both F1 and F2 values for /aɪ/ are significantly affected by the pre-voiceless environment, but sub-groups may vary in the degree to which allophonic contrasts manifest on F1 or F2. This type of variation will be discussed in more detail in Chapter 6.

4.7.7 Comparing /aɪ/ raising across Seattle and Vancouver Speakers

When modeling F1 values for /aɪ/ across Seattle and Vancouver a significant four-way interaction was identified for City, Voicing, Age Group and Sex and a separate four-way interaction of City, Voicing, Position.ord, and normalized Duration was also identified. Both four-way interactions were retained in the final model. Information about the preceding phone significantly improved the model, but no single preceding phone reached significance as a predictor of F1 values, therefore the term was not included in the final model. Post-hoc testing revealed no significant improvements to the model with the inclusion of speakers' sociocultural responses.

```
F1.lmerA <- lmer(normF1 ~ City*Voicing*normdurms*Position.ord + City*Voicing*as.factor(AgeGroup)*Sex + (1 + Position.ord | Name) + (1|Word), data=BOTHaI)
```

	Est.	Std. Er.	t value	p
(Intercept)	0.355	0.05	7.60	< 1e-04
CityVAN	0.184	0.05	3.55	0.000
Voicingvoiceless	-0.547	0.05	-11.47	< 1e-04
normdurms	0.018	0.01	2.65	0.008
Position.ord.L	-1.205	0.04	-31.28	< 1e-04
Position.ord.Q	-0.334	0.03	-11.07	< 1e-04
Position.ord.C	0.139	0.02	9.03	< 1e-04
Position.ord^4	0.031	0.01	2.35	0.019
CityVAN:Voicingvoiceless	-0.397	0.03	-15.63	< 1e-04
CityVAN:normdurms	-0.089	0.01	-11.15	< 1e-04
Voicingvoiceless:normdurms	-0.040	0.01	-2.96	0.003
CityVAN:Position.ord.L	0.282	0.06	5.08	< 1e-04
CityVAN:Position.ord.Q	-0.129	0.04	-2.96	0.003
CityVAN:Position.ord.C	-0.077	0.02	-3.38	0.001
Voicingvoiceless:Position.ord.L	-0.481	0.02	-20.16	< 1e-04
Voicingvoiceless:Position.ord.Q	0.332	0.02	13.95	< 1e-04
Voicingvoiceless:Position.ord.C	0.145	0.02	6.09	< 1e-04
Voicingvoiceless:Position.ord^4	-0.058	0.02	-2.43	0.015
normdurms:Position.ord.L	-0.102	0.01	-8.70	< 1e-04
normdurms:Position.ord.Q	-0.132	0.01	-11.27	< 1e-04
normdurms:Position.ord.C	0.021	0.01	1.78	0.075
normdurms:Position.ord^4	0.016	0.01	1.41	0.160
Voicingvoiceless:as.factor(AgeGroup)2	-0.104	0.02	-5.00	< 1e-04
Voicingvoiceless:SexM	-0.070	0.02	-3.19	0.001
CityVAN:Voicingvoiceless:normdurms	0.096	0.02	5.06	< 1e-04
CityVAN:Voicingvoiceless:Position.ord.L	-0.142	0.04	-3.83	0.000
CityVAN:Voicingvoiceless:Position.ord.Q	-0.074	0.04	-2.00	0.045
CityVAN:Voicingvoiceless:Position.ord.C	0.082	0.04	2.22	0.026
CityVAN:normdurms:Position.ord.Q	0.046	0.02	2.63	0.008
Voicingvoiceless:normdurms:Position.ord.C	0.126	0.03	4.72	< 1e-04
Voicingvoiceless:normdurms:Position.ord^4	-0.063	0.03	-2.37	0.018
CityVAN:Voicingvoiceless:as.factor(AgeGroup)2	0.246	0.03	8.09	< 1e-04
CityVAN:Voicingvoiceless:SexM	0.184	0.03	5.90	< 1e-04
Voicingvoiceless:as.factor(AgeGroup)2:SexM	0.150	0.03	4.92	< 1e-04
CityVAN:Voicingvoiceless:normdurms:Position.ord.L	0.101	0.04	2.42	0.015
CityVAN:Voicingvoiceless:normdurms:Position.ord.Q	-0.190	0.04	-4.58	< 1e-04
CityVAN:Voicingvoiceless:as.factor(AgeGroup)2:Sex M	-0.254	0.04	-5.75	< 1e-04

Table 51. Statistically significant fixed effects for linear mixed-effects regression model of F1 for /aɪT/ ~ /aɪD/ across both Seattle and Vancouver; full model output available in Appendix C

Voicing has a large independent effect, with F1 values across both cities being substantially lower in the pre-voiceless /aɪ/ tokens than in the pre-voiced ones. Voicing also interacts with Position.ord to reveal significant differences in the slope, parabolic and cubic shapes of F1 trajectories for /aɪT/ and / /aɪD/. F1 before /aɪT/ has a steeper (more negative) slope than before /aɪD/, and this is one of the largest effects in the model. There are additional significant effects related to duration. The slope of /aɪ/ tokens tends to be more negative with an increase in duration, but this works differently for Vancouver speakers' realization of /aɪT/. With increased duration for /aɪ/ in the pre-voiceless environment, Vancouver speakers do not exhibit the same increase in negative slope, due to the lower F1 values they exhibit at onset. These differences also relate significantly to the parabolic shape of the F1 trajectories. Pre-voiceless /aɪ/ tokens across the sample dislay a wider parabolic form, but this is less so for Vancouver speakers, as a result of their lower F1 values at onset.

City is a significant independent predictor of F1 values for tokens of /aɪ/. City also participates in a significant interaction with Voicing, identifying differences between Seattle and Vancouver with respect to /aɪT/ raising. Compared to Seattle speakers, Vancouver show significantly lower F1 values for /aɪT/ relative to /aɪD/. While Seattle speakers also have lower F1 values for /aɪT/ than /aɪD/, the difference is greater for Vancouver speakers. This is one of the largest effects in the model after differences in the slope of F1 trajectories. The significant interaction of City, Voicing, and Position.ord also reveals that Vancouver speakers have a slope that is steeper (more negative) for /aɪT/ (relative to /aɪD/) than Seattle speakers. City also interacts significantly with Voicing and Age Group, as well as with Voicing and Sex. While Vancouver speakers generally have lower F1 values for the pre-voiceless environment than Seattle speakers, Group 2 Vancouver speakers' are not as low in comparison to Seattle speakers. This suggests that the difference between the allophonic realizations of /aɪT/ and /aɪD/ is generally greater across the cities for Group 1 speakers. Vancouver men participate in the same type of interaction: Vancouver men have F1 values for pre-voiceless /aɪT/ (relative to /aɪD/) that differ less from Seattle speakers' F1 values than women. Finally, a significant four-way interaction of City, Voicing, Age Group and Sex reveals a further distinction between the Age Groups and Sexes. The interaction of City, Voicing and Age Group is not the same for men as it is for women. While Group 2 Vancouver speakers generally show less differentiation of the allophones and more proximate values to Seattle speakers, Group 2 men show relatively more differentiation. This is related to the observation that it is not Vancouver men who are behaving differently than their same city counterparts, but Group 2 Seattle men who stand apart. Older Seattle men begin with much higher F1 values for /aɪT/ relative to /aɪD/ at onset and seem to differentiate these less than the other speaker sub-groups in Seattle, causing a significant and complex difference to emerge in the comparison of sub-groups across cities. The effect size of this effect is not the largest in the model, but it is substantial.

F2

The F2 model comparing /aɪ/ allophones across Seattle and Vancouver considered a four-way interaction of Voicing, City, Age Group and Sex and a separate four-way interaction of City, Voicing, Position.ord, and normalized Duration. No significant interaction was identified for Voicing, City, Age Group, and Sex, and the representation of City, Voicing, and Sex separately from City, Voicing, and Age Group did not result in a less predictive model as compared to the original four-way interaction. Because Sex participated in no significant three-way interaction with City, the model was further reduced to represent only the significant interaction of Voicing and Sex. For the interaction of City, Voicing, Position.ord, and normalized Duration, a significant four-way interaction was identified as were several significant three-way interactions involving these terms, and all attempts to unpack these interactions resulted in significantly less predictive models. The addition of information about Preceding Phone also significantly improved the model. Post-hoc revealed no significant improvement to the model with the additional information of speakers' sociocultural survey responses. The final model is:

```
F2.lmerG <- lmer(normF2 ~ City*Voicing*Position.ord*normdurms + Voicing*Sex +
Voicing*City*as.factor(AgeGroup) + PrecedingPhone + (1 + Position.ord | Name) +
(1|Word), data=BOTHaI)
```

	Est.	Std. Er.	t value	p
(Intercept)	-0.425	0.06	-7.31	< 1e-04
CityVAN	-0.126	0.05	-2.35	0.019
Voicingvoiceless	0.587	0.03	17.23	< 1e-04
Position.ord.L	0.756	0.05	16.12	< 1e-04
Position.ord.Q	-0.050	0.02	-2.03	0.042
Position.ord.C	-0.175	0.02	-9.60	< 1e-04
normdurms	-0.019	0.01	-2.33	0.020
SexM	-0.077	0.04	-2.17	0.030
PrecedingPhoned	0.197	0.08	2.36	0.018
PrecedingPhoneg	0.262	0.11	2.44	0.015
PrecedingPhoneh	0.179	0.06	3.05	0.002
PrecedingPhonen	0.277	0.07	3.94	< 1e-04
PrecedingPhonew	-0.216	0.11	-1.99	0.047
CityVAN:Voicingvoiceless	0.178	0.02	7.11	< 1e-04
CityVAN:Position.ord.Q	0.100	0.04	2.77	0.006
Voicingvoiceless:Position.ord.L	0.169	0.03	5.71	< 1e-04
Voicingvoiceless:Position.ord.Q	-0.167	0.03	-5.65	< 1e-04
Position.ord.L:normdurms	0.171	0.01	11.82	< 1e-04
Position.ord.Q:normdurms	0.122	0.01	8.41	< 1e-04
Voicingvoiceless:SexM	-0.060	0.01	-4.41	< 1e-04
Voicingvoiceless:as.factor(AgeGroup)2	0.072	0.02	3.83	0.000
CityVAN:Voicingvoiceless:Position.ord.L	0.109	0.05	2.35	0.019
CityVAN:Voicingvoiceless:normdurms	-0.062	0.02	-2.61	0.009
CityVAN:Position.ord.Q:normdurms	-0.044	0.02	-2.02	0.043
Voicingvoiceless:Position.ord.Q:normdurms	-0.170	0.03	-5.10	< 1e-04
CityVAN:Voicingvoiceless:as.factor(AgeGroup)2	-0.146	0.03	-5.36	< 1e-04
CityVAN:Voicingvoiceless:Position.ord.Q:normdurms	0.103	0.05	2.00	0.045

Table 52. Statistically significant fixed effects for linear mixed-effects regression model of F2 for /aɪT/ ~ /aɪD/ across both Seattle and Vancouver; full model output available in Appendix C

Voicing is a significant independent predictor of F2 values with /aɪT/ tokens having significantly and substantially higher F2 values than /aɪD/ tokens. This is the largest effect in the model. Across the sample, slope and parabolic shape of F2 are also different before a voiceless consonant than before a voiced one. Before a voiceless consonant, the F2 slope is steeper (more positive) than before a voiced one. The parabolic shape of F2 for /aɪT/ is significantly sharper (less wide) than for /aɪD/. Preceding Phone also significantly affects F2 values for /aɪ/. As compared to /b/, /d/, /g/, /n/, and /h/ are associated with higher F2 values. As a preceding phone, /w/ is associated with lower F2 values. In general, a longer duration for /aɪ/ tokens is associated with lower F2 values.

There is a significant interaction of Age Group and Voicing, which identifies that across both cities, Group 2 speakers have slightly higher F2 values for /aɪ/ in the pre-voiceless environment than Group 1 speakers. This suggests that, pooling all subjects from both cities, Group 2 speakers are differentiating /aɪT/ and /aɪD/ more than Group 1 speakers. On the other hand, a significant interaction of Sex and Voicing indicates that across the sample men have lower F2 values for /aɪT/ (relative to /aɪD/) than women, which suggests that they are engaging in less fronting of /aɪT/ than women. These trends must be examined further as interactions with City.

City does not have an independent effect on the F2 values of /aɪ/ across Seattle and Vancouver, but a significant interaction of City and Voicing illustrates that the two cities differ in terms of their F2 values in the pre-voiceless environment. Vancouver speakers' F2 values for /aɪT/ are higher than Seattle speakers', relative to /aɪD/. The effect size for this interaction is substantial. As compared to Seattle speakers, Vancouver speakers also have steeper (more positive) F2 slopes for /aɪT/. While Vancouver speakers generally have higher F2 values for the pre-voiceless environment than Seattle speakers, this is less so of Group 2 Vancouver speakers, as the negative co-efficient for the three-way interaction of City, Voicing and Age Group indicates. This three-way interaction distinguishes the patterns observed across Age Groups in the two cities. Group 1 speakers in Vancouver are differentiating /aɪT/ and /aɪD/ to a greater degree than Group 2 speakers, but this is not the case in Seattle.

4.7.8 Summary of /aɪ/ Raising in Seattle and Vancouver

Both Seattle and Vancouver speakers participate in raising and fronting of /aɪ/ before voiceless consonants, as demonstrated by significant differences affecting both F1 and F2 values for the allophonic environments in contrast. For speakers in both cities, these differences are observable at onset, indicated a phonologized process. Voicing also emerges as a significant predictor or both F1 and F2 values when the data from the cities are pooled. When the two cities are compared, Vancouver speakers tend to engage in a greater degree of differentiation of these allophonic environments than Seattle speakers. This tendency is born out by significant differences on both the height and front/back dimensions. The variation among sub-groups within and across cities is relatively small. In general, women in both cities tend to differentiate the allophonic environments to a greater extent than men. There may be different age-related trends at work across the two cities, as Group 1 Vancouver speakers tend to differentiate the allophonic environments more than Group 2 ones, while the opposite is true among Seattle speakers.

4.8 Summary of Results

The table below provides a simplistic summary of the allophonic analyses within each city (ignoring momentarily the question of variation between social sub-groups) and also summarizes the comparison of the two cities regarding the five dialect features under consideration. For the city-internal columns, a "*" indicates that significant differences were found for the allophonic environments (e.g. /æk/ versus /æg/) on the dimension specified (F1 or F2). For the comparison column, a "+" indicates that Vancouver speakers generally showed greater allophonic difference (greater participation in this allophonic distinction) than Seattle speakers. A "-" suggests the opposite; Vancouver speakers generally show participation in this allophonic process or a lesser degree of allophonic participation than Seattle speakers. A blank cell indicates that no significant difference was found.

	Seattle		**Vancouver**		**Comparison (VAN to SEA)**	
	F1	F2	F1	F2	F1	F2
/æg/ Raising	*	*	*	*	+	+
Pre-nasal /æ/ Raising	*	*	*	*	-	-
/æ/ Retraction Before Fricatives				*		+
/æ/ Retraction Before Laterals		*		*		+
Pre-vcls /aʊ/ Raising	*	*	*	*	+	+
Pre-vcls /aɪ/ Raising	*	*	*	*	+	+

Table 53. Summary of significant effects for Seattle and Vancouver for five dialectal features

While Seattle and Vancouver speakers can be said to participate in many of the same allophonic processes, there are significant differences in the extent to which the two cities participate. Vancouver speakers show quantitatively more raising of /æg/ than Seattle speakers, though they show less pre-nasal raising of /æ/ than Seattle speakers. Vancouver speakers also show more retraction than Seattle speakers. While Seattle speakers do show retraction of /æ/ before a lateral consonant, Vancouver speakers show significant retraction before both fricatives and laterals, as compared to stops. Despite significant differences between pre-voiceless and pre-voiced environments for Seattle speakers' realizations of the "Canadian Raising" diphthongs /aɪ/ and /aʊ/, Vancouver speakers do still show a greater degree of differentiation between the allophonic environments than Seattle speakers. There are additional differences, not captured by the table above, in the variation observed among age and sex sub-groups in each city. Finally, it is noteworthy that four out of five of the allophonic processes considered here affect both the F1 and F2 dimensions and entail significant differences of trajectory direction and shape. These are highly dynamic processes that must examined using dynamic methods. Chapter 6 offers a more developed discussion of these issues.

Chapter 5

5 SOCIOCULTURAL SURVEY RESULTS

This section presents a closer look at the sociocultural identities of the participants in the production study and discusses their perceptions of speech and culture in Seattle and Vancouver and the broader Pacific Northwest. The full interview protocol is available in Appendix B. These questions are meant to better acquaint the researcher and reader with the social and cultural identities of the respondents from both cities with the goal of better understanding their acoustic realities in the social context in which they occur. This protocol extends beyond a basic questionnaire about macro-sociological categories. Instead, it asks speakers to articulate their stances, attitudes and beliefs toward their own city, region and country.

5.1 Methods

All sociolinguistic interviews were conducted orally by the researcher, and all interviews were conducted concurrently with the completion of the production task. These sociolinguistic questions were interspersed with the repetitions of the word list reading task such that there were three stretches of sociocultural identity questions of about six to eight minutes, depending on the respondent. These were transcribed and stored in separate text files for each speaker. The numeric responses to the Likert scale questions were stored in a Microsoft Excel spreadsheet along with basic demographic information for each respondent. Basic descriptive statistics such as means and standard deviations were computed for these questions using R. Note that these descriptive means and standard deviations are presented in the city descriptions as non-normalized raw means. This is meant to allow for a more reader-friendly interpretation of respondents' ratings, though participants ratings were normalized prior to the regression as described below. Emergent coding was used to analyze the qualitative responses by considering each free-response question one at a time. For each city, a separate text file was created to contain all speaker responses for each question. Common themes in participants' responses are presented in this question with quotes to illustrate. After conducting an independent qualitative analysis for each city, the results for both quantitative and qualitative responses were compared. Participant responses to the one to seven Likert scale questions were normalized as z-scores. Statistically significant predictors were identified separately for each question using linear regression models. The results will be presented first for Seattle and then for Vancouver, followed by a comparison of the two, discussion and summary.

5.2 Results for Seattle

5.2.1 Demographics

The average participant in this study is a White, 25-year-old native of the Seattle area who identifies with a middle class background and has earned a 4-year college degree. Only two speakers in the current sample identified their ethnic identity as other than White or Caucasian. One speaker identified as Black and another as African American. In addition, the majority of participants defined their sexual orientation as straight or heterosexual. One participant defined his sexual orientation as gay; another defined hers as lesbian. Two male participants who were in romantic relationships with women defined their sexual identities as "pan-sexual" and "queer," respectively. Ten of the twenty participants identified as male; ten identified as female. Sixteen out of twenty participants had completed a Bachelor's degree or were currently making progress towards one. One speaker had not completed high school, while two speakers had completely Associate's degrees. Four participants had completed Master's degrees. Among Seattle participants, five were full-time students, and two others had graduated within the past six months. Student status also patterned with age; all five full-time students belonged to the Group 1 age group (age 18 to 25). In Group 2, respondents were employed in a variety of fields including in grocery retail, teaching English as a Second Language, in non-profit administration, as artist's assistants and even stilt-walkers.

5.2.2 Commentary on social class

The majority of respondents (15 out of 20) described their upbringing as middle class, with six of these 15 middle class respondents using the term "upper middle class" to describe their background. Four respondents identified a working class background, and no speakers identified an upper class upbringing. Many of the respondents identifying as "middle class" made commentaries about not having had to worry considerably about their financial situation while growing up. They identified with being middle class because they did not perceive that their family had faced the financial struggles or instability they felt characterized the working class.

> *I figure because we never worried too much about money, but we also didn't spend it a lot, so...* SSM11

Some also related a middle-class standing to their parent's level of education and type of employment, listing more "white collar jobs" (lawyers, teachers, computer engineers were all mentioned) as related to class standing.

> *Both of my parents my mom was a lawyer, my dad worked in the education department, they both had a Master's degree.* SSF01

A few respondents also mentioned the effects of their parent's divorce on their class and financial situation:

> *Both my parents were lawyers, although my mother stopped practicing in 2000 and hasn't practiced since, so uh my parents are divorced and my dad had more money than my mom.* SSM03

Others referenced the values of their social networks being largely middle class:

> *I know a lot of like middle class people, especially as far as like educational background and pop culture and things like that, so...* SSM15

For the four respondents who identified with a more working class upbringing, most mentioned their parent's lack of educational attainment and participation in more typically "blue-collar" industries.

> *Working [class] for sure. My father was in construction, and my mother, I guess she started working in the grocery business when I was in middle school, so I guess, it wasn't a middle class lifestyle at all.* SSM13

> *Both my parents they did not graduate college, my dad didn't graduate high school, I mean they were lucky in the sense that they got jobs, my mom worked for she worked as a 9-1-1 dispatcher, my dad got a job with the logging company in Aberdeen...* SSM14

For respondents who grew up with what they considered a middle class lifestyle, one of the most common responses was uncertainty about how to rate their current socioeconomic status in comparison to that of their parents or their childhood. Many informants commented that they felt they struggled considerably more than their parents had, that they had encountered difficulty earning a living middle class wage, despite a middle class upbringing and an education. While this challenge of becoming established may be related in part to the age of the participants, it is likely that these experiences are also part of a larger trend by which it is increasingly difficult to attain a middle class lifestyle. Despite having undergraduate or advanced degrees, many informants reported struggling with their income or assets:

> *My husband and I both have a consistent job. I would say we're probably lower middle. Upper working to working? Yeah… We've both had to bounce around quite a bit with work, I feel like we're finally getting a little more stable, but… um, being younger, I feel like younger working professionals, no matter what the degree background is finding consistent work has been a big struggle.* SSF15

> *I don't know, I wanna say working class cause I'm definitely not anywhere near, you know, I rent a studio apartment and have a bunch of student loan debt and don't really have… I have a '98 Ford Ranger. I mean I guess at least I have a car? I don't know. Upper working class, I guess is what I would say.* SSM14

In some cases, participants felt confused by how to define their socioeconomic or class status. While they were not employed in what are typically considered to be "blue collar" industries, they felt their earnings placed them in a lower socioeconomic class.

> *I don't know, I'm poor, I guess, I don't make a lot of money, I don't spend a lot of money. I mean I work for a non-profit arts organization so I don't know, I mean working class seems like I should be like a plumber or like working in a factory. I don't make a great deal of money. I guess working class, the lowest of those options. I'm downwardly mobile is how I like to say it.* SSM03

These perceptions and observations suggest the need to redefine conceptualizations of class and cultural background. Generally speaking, most of the participants in this study felt that they had experienced a middle class background growing up, but while continuing to identify with the cultural values of the middle class, they perceived themselves as struggling more and have great financial instability than their parents.

5.2.3 Neighborhood

While speakers in this study were not recruited to be a representative sample of Seattle neighborhoods, they do represent a diverse set of neighborhoods within the city and

Puget Sound Metro area. Most of the participants in the study described having lived in at least two neighborhoods in the Puget Sound Metro area, either as children growing up or as adults. As a group, the respondents represent a varied set of Seattle neighborhoods ranging from Capitol Hill, the University District, the Central District, Wallingford, Fremont, Ballard, Green Lake, Beacon Hill, and West Seattle. A minority of speakers also identified with a nearby suburb (such as Renton, Shoreline, Medina, Kent, Snohomish, Bothell, and Lake Stevens) after having grown up there or lived there for some time. These neighborhoods vary considerably in their socioeconomic and ethnic compositions. Most respondents described their neighborhoods as urban and lively.

> *Tons of different types of people, lots of different cultures that just kind of merge into this neighborhood, it's got two or three colleges I think that are in the neighborhood, it's got a huge difference in class, yeah, there's a big class range, lots of poverty, yet lots of wealthy people...* SSM14 of Capitol Hill

They made reference to ethnic, socioeconomic, and linguistic diversity within the neighborhood and frequently drew contrasts between family-oriented residents and younger single residents.

> *I like being in a place where I do not feel like my race has some kind of like direct correlation to how I live there and like I do not feel like either a majority or a minority in my neighborhood, and to be able to get on a bus and everyone is speaking Vietnamese or a different language besides English is like this is like what I wanna be and you know the food is like bomb dot com, I love it, it's fantastic.* SSM05 of Beacon Hill

> *I live in Fremont, it's urban, close to the heart of the city, not densely crowded, but it's a crowded neighborhood, mostly middle to upper class young professionals I would say. Um, a few families...* SSM11

A few described more residential urban neighborhoods or a suburban feel.

> *Uh, it's Green Lake, quiet, small homes, couple blocks from the lake so… it's lovely.* SSF13

The present study does not seek to compare the social identities or speech realities of speakers from the different neighborhoods in Seattle, though it recognizes an opportunity for future research in this area.

5.2.4 National identity and pride

As a group, Seattle respondents ranked their national pride at a 4.2 (sd=.54). Two respondents ranked their national pride at a 7 and a 6 respectively, but the majority of respondents responded with ratings of 5 or less. Most respondents felt that they did not wish to be very forward with their national identity, especially while traveling abroad:

> *I mean I'm an American citizen, but when people ask me to describe myself that's not something I would, that would not come up unless questioned I guess.* SSM03

Many respondents explicitly referenced a lack of pride in their national identity, and one even described a desire to be oppositional to patriotism. A few respondents tried to identify the qualities of American identity and included descriptions of an ethnocentric attitude, materialism, wastefulness, opinionated and argumentative personalities, patriotism, and derivative cuisine. One respondent observed a trend toward a national identity defined by tragedy in the Post-9/11 U.S.:

> *...I think it's also one of those things that like as of late our national identity, seems to be completely sort of conceptualized in the focus of tragedy Post 9/11, that whole concept of like we're like banding together because we have soldiers fighting in a war. We're banding together cause we got attacked, none of it... we do not have like a whole lot of distinction as a nation, in any kind of cultural happy concepts...* SSM05

Several Seattle respondents made specific reference to a greater sense of regional rather than national identity:

> *I mean I definitely feel part of the Pacific Northwest versus America as a whole, I mean I guess there's probably some little bit aspect [sic.] in there, but not much.*

SSM02

I feel like sort of just just [sic.] like the cultural and ecological milieu of this area has really affected the way I position myself in this world more than, I don't know, this concept of an abstract national border or something. SSM15

5.2.5 Municipal and regional pride

Twenty out of 20 Seattle informants said that they identified as Pacific Northwesterners. For nearly all of the informants, the sense of regional identity and municipal pride exceeded national identity and pride. (Only two of the 20 participants rated national pride higher than municipal pride.) Instead, many made explicit comments about the more influential nature of their more immediate regional environment on their identity, values and preferences.

Born and raised here, I identify with that a lot more than a larger grouping like American or Western. SSM03

When asked how proud they were of their city, Seattle speakers responded with a raw mean of 5.8 (SD= .86). On the same scale they averaged a 6.2 (SD= .71) in terms of how much they liked their city. Interestingly, despite expressing largely positive feelings about their home city, they were also not entirely adverse to moving. As a group, the interest in moving reach a 4.6 on the same scale of one to seven, with seven being "very interested." There was also more variation in responses with respect to interest in moving (SD= 2.2). Some respondents had very little interest in moving, while others commented that they would be interested in moving to live away for some time, but that they thought they would want to settle back home in the Pacific Northwest. As they expanded on the idea of defining Pacific Northwest identity, Seattle informants touched on regional goals of sustainability, cultural diversity, climate and ecology, a like-minded liberalness and passive or laid-back persona of the region's inhabitants.

> *I think the culture is defined by nature, um which, or geography I guess. And I think that people who are natives here feel very connected to their geography, and people that are drawn to this region are drawn to it because of the ocean or mountains or both and I think that's kind of the common bond.* SSF05

> *...I identify very strongly with the ecosystem here, I go hiking and camping a lot and there's a very distinct ecosystem here that you don't really find anywhere else in the world and I love being out in and most especially because the smell of the forests here make me feel like I am at home. SSF12*

> *...I think maybe one of the biggest signs would be how with like green marketing is a huge thing because they know that the consumers here feel better about themselves if they're gonna go for something that's like quote unquote green.* SSF03

Informants described the city and its inhabitants as "calm," "polite," "laid-back" and "passive:"

> *I'm very laid back, and kind of have more of a passive personality, which I think is kind of more common for Pacific Northwest people, and am fairly polite, and just amicable, I guess.* SSF13

Most informants had a strong sense of municipal pride with 11 participants rating their pride at six or higher on a scale of one to seven. They cited similar qualities at the city level as they did while defining the region's identity including the natural beauty of the city's geography, the access and protection it provided for nature, and its progressive, forward-thinking mentality and policy decisions.

> *I like being like 'I was here before like all these Californians came up and they destroyed everything.' SSM15*

> *I think we're super progressive especially compared to many many other places in the country just with like legalizing marijuana and marriage equality and just the politics of Seattle and then... just like protecting our natural resources and like parks and stuff.* SSF13

For a comparison of the normalized national and municipal pride results for Seattle and Vancouver, see Figure 1 in section 5.3.

5.2.6 Investment in municipal enterprises and networks

Participants were asked a series of questions to better understand their commitment to local purchasing, interest in local events and affiliations with cultural groups of their home city. These questions inquired about the important of purchasing from municipally-based businesses versus the Pacific Northwest region at large. They also addressed the frequency with which Seattle residents read local publications, participated in clubs or extra-curricular activities, and to what extent they followed local sports teams.

Purchasing

In terms of purchasing goods from locally-owned businesses, participants rated their frequency at a 5.0 on a scale of one to seven, with seven being "very frequently" (SD=1.7). While many participants inquired about the definitions of "local," they were prompted to expand on what counted in their own definitions and what did not. For example, most people reasoned similarly that coffee roasted in Seattle and purchased from a locally-owned café counted as local despite the fact that the beans were grown in another region. Likewise, it was acknowledged that local manufacturers sell their products at even larger-scale supermarkets and shops.

Well, I try to get groceries that, it'll tend to be that I'm in a suburb, they have like Fred Meyer's like so it'll be from a big place, but I'll try to specifically buy products that are from close by. SSF03

Among the products that they preferred to buy from local establishments, foods and beverages topped the list. From produce to prepared foods to coffee and craft beer, Seattle respondents were invested in the local food scene.

I love eating at local restaurants, especially if they're using local ingredients, and then I try and do gifts at local boutiques. SSF13

Coffee (except it's imported beans roasted locally), local cheese, local foodstuffs, produce... SSF14

When asked how important it was to them to buy from Seattle-based businesses, they rated the importance of shopping locally even higher than the frequency with which they did it: 5.5 out of seven (SD=1.3). While the majority of participants found local shopping to be moderately to very important, they cited some constraining factors such as higher costs, convenience, and availability of products.

I mean I would say in the middle, like four or five, I mean, if I'm honest, I would say I like the ideal, but if I'm honest with myself, I'm going to Fred Meyer and other places a lot, so I only give myself a half and half, even though I might say I'd like to be more, I'm not. I'll be honest. SSF15

Furthermore, most participants articulated a distinction (not prescribed by the original question) between Seattle-based business that had become chains or were very large-scale (such as Costco, REI, Starbucks, or Amazon) and smaller, independently-owned businesses:

It's relatively important, as far as like Seattle-based, I think it's mostly just small business in general. I'd rather go to a neighborhood bar that's been in the same place for fifty years that has the same owners than go to like a McCormick and Schmick's or one of those places like that. SSM13

How often shop from PNW

When asked how often they purchased goods or services from the Pacific Northwest outside of just Seattle, participants estimated that they did this slightly less often than they purchased goods from Seattle specifically at 4.1 out of seven (SD=1.4). Participants varied on how they interpreted this question. Some described their frequency of travel to Pacific Northwest locations outside of Seattle and their purchasing habits while traveling regionally; others considered the prevalence of products grown or produced in the broader Pacific Northwest and offered for sale in Seattle. Again, participants were asked to elaborate on their choices and impressions.

> *I said less for Seattle because I know that for the urban area it's not as feasible to get like the same foods and stuff like that.* SSF03

> *Um, it's probably closer to a four or five. Just because a lot of produce and stuff comes from Eastern Washington, at least in the summer.* SSM04

As a group, respondents rated the importance they felt for purchasing from Pacific Northwest-based businesses similarly to the importance they felt for purchasing from Seattle-specific businesses: 5.3 out of seven (SD= 1.4), as compared to a 5.5 for Seattle. Five respondents felt shopping from Seattle-specific businesses was more important, six felt that shopping from the Pacific Northwest broadly was more importantly, and nine felt that they were equally important.

For a comparison of the normalized local purchasing results for Seattle and Vancouver, see Figure 2 in section 5.3.

Local Sports

When asked how closely they followed sports in Seattle, participants returned an average of 4.2 out of seven where seven is the most frequent (SD=1.9). Nearly all of the respondents mentioned professional football (The Seahawks) as a major sport among their families, friends, or Seattle sports fans. In some cases, they admitted not really wanting to follow football, but feeling that it was unavoidable.

> *It's hard to avoid hearing about the Seahawks, but I'm personally more interested in baseball so I kind of choose to follow that.* SSF11

> *Well, it's kind of hard not to follow football when it's going on, just because everybody talks about it, so I usually know who is winning and who is not. Other than that, I don't really care about the outcomes.* SSM02

They occasionally mentioned baseball and soccer. A few participants in the Group 2 bracket mourned the loss of Seattle's professional basketball team.

> *Well, I was kind of into, I like basketball, and that's the problem right there, I like the WNBA, and then I was into the WNBA, but it wasn't enough, like I would have been into the Sonics, I was into the Sonics when I was a little kid, but other than that, no. I'm not a big Sounders, or Seahawks, or Mariners fan.* SSM05

Overall, the question about investment in Seattle sports teams produced considerable variation. Respondents spanned the range of possible replies from one to seven. The distribution of responses was slightly more concentrated toward the higher end of the scale with 12 of 20 participants rating their interest at four or higher on the scale of one to seven.

Local Publications

Participants were asked how frequently they read local publications such as magazines, newspapers or event guides in Seattle. Their mean response was 4.4 out seven (SD=1.9). Twelve out of 20 participants said they read the Seattle Times regularly, and ten out of 20 participants said they read the Stranger regularly. The Stranger is an alternative weekly newspaper and event guide targeting a younger, urban population. A few participants also mentioned reading local blogs or smaller-scale newspapers and publications such as the Kent Reporter or the Alliance for Pioneer Square, and the Capitol Hill blog.

Membership in Clubs or Groups

The majority of participants (12 of 20) reported that they had no official membership in any clubs or groups. Among those who mentioned participating in clubs or groups, the responses were largely idiosyncratic and related to personal preferences and interests. For instance, one participant was part of the Seattle Nantes Sister City Association; another belonged to the Auburn Free Thought Society while yet another participated peripherally in Divest UW.

> *I'm a member of the Fremont Arts Council, the Center for Wooden Boats, they have a sea shanty night, it's great, and the Friends of Yesler Swamp which is an environmental restoration group.* SSF12

Most respondents replied that they were not part of any particular clubs or groups in Seattle. A few explained that they were technically considered to be members of a group, but did not feel that they had been very participatory members.

> *... technically I'm part of the Black Student Union and Sisterhood, although I don't go to them quite as often, I'll go like once a year or something.* SSF01

For a comparison of the normalized municipal investment results for Seattle and Vancouver, see Figure 3 in section 5.3.

5.2.7 City comparisons

Participants were asked to rate the similarity of three different pairs of cities: Seattle and Vancouver, Vancouver and Toronto, and Portland and Seattle. Overall, Portland and Seattle were ranked as being the most similar pair of cities with a mean rating of 5.5 on a seven-point scale. Vancouver and Seattle were rated as more similar than Vancouver and Toronto with the former rated at 4.9 out of seven (sd= .84), and the latter rated at 3.7 (sd=.85) out of seven. Participants remarked on considerable similarities shared by the three Pacific Northwest cities, and many impressionistically viewed Toronto as being dissimilar and "East Coast."

Seattle Vancouver Similarities

With respect to Seattle Vancouver similarities, informants identified obvious similarities in geography, ecology, and climate. They also noted relatively similar costs of living, while Vancouver was perceived as being even more expensive a place to live than Seattle. They also commented on the similar demographics and immigrant populations, but many also commented a more "cosmopolitan" or "international" impression they had of Vancouver. They highlighted what they perceived to be a numerically greater or more prominent inclusion of Asian and Southeast Asian immigrant groups in Vancouver as well as a tie to greater European feel in food and language.

> *We share this kind of Pacific Northwest kind of uh vibe, if you will, and then I forgot the Separatist movement, is it called Cascadia? You know this kind of weird like weird I don't even know enough about it to even quote it, but you know that would be something that would happen here. Like there is kind of like a sister city kind of vibe to how we interact on like the Pacific Northwest and that's like you know inclusive with um B.C.* SSM05

> *...they're both big port cities on the Salish sea, and they both have Salish coastal cultures so I think to me the biggest thing that unites them is the fact that they're*

really part of the same not single cultural, but big cultural group and that you see a lot of evidence of that history in both towns. Of course, they both have very similar modern economies, tech industry with an industrial background. SSF12

I haven't lived in Vancouver, but the minorities are more prevalent in daily life and maybe that is an indicator of the inclusiveness, multi-cultural inclusiveness there. SSM11

Toronto Vancouver Similarity

Many respondents were hesitant to compare Toronto and Vancouver as they had never visited Toronto and were largely unfamiliar with it.

Is Toronto on the West Coast side or the East Coast side? SSF01

When asked to respond based on their impressions, most speakers reasoned that Vancouver and Toronto would have less in common than Vancouver and Seattle, giving a mean ranking of 3.7 out of seven (SD=.85). A few respondents commented on the similarity of Vancouver and Toronto as the largest, most urban centers in Canada, but most also identified the likelihood of different cultures in the two cities based on East coast and West coast trends.

Seattle Portland Similarity

Respondents generally rated Seattle and Portland as more similar than Seattle and Vancouver, but they were also slightly more varied in these responses. Many mentioned a strong rivalry that they perceived between Portland and Seattle. In several cases, they gave testimonials of the cities similarities only begrudgingly with phrases like *"We're kinda similar, but I don't like to say we're similar..."* SSF01.

I think we pretend that we're very different, but I think we're really just the same city. Just like what people do for fun, like outdoors stuff, and they're like really big on like being green, too, so are we. SSM04

Among the similarities they mentioned were similar trends of environmental conscientiousness, and "green" consumer trends, as well as weather.

> *There's almost like a Seattle Portland rivalry kind of thing, but at the same time, we're both Pacific Northwest cities, we're both kind of wacky, and we're pretty diverse as far as who lives there, so we're pretty similar, but we don't want to admit it.* SSF02

Respondents also identified differences including the perception that while Portland and Seattle were both progressive and quirky cities, Portland was even more extreme in embracing anti-mainstream trends than Seattle:

> *Every time I go down there it's just full of hipsters and people who think vaccines give you autism and all that. People who wear hats. There's a lot of Seattle Portland rivalry. Seattle's better.* SSM03

> *Culturally, you end up with a lot more hippies a lot more anarchists, a lot more extremely liberal people. Seattle tends to be a little more business-like.* SSM01

Respondents also perceived some important differences in terms of the cities' priority economic sectors. Portland was viewed as having a stronger agricultural presence than Seattle. Seattle was described as having more tech-related business and a generally bigger business culture than Portland. Some respondents also viewed Portland as being less ethnically diverse than Seattle.

> *I think Portland has a lot more influence of like the Willamette Valley continuum of you know agriculture and agricultural industry and stuff than Seattle does. Seattle is much more of an extracted industries sort of town.* SSM15

> *Because they share a Pacific Northwest identity which of course influences a lot and they do both have tech industries, but um from my experiences in both cities, Seattle is much more industrial, Portland is much more agricultural, and there were some fundamental decisions that both cities regarding cultural diversity back in the eighteen hundreds that still shape both town today.* SSF12

For a comparison of the normalized municipal investment results for Seattle and Vancouver, see Figure 4 in section 5.3.

5.2.8 Impressions of people from Vancouver

Participants were asked to offer their impressions of people from Vancouver and to comment on any traits they felt characterized the city's inhabitants. Their impressions were favorable and positive. Only one respondent offered any negative description of Vancouverites stating that Vancouverites don't know how to drive. Seattle respondents generally perceive Vancouver inhabitants to be friendly and kind.

> *Very friendly, extremely friendly, the people that I've met in Vancouver and from Vancouver are very, Canada in general, but in Vancouver and all parts around there, friendly, honest.* SSM13

They also perceive Vancouverites to be more international or cosmopolitan than Seattlites:

> *They seem more cosmopolitan than Seattlites, and I asked them about that and they said that even though they are a smaller city, they are the third largest city in Canada, so they you know they're from the third largest city so they have some confidence and some style that I don't think we have yet.* SSF12

Others made reference to a greater sense of security and stability portrayed by Canadians as a result of what they perceived to be better policy and support from the government. In other words, they viewed Vancouverites (and Canadians, in general) as being less disenfranchised than Seattlites or U.S. citizens.

> *Um, I don't know why I keep thinking that they're warmer, but I keep thinking that. And also maybe there would be like more of a sense of like 'Canada is an alright place' than there would here where people are like 'Oh man, what's happening to this country!' and like freaking out about that because it seems like they're more stable and taken care of socially and governmentally.* SSF03

Some respondents either felt that they did not have enough information about Vancouverites to make observations about their personal attributes, or they found it difficult to articulate any major differences between Seattleites and Vancouverites.

> *I guess they're similar than to Seattle, I don't think I would like be able to pinpoint them as being overtly different than Seattleites.* SSF01

> *Um, they are, I don't know, pretty like-minded individuals like ourselves, I don't know, you know it's like another port city on the Pacific Coast so I think it kinda has the same kinda you know like vibe.* SSM05

Stereotypes of speech in Vancouver

Respondents were asked whether they would be able to identify a person as being from Vancouver if they overheard their speech. Most respondents were hesitant or uncertain about whether they would be able to accurately pinpoint a Vancouver talker and commented on the general similarities they observed between Vancouver speech and Seattle speech.

> *Because some people from Vancouver all really just sound like they're from the Northwest as I know it, but I wouldn't pick that out, but then sometimes you can hear like really subtle differences, like the classic 'about' and that kind of stuff.* SSF03

Four of the 20 respondents felt that they would be able to identify whether a talker was Canadian, but that they could not differentiate a talker as being from one particular city in Canada.

> *I guess I would know maybe they were from Canada, like if they were Canadian, I would probably know they were Canadian.* SSF04

> *Some people I've noticed in Vancouver, don't have an accent just like people in the Northwest, and others have a Canadian accent, and that I think might be*

> *prevalent across all of Canada, so they might be from Toronto, they might be from somewhere else in B.C. or maybe Alberta, I don't know.* SM11

One participant also mentioned a difference between a perceived rural Canadian accent and an urban one:

> *Yeah, I mean, just like the general Canadian accent, just like Canadian raising, but I don't think Vancouver's that pronounced, not like it is in Midwestern rural parts of Canada.* SSM03

They were also asked to comment on whether they had ever noticed that people from Vancouver spoke differently than they did. Participants tended to cite stereotypes or isolated lexical items as cues that would allow them to identify the talker as "Canadian." Among these, the most commented on difference was the stereotypical raising of "ou" in words like *about* and *house* (mentioned by out 13 of 20), plus frequent use of *'Eh*?' (mentioned by 6 out of 20). One or two respondents also mentioned a difference in other vowels such as /oʊ/ as opposed to /ɑ/ in words like *progress* and *process* and /æ/ rather than /ɑ/ in words like *pasta* and *Mazda*. No respondents cited or described raising of /aj/ or retraction of /æ/ as cues of Canadian or Vancouver identity.

Participants were asked how likely they would be to visit Vancouver on a scale of one to seven. As a group, they reported being very likely to visit other city with an average rating of 6.4 out of seven (SD=1.1).

5.2.9 Impressions of people from Seattle

When asked to describe their impressions of people from their home city, Seattleites often cited passive, laid-back and polite personalities, referencing people who were interested in the outdoors, technologically savvy, and socially and environmentally aware.

Um, very technologically-driven, so like always really important to always have a phone on you, for many people, very important to have specifically a smart phone, um, and kind of using technology as not necessarily a crutch, but definitely as a way to escape a social situation. SSF03

They probably own a pair of Birkenstocks or know somebody who in their house has Birkenstocks, interested in the outdoors... SSM04

Generally uh environmentally-conscious and outdoorsy and socially-progressive, generally... SSM11

Stereotypes of Speech in Seattle

For the majority of speakers, Seattle's accent did not stand out as having any unique features that allowed it to be differentiated from other West Coast dialects.

No, I think if they specifically had a lack of accent, then I'd be like 'Oh maybe they're from the West Coast…' but no, not specifically from Seattle. SSF13

I cannot pick anything very definitive out from people from Seattle from people that speak maybe Pacific Northwest, but even then, I don't think I'd be able to notice it. SSM14

Six out of 20 Seattle respondents mentioned their awareness of pre-velar /æ/ raising in some way or another. This was either because they had overheard it from other friends and family members or because someone had identified and pointed out this feature of their own speech.

Well, I found out about maybe specifically the beg versus bayg, is that when I tell people that like there's this thing where people say beg instead of bayg, they're like "what is that even?!" It's like super foreign to us to say not bayg, and then bag versus bayg, my mom says bayg, and then I started living with her more than my dad and then my dad would make fun of her for that when we were little, but I lived with her more and I always heard bayg and now I have this weird like in between thing, like when I really started like paying attention I was like 'Wait, *what do I say?' I just have like this little crisis about that letter in between like b and g, that's a big one that I notice.* SSF03

The only thing that friend that grew up here also when we were in New York would make fun of the way we said 'bag' or that asked us where we were from because of that. SSF15

5.3 Results for Vancouver

The mean age of Vancouver participants taking part in the production study is 25.7 years (sd= 6.0).

5.3.1 Demographics

The mean age and education background of participants indicate a lifelong Vancouver resident around 26 years of age who has completed an undergraduate college degree.

Five speakers in the Vancouver sample, identified an ethnic background other than White or Caucasian. Two defined their ethnic identity as "Asian Canadian," two as "Chinese," and one as "Asian." Nine participants identified as male; ten identified as female. Two speakers defined their sexual orientation as "gay," eighteen speakers defined theirs as "straight" or "heterosexual."

Sixteen speakers had already completed an undergraduate degree or were currently making progress toward one. Two speakers had completed an undergraduate degree plus a Master's degree, and one speaker had completed a two-year technical certificate. Ten participants were currently students. This was related to age with the Group 1 age group being comprised almost entirely of full-time students. Speakers in the Group 2 bracket (age 26 to 36) were employed in a variety of fields and help positions as retail managers, pharmacy technicians, software developers, and editors.

5.3.2 Commentary on social class

The majority of respondents (15 out of 20) described their class upbringing as either upper or lower varieties of "middle class." Four speakers described their class upbringing as "working class," and no respondents used the term "upper class" to describe their class upbringing. In describing their class upbringing, respondents referenced their parents' levels of education and employment, whether they lived in a single parent household and whether they experienced opportunities to travel as children

> *I mean we weren't lower class just like the house that we lived in the fact that my mom worked part time when I was young, like the fact that we went on vacation, but I definitely wouldn't say that we were upper class either*. VSF04

Another speaker referenced the lack of struggle he felt his family faced when he was a child:

> *...just like a comfortable lifestyle, like compared to my parents were definitely working class like they worked very hard, but I think like they had a good foundation for me, so I grew up not with a struggle.* VSM02

For speakers who identified as working class, they provided commentaries about the types of occupations held by their parents and their observations about the financial or lifestyle challenges their parents faced:

> *"My mom didn't work, my dad was a trucker and it was very much working class, like um, the amount of money that we had, the kinds of non-vacations that we had, as in not at all, um, and the types of the ease of which we could acquire things I guess, and just, I don't know, it was usually just money was always an issue growing up, so yeah, I would definitely say working class."* VSM12

A few also made reference to the financial impact of growing up in a single parent household.

> *Working class, yeah...Well, single mom, parents divorced, mom had no job that sort of thing, welfare, that sort of thing.* VSM12

Many of the respondents were conflicted about how to describe their class currently. Considering both age brackets, the majority of respondents (17 out of 19) identified as middle class, but two identified as working class. Among the Group 1 bracket, most were still living at home with their families or were living on campus, but still receiving significant help from their parents. While none of these respondents described in detail the reasons for living with their parents, this is presumably due to the high cost of living in Vancouver. It can be inferred that university students in Vancouver expect to continue living with their parents until they have completed their degrees and transitioned into the workforce. This practice may also be related in part to the cultural norms of different ethnic groups: all five participants who identified as Asian or Chinese lived at home with their parents or their grandparents. For Group 2, more respondents were living on their own or had started their own families. Even among these speakers (age 26 to 36), three out of nine respondents still lived at home or with a parent. One older White speaker made reference to the cost of living in Vancouver:

> *Working class. I work hard just to barely pay the bills. It's a very expensive city, it's hard to be anything higher than that.* VSF12

Overall, the following statement typified the situation of most respondents in the study, regardless of age.

> *I'd say I consider myself still middle, upper middle cause I'm still living at home.* VSM01

5.3.3 Neighborhoods

While participants in this study were not recruited to be a representative sample of Vancouver neighborhoods, they represent a diverse set of neighborhoods within the city and the Vancouver Metro area. The varied set of neighborhoods that participants identified with included Kitsilano, Dunbar, North Vancouver, South Vancouver, West Vancouver and East Vancouver and nearby suburbs or municipalities including Surrey, Richmond, Port Coquitlam, Burnaby, and Ladner. Taken together, these neighborhoods and areas capture the range of socioeconomic and ethnic diversity in Metro Vancouver. Participants generally used many positive adjectives to described their neighborhoods including references to their ethnic and linguistic diversity, beauty, safety, outdoor features like parks and mountains, and their liveliness:

> *Very multicultural, interesting, exciting, ever-changing, awesome.* VSF14 of Commercial Drive

> *It has one of the highest immigrant populations in Canada, so um, there's a very large Asian population there and you can, that's very much reflected in um sort of like the types of stores and a lot of language signage and stuff like that is all in Asian languages.* VSF01 of Richmond

They also made reference to the physical setting and geographic beauty they saw in their neighborhoods:

> *Very community oriented, very I feel very safe, very beautiful.* VSF13 of North Vancouver

> *"I really like the outdoors, so that would be one thing. Definitely living in North Van, there's lots of stuff to do. I grew up snowboarding and mountain biking and I am still involved in that."* VSM05 of North Vancouver

A few speakers' descriptions included some negative characterizations of their neighborhoods based on their perceptions of its residents:

> *Urban, upper middle class, dense, snooty.* VSF11 of South Granville

> *Um, I would say like age thirty to forty yuppy type people.* VSM13 of Kitsilano

Given that most Vancouver speakers were still living at home, they often had very long term connections to their neighborhoods and had witnessed its growth and change over the course of their lifetimes. These changes often involved an increase in the relative cost of living in the neighborhood and the types of residents they felt were coming into it:

> *It's definitely changed since I was since we first moved there when I was five, umm, probably there's a lot more Asian people who live there now, and like people who live there, houses are very expensive so it tends to be people who have more money.* VSF04 of Dunbar

> *Yes, a lot more immigrants, especially from like China. A lot of foreign money has come and started living there. A lot of the houses have been torn down and rebuilt up.* VSM01 of Dunbar

> *There was less money then, less money, more families and then all the families went away, and now they're all coming back but it's like young, young kids now and the houses weren't all as nice.* VSF14 of Kitsilano

5.3.4 National identity and pride

As a group, Vancouver residents rated their national pride at a 5.9 on a scale of one to seven with seven being "very proud" (sd=1.0). Most respondents described a strong sense of national pride related to Canada's role in global issues such as foreign policy and standards for human rights, and the standard of living it provides for its citizens including health care, education, and acceptance of immigrants or citizens from diverse cultural backgrounds.

> *I'd say the standard of living in Canada is pretty high and the opportunities are pretty good for everyone..*VSM05

> *I love where I live, I love the environment, I love my fellow Canadians, I love our freedom, I love our unity, what we stand for on a global scale, what we stand for nationally.* VSF13

> *I don't know, I think we've got a good system in Canada, when you compare it to other countries, as well as, un-comparable, it's awesome.* VSM14

Several speakers with both “White” and “Asian” ethnic identities made reference to their perspective and national pride being informed by experiences they had had traveling and visiting elsewhere or being connected to a culture in another part of the world.

> *Well, you know like coming from Taiwan, and knowing like a lot of things and I know, I read a lot of the world news and see what's going on, and usually I have a lot of, you know like cause I read Mandarin and Taiwanese, I have all these different perspectives, and seeing other countries where they don't have human rights, they don't have the privileges you know such as health care, and the education system to accept people, and the diversity, it makes me really proud to think that we are you know, advanced in that sense and also everybody, so many people have come together to be like a nation.* VSM04

Several respondents mentioned the range of diverse cultures within “Canada” and the implication that what they perceived to be “Canadian” identity was largely affected by the culture of the region they had grown up in. In other words, their regional culture had had a more tangible impact on their pride and identity than a national culture.

> *Um, not, more regional identity than national identity. It's hard to really relate to the rest of Canada, they just seem to have all this other stuff, inside jokes that we don't have on the West Coast.* VSM13

I think that growing up in Vancouver and still living here, I think that in the past I would say, yes, I think that I thought that all of Canada was like it is here, and then as like I traveled and as I got older, the more I realized that it's really not like a national identity and it's really like a niche pocket of the country, so in some ways yeah, there's the stereotypical national identity, but I don't really feel like that's a real national identity that's really within Canada, you go abroad, and then of course, that's what everybody sees you as, but of course… so no. VSF14

5.3.5 Municipal and regional pride

Nineteen out of nineteen participants responded that they considered themselves Pacific Northwesterners. When they discussed their perceptions of the unifying trends across the region, they mentioned environmental sustainability, healthy lifestyles, outdoor activities, a coastal culture for food and leisure, obvious geographic and climatic similarities.

I mean our geography I guess is sort of obvious, but, I guess you know what our climate brings, our environment in terms of flora and fauna, and all of that that we have in common. VSF13

Outdoorsiness, what else? Well, especially in Vancouver, it's very like healthy lifestyle, like Whole Foods, yoga, hiking, outdoorsiness, running... VSF01

Well, I think being a coastal city our diet, our activities, our trade, our economy are all sort of based around that and the history it is, um, and so, I grew up eating a lot of seafood, just like diet and because we're so close to so much like natural resources, um, you know our leisure activities involve hiking, well more Rich than me, but you know, being outside, sort of being more environmentally conscious of the ocean and forestry than our city what is our city's profile... Salmon, sushi, and coffee. VSF11

I've lived in Vancouver for 25 years now, I'm very much a Vancouver girl. I like hoppy beers, I like good coffee, I'm very much a Pacific Northwesterner, yes. VSF12

Many respondents made reference to the close connection they felt with other inhabitants of the region based on geographic, climatic and cultural or lifestyle similarities. In some cases, they felt that their connection to the rest of the Pacific Northwest (including U.S. parts of it) was greater than their connection to the rest of Canada:

> *Because I feel like I have more in common with people that live in this area than like, I've been to Portland, for example, more times than I've been to Ontario, and I feel like I have more in common with them just because it's I don't know, the geography is more similar as well as just the general vibe, like it's a little bit more laid back like Vancouver is, it's not quite so just I don't know, people seem cooler and more laid back.* VSF02

In particular, Vancouver natives seemed to contrast urban and rural parts of Canada as well as East and West Coasts:

> *Canada's so huge, you can't really just be Canadian. There's a difference between being from BC and being from the Prairies.* VSF04

> *I think that there's a lot of things that make the Northwest a coastal city and make it different than the rest of the country. I know that people in B.C. feel lead very different lives than people in Eastern Canada. And I feel like a lot of those things that make the Pacific Northwest um unique I identify with and believe in the same ideals and sort of live the same lifestyle.* VSF11

One respondent even commented that the national border running through the Pacific Northwest region seemed arbitrary:

> *I think we were all part of the Pacific Northwest, really you know putting that border there, there's no no point, but there is, like there is, like protecting national identity and stuff, but besides that and gun control and maybe healthcare, everything is relatively similar.* VSM04

When asked how much they liked their city, Vancouver respondents averaged a 6.3 out of seven (SD=.84). Most Vancouver natives spoke very positively of their city, mentioning it’s proximity to nature and the outdoors combined with a lively and diverse urban atmosphere as the key factors for their high rating.

> *I just think that it's you know how all those stories they say that people going into the West and it's like the promise land? I think this is it. This is as west as you can go, and everything's awesome about it, you can do all sorts of really city like activities, you can be a foodie in the city but there's also nature and snowboarding and hiking really really close. The views are really great without sacrificing city life to live in a place with those views.* VSF15

Among the drawbacks to Vancouver were the high cost of living and the underdeveloped public transit system.

> *I like that Vancouver even if doesn't always succeed, it prides itself on being a green city and being environmentally responsible, um, socially responsible, like social equality, social justice, these are types of things that Vancouver seems to pride itself on. I mean, it's expensive here, but that's probably one of the few. That would be the down side of Vancouver is cost of living, but I don't say it detracts from my seven.* VSM12

They also mentioned challenges with homelessness and poverty in certain areas of the city, such as downtown and the East Side.

> *It just reminded me the there's a big problem the homelessness, the downtown Eastside, so it's like a big problem, I used to volunteer there, and it's I don't see it getting any better so it's why I'm not proud of that part*. VSM02

Participants were asked to rank their pride for Vancouver on a scale of one to seven and responded with a mean of 5.7 (SD=1.1). Using the same scale, they rated how much they like their city as a 6.3 (SD=.84). Their interest in moving was rated at a 4.1 (SD=1.5). Only five participants rated their municipal pride more highly than their national pride. Eight rated their municipal pride more highly, and six rated them equally.

Among the reasons offered for pride in Vancouver were an interest in sustainable lifestyles and agriculture.

I think Vancouver is different than the rest of Canada at least, even parts of B.C., it's different, um, there's definitely, like what I'm interested in is like sustainable agriculture, we definitely are a lot more focused on that, and invest in that in like this sort of region the Northwest coast is more into that as a region than the rest of North America, and I think that because I'm into that that's something that because I'm interested in, I feel proud of, I guess. VSF05

When asked about their interest in moving elsewhere, Vancouver natives responded with a mean of 4.1 (SD=1.5). For some speakers, a career or education opportunity would be the only likely reason for a move. When asked where the would move, most speakers either listed other cities in the Pacific Northwest or other Anglophone locations like London, Edinburgh, Australia, and New Zealand.

I really like London, I really like Edinburgh, mainly because I can speak the language there, and um I really like the people there, oh, especially in Edinburgh really laid back I found them to be very similar to here. VSM13

I'd really like to live in Europe, and I'd like to go back to New Zealand. VSF04

A few participants expressed an interest in moving to international locations that their parents had emigrated from including Hong Kong and Dublin.

5.3.6 Investment in municipal enterprises and networks

Participants were asked a series of questions to better understand their commitment to local purchasing, interest in local events and affiliations with cultural groups of their home city. These questions inquired about the important of purchasing from municipally-based businesses versus the Pacific Northwest region at large. They also addressed the frequency with which Seattle residents read local publications, participated in clubs or extra-curricular activities, and to what extent they followed local sports teams.

Purchasing

Participants were asked a series of questions about their purchasing habits from Vancouver-based business and from other businesses in the Pacific Northwest.

Shopping Local in Vancouver

When asked how often they purchased goods or services from Vancouver-based businesses, respondents rated their frequency of local shopping at a 4.7 out of seven (SD=1.2). Among items they purchased, the most common answer was food items including groceries and produce from local small grocery stores and farmer's markets as well as prepared foods and beverages from cafes and food trucks.

> *I do a lot of the food from local places. That's probably it.* VSF03

A few respondents also mentioned buying clothing or jewelry from local stores.

> *Mostly like food, um like things from Farmer's Markets, and vendors like jewelry and things like that that are around the city.* VSF13

Vancouver speakers also implicitly interpreted "local Vancouver business" to mean small businesses rather than larger chain that might have originated from Vancouver, but were now found nationwide or even internationally.

> *I don't think Lululemon counts as a local business anymore.* VSF13

When asked to rate how important it was for them to buy from Vancouver-based businesses, participants responded with a mean of 4.6 out of seven (SD=1.4). Most speakers judged it to be “preferable” or “moderately important” to buy from local businesses, while a few others explained that it wasn’t very important to them.

> *I'm not too inclined, there's not a particular reason I would choose Vancouver, like it depends on the quality right, if it's good quality, I don't really care where it's from.* VSM02

As factors constraining the frequency or importance of buying local products, they cited higher prices for local goods (especially clothing), availability, potentially poor quality and generally infrequent shopping or purchasing.

> *I'd say five, in the sense that I find it like really easy to support Vancouver-based businesses with food, but I find anything Vancouver based like with clothing can be cost-prohibitive in more often than not.* VSF14

Shopping Local from the Pacific Northwest

As a group, respondents judged their frequency of buying from regional businesses at a 4.3 out of seven (SD=1.7), which was slightly lower than their frequency of purchasing from the city. Beer and produce were among the items they purchased. A few participants also mentioned shopping for less expensive goods or purchasing sports memorabilia while traveling in Seattle or other parts of the U.S.

I mean I buy loads of like Seahawks, like way too much Seahawks stuff I got a couple Mariner's memorabilia also, and that's probably all that probably the extent of my shopping. VSM01

How important

Additionally, Vancouver respondents described the importance of buying from Pacific Northwest businesses at a 4.3 out of seven (SD=1.6). Some thought it was important for reducing the impact of longer transportation for goods and services. Others expressed a lack of awareness and familiarity with whether products were coming from the Pacific Northwest or not.

I guess my biggest problem is that I just don't even know where this stuff is coming from, so… I'm gonna say probably a knowingly? A one, cause I just don't know. VSM13

In general, participants' responses indicate that it is only moderately important:

It's moderately important but…I wouldn't break the bank to do so. VSF14

For a comparison of the normalized responses about purchasing for Seattle and Vancouver, see Figure 2 in section 5.3.

Local Sports

The mean response provided by Vancouver participants with respect to how closely they followed sports was a 3.8 out of seven. Seventeen out of 19 respondents mentioned hockey or the Canucks explicitly when asked what sports they followed in Vancouver. Some gave themselves lower ratings for how closely they followed now based on the fact that the Canucks were not having as much success as they were previously. While the majority of respondents expressed an active interest in following hockey, a few said they felt like overheard more about hockey than they would deliberately seek out if let to personal choice.

> *...the Canucks, too, sort of cause everybody's like talking about it so it's hard to like not [sic.] filter it out...* VSM04

After hockey, soccer was the next most commonly mentioned sport followed by Vancouver respondents (nine out of 19). A minority of respondents mentioned basketball, baseball or football.

Local Publications

Taken together, participants responded with an average of 4.3 out of seven (SD=1.6) when asked how often they read local publications such as newspapers, event guides or magazines. The most commonly cited publications were Metro News Vancouver ("the Metro"), 24 Hours Vancouver ("the 24"), The Province, and The Vancouver Sun. Other publications referenced by one or two respondents include The Georgia Strait, Van City Buzz, and Scout Magazine, a magazine about the local food scene.

Membership in Clubs or Groups

Ten out of nineteen respondents answered that they held membership in a club or group through school or in Vancouver, at large. Many respondents described their participation in academic clubs or groups related to their University field of study such as the Supply Chain Club, the Institute of Electronics and Electrical Engineering, and the Linguistic Student Union. Among non-university clubs and groups, clubs varied idiosyncratically by personal interest.

For a comparison of the normalized ratings of municipal investment for Seattle and Vancouver, see Figure 3 in section 5.3.

5.3.7 City comparisons

Participants were asked to rate the similarity of three different pairs of cities: Seattle and Vancouver, Vancouver and Toronto, and Portland and Seattle. Of the three pairs of cities, Vancouver and Seattle had the highest average similarity rating at 5.3 (SD=.71), followed closely by Portland and Seattle at 5.3 (SD=1.1). Vancouver and Toronto were rated as least similar at a 4.0 out of seven (SD=1.1).

Seattle Vancouver Similarities

When asked how Seattle and Vancouver were similar, respondents referenced a similar "West Coast" culture, similar climate and geography.

> *I know in Vancouver we always joke that Seattle is basically just an extension of Vancouver, or vice versa, um, I think that we're we're both very West coast...* VSF03

> *I think it's like kind of similar, I haven't been all over Seattle or anything, but from what I've seen, it kind of reminds me of home, but not quite as good.* VSF05

> *I think that we are both more liberal cities that are really into sort of like into there's a lot more acknowledgment of New Age, like New Age health and health, I think we're a lot more liberal and accepting. I think even demographically, we're just much more left-wing than the rest of Canada or the rest of the States, we're both coastal cities, so there're a lot of similarities when you go there, even like the architecture, and sort of like the retail stores and things like that are really similar.* VSF11

> *Well they're close, and both have similar climates, and they're similar sized I think, if you're talking, I think Seattle itself is a bit bigger than Vancouver, but great Vancouver is a bit bigger than Seattle and I'd say it's fairly similar, both have like, you have Pike Place Market sort of like Granville Island here, it's sort like, I think there are a lot of similarities in terms of like the style of living and the location of the city.* VSM01

When asked how Seattle and Vancouver were different, Vancouver participants described different racial and ethnic composition with more African Americans in Seattle and more Asians or Canadian Born Asians in Vancouver.

> *I think there's like I mean, there's definitely like a culture difference between the States and the U S [sic.], I think like first of all politically, I think the States is sort of like two steps to the right of Canada, in general, and you also have different demographics, a lot more African American people in the States, and probably a few more Asian Canadians up in Vancouver...* VSM01

They also perceived that things were cheaper in Seattle and referenced the fact that many Vancouverites liked to go shopping in Seattle.

> *Well, I know there's a lot of cross-border shoppers so it's kind of like Vancouver, price-wise it's probably like there is a difference there...* VSM14

One respondent also commented that she felt there was a unidirectional awareness on the part of Canadians about U.S. culture that Americans did not match in terms of their awareness of or interest in Canadian culture.

> *I find they're like with some Americans there's a big naivety about the rest of the world particularly Canada, because America's a super-power, I feel that Canadians know a lot about the States and that it's not vice versa. Whenever I've met like Americans, a lot of them, like a big thing for Canadians was when the dollar was on par, like it was all over the news, people knew about it, and when I asked Americans, they weren't like even aware of it, and so that's like something I think with Canadians are likely really aware of the States and wanna be identified as different and the States are just like "We're neighbors!" and don't think that way, different mentality.* VSF11

Seattle Portland Similarity

On the one to seven scale, Seattle and Portland were judged to reach a 5.0 in terms of similarity (SD=.99). Some participants had not visited Portland, but made judgments based on their impressions. Others described that they viewed Portland as a smaller version of Seattle with more extreme tendencies. Some described Portland as more "hipster," and one respondent used the term "more ghetto."

> *I've only been to Portland once, but yeah I'd say a five or six, seems like a similar relationship, like Portland's a more niche hipster brother of Seattle.* VSF11

One respondent also explained that he thought Portland was more spread out than Seattle:

> *Portland's a little more ghetto...They're a little bit more like like backwards in the sense that you know in Seattle you have like the downtown Seattle area and then you got like the you got like the Queen Anne area and the University of Washington area, and all this area, like it's more concentrated, but Portland seems like it's very spread out...* VSM04

Toronto Vancouver Similarity

Vancouver natives perceived Toronto and Vancouver as less similar than Seattle and Vancouver, giving a mean similarity rating of 4.0 out of seven (SD=1.1). Many Vancouver natives admitted that they had never visited Toronto, and some refrained from rating the cities as a result. Many made reference to an "East Coast" versus a "West Coast" lifestyle.

> *I've only been to Toronto quite briefly, but I have a best friend that lives there and she says that it's quite different. I think East Coast living or like Eastern living is very different, weather definitely, weather sucks there. It's really cold and snow or really gross and humid in the summer.* VSF12

Others explained that they thought the pairs of cities were dissimilar for different reasons.

> *Oh, yeah, well, definitely less similar, or maybe dissimilar but for different reasons...* VSM12

Respondents referenced the national identity and government structures shared by Vancouver and Toronto, but also identified the more local, cultural like-mindedness they shared with Seattle and the rest of the Pacific Northwest.

> *I think we're different in different ways, like the things that we're similar with Seattle with, we're not similar with Toronto with, but we're similar just being Canadian. Ok, so Toronto's sort of like the super power city of Canada, and so Vancouver often feels, and they're closer to like our big Prime Minister and Parliament and things like that, so Vancouver and B.C. often feels ignored and resentful when everyone talks about Toronto being the big city, so there's this rivalry, but then at the same time when it comes to like global issues, we identify as Canadians, we have the same government, we have healthcare, same history, um, but they're much more conservative, like I think they think of us and tofu-eating hippies, which we are and I think to some extent that's true, and then we share that with Seattle, so...* VSF11

For a comparison of the normalized ratings of city similarities for Seattle and Vancouver, see Figure 4 in section 5.3.

5.3.8 Impressions of People from Seattle

Vancouver respondents generally described their impressions of Seattle as similar to their impressions of Vancouver and sharing a general "West Coast" lifestyle or mindset.

> *They seem pretty similar to Vancouver people and they're… all the people I have interacted with have been friendly and um, I have a disproportionate representation cause I just go to football games so you see like more drunk people and more overweight people, but no, I'd say, people in Seattle seem very similar to people in Vancouver.* VSM01

People from Seattle were perceived to be outdoorsy, yet urban at the same time.

> *Probably outdoorsy as well, um, you know city dwellers, yeah.* VSF12

Vancouver speakers used adjectives like "chill" and "friendly" to describe people from Seattle.

> *Chill people who like to do yoga and eat and support green initiatives.* VSF15

They also described a perceived love of food, coffee, and grunge music.

> *Well, they love their coffee, they like food, although I notice a lot of times when I go to restaurants in Seattle that it's more about servings, a lot of places, it's more about quantity vs. quality. Big serving sizes there, it's kind of crazy, but they definitely like their music, but they own very much the people that come from there music-wise.* VSF12

A few speakers described Seattle as being more business-focused and less "hipster" and less "earthy" than Vancouver.

> *I think very much like a Vancouver, just kind of minus the Earthy, minus the hipster, just a lot more of the like working, the business, a lot more like Granville Street, less like Kitsilano.* VSF03

A few speakers made references to less urban density or more residential spread in the Seattle areas, which they inferred caused people to spend more time commuting:

> *I don't have any facts here, people in Seattle spend lots of time in their cars because the roads are always clogged and they must be going home to houses because if they all lived downtown then they wouldn't feel the need to all drive.* VSF14

Stereotypes of Speech in Seattle

Most respondents said that they would not be able to identify someone they overheard as being from Seattle. They commented that this was due in part to the fact that Seattle speakers sounded very similar to Vancouver speakers.

> *I think it would be difficult for me to differentiate between someone from Seattle versus Vancouver.* VSF13

> *"Um, no, I think it would be similar to Vancouver."* VSM02

Some made reference to an absence of stigmatized dialectal features as guiding them in identifying Pacific Northwest speech:

> *I feel like the general dialect dialect is sort of West Coast when it comes to sort of like a general, like when you're in Hollywood, they say they sort of learn to lose like specific dialect, um, so unless they, it would probably be a process of elimination, I probably wouldn't hear a Southern accent, or like a Texas accent or whatever.* VSF11

> *It would depend, I mean if they were from the South and had moved to Seattle and still had like that drawl, then yes, but I honestly don't, you know, if they weren't saying like 'eh' or something like that at the end of sentences that might, you know, that's kind of stereotypical. It's difficult.* VSF12

Some speakers thought they would be able to identify a Seattle speaker as being from the U.S., but not necessarily as specific as being from Seattle.

> *Probably would be able to recognize that they weren't from Canada. They would have more of accent that's more from the States.* VSF04

The folks who thought they could identify a Seattle speaker described some differences in vowel quality, while acknowledging that these differences were sometimes idiolectal:

> *There's like a small difference in the way that we pronounce some of the vowels, and it depends on... from person to person, for some people it's like completely, there's no difference whatsoever, but with people, and maybe because they might not be native to Seattle, some of the vowels, some of them might be a little bit longer, or a little bit higher or flatter or sharper.* VSF15

A few respondents also perceived more “twang,” more nasally and more “Southern-sounding” speech from Seattle speakers.

Finally, Vancouver natives were asked how likely they would be to visit Seattle. Collectively, they responded that they would be very likely to visit Seattle with a mean of 5.9 out of seven (SD= 1.3).

5.3.9 Impressions of people from Vancouver

Vancouver natives generally used positive adjectives to discuss their impressions of people from their home city. They described people from Vancouver as being socially and environmentally aware, outdoorsy, earthy, relaxed, and polite.

> *They Vancouver, for whatever reason I think sort of like health conscious fitness type of people. I mean, a lot of people run on the Sea Wall and on the trails and stuff like that. It's a pretty healthy active city.* VSM01

> *Uh, very easy-going, very well-rounded, like they're concerned about the environment, it's very important, and just the well-being of people, um, like in a like especially like the homeless and stuff like that, I think there's a heart there.* VSM02

On the other hand, a few respondents took a more critical eye to the city and its citizens explaining that they felt the commitment to healthy lifestyles and environmental awareness was at times image-based or superficial.

> *Yeah, I think that people from Vancouver are cliquey and pretentious in a way that they don't think they are, like we're pretentious about the way that we eat organic food and we do yoga, you know we don't have like Chanel logos, but it's a very like subtle pretentiousness, like 'I drive the latest, nicest hybrid.' And, you know, it's a different kind of less flashy in your face pretentiousness, but it's just, I think it's just a different version of L.A. Like people all really care about status, it's just a different way of showing it.* VSF11

Everyone's a foodie, we love our leggings, I think we think we do a lot more for the environment than we really actually do in our actions, um, like I think we think we treat the city a lot nicer than we do and I think we think we treat each other a lot nicer than we actually do. VSF14

While Vancouver respondents often found truth in the stereotype that Canadians are polite, some also commented that they did not think people in Vancouver were very friendly. In fact, respondents seemed to be in conflict with respect to the friendliness of people from Vancouver.

I think the stereotype that Canadians tend to be polite is somewhat true. VSM05

I think that people from Vancouver are not as overtly friendly as they are in other places, I mean, there's definitely this belief that it's hard to get to know people in Vancouver and I definitely agree with that, yeah, it's definitely hard to meet people, I mean you don't talk to people on the SkyTrain or on the bus, and it's weird if someone does talk to you, and people are like 'red flags!' we can't talk to each other! VSF01

One respondent explained that what might be interpreted as a lack of friendliness might actually be caused by politeness:

...we always joke that we're so polite that we're almost stand-offish, because like if we see you on the bus or some, people don't make conversation on busses, and we think that that's probably because they're like 'Well, they probably don't want to be bothered' so you do your thing and I'll do my thing, so we can come off as stand-offish to out-of-towners, when really we just don't want to bug you. VSF03

Others attributed the perceived lack of friendliness to the nature of being in a larger city with high urban density.

Highly dense places, more people around you all the time, I think the more people tend to shut off, disconnect from people. VSF14

Stereotypes of Speech in Vancouver

Respondents were asked whether they thought they would be able to identify someone from Vancouver if they heard them talking while they were traveling or away from Vancouver.

> *There's just something about, not even necessarily from Vancouver but just from the Pacific Northwest, I've been traveling and heard someone speak English and once you've heard all the different well whatever wherever you're from, people will speak English to you and then suddenly, you'll hear like someone talk, and it'll be in your own accent and you're just inexplicably really happy.* VSF15

Speakers were also asked what features would lead them to identify a talker as being from Vancouver. Several speakers noted the pronunciation of the city's name explaining that Vancouver natives seemed to assimilate the nasal to the voiceless velar causing it to sound more like [ŋ] :

> *Well, first of all do they say 'Vancouver' or 'Vangcouver?'* VSF01

They also commented that they did not perceive Canadian Raising to be as strong or intense as in other parts of Canada, such as the Central provinces or the East coast. Even some more rural parts of B.C. were described as sounding "more Canadian."

> *I would probably be able to pick up, cause I find Calgary and Vancouver, or Alberta and B.C. have very similar ways of talking in the Southern parts, but the more North you go the very strong Canadian accent starts to come in 'oot and about' starts to come in more, and then on the East coast, you get more of the Maritime Irish sort of accent that comes through so, yeah.* VSF12

> *It depends like the accents around, but I can definitely tell like the different between like someone who's from Vancouver, and someone who's from like*

> *Abbotsford, in the Fraser Valley. The people in the Fraser Valley sound more Canadian.* VSF04

A few respondents commented that the notion of a singular "Vancouver English" was difficult in and of itself due to the ethnic and linguistic diversity of the city:

> *"I feel like if somebody asked me where I thought they were from and I put some thought into it, yeah, but because we have so many different varieties of Vancouver English, I wouldn't clue into at first."* VSF03

Many participants cited frequent use of the interrogative discourse-marker 'Eh?' as a stereotype of Vancouver or Canadian English.

> *Well, we say 'eh?' a lot, we say sorry a lot, I think we're pretty polite, and I think we just try to get out of people's way, and don't want to ruffle feathers and have confrontation, and uh generally I think people are pretty quiet, like they don't really talk as much, like if you think of like people in New York how they're just like loud and stuff, I think Vancouver people are quite quiet and shy.* VSM11

Three of the 19 Vancouver participants identified pre-velar raising of /æ/ as a feature of Vancouver speech. The only speakers who mentioned this trait were current or former linguistics students who had gained a meta-linguistic awareness of the feature. Among lay speakers, the raising was not mentioned. None of the respondents mentioned retraction of /æ/ in other environments, although a few described a small set of lexical items for which Canadian English and American English differed such as *pasta, Mazda* and *Americano*.

Vancouver speakers were also asked whether people ever commented on their speech when they were in the States or traveling elsewhere. They mentioned lexical items that stood out between Canadian English and U.S. English such as *washroom* versus *restroom*. They also mentioned that they had been teased for their pronunciation of *sorry*, which sounded different than the typical American pronunciation.

5.4 Seattle and Vancouver Compared

5.4.1 Overview

A linear regression model was used to examine the significant predictors of response values for each question. City, sex, age and class upbringing were considered as possible factors. Ethnicity was not considered in this model because the sample populations were too small. The results from these linear regressions are summarized in the table below:

	City	**Sex**	**Age**	**Class Upbringing**
National Pride	*	-	-	-
Seattle Vancouver Similarity	*	-	-	-
Vancouver Toronto Similarity	-	-	-	*
Seattle Portland Similarity	-	*	-	-
Like Your City	-	-	-	-
Proud of your City		*		
Likely Visit Other City	-	-	*	-
Interested in Moving Elsewhere	-	-	-	-
Follow Sports	-	-	-	-
Read Local Publications	-	-	-	-
Frequency of Shopping in Home City	-	-	-	-
Importance of Shopping in Home City	-	-	-	-
Frequency of Shopping from the PNW	-	-	-	-
Importance of Shopping from the PNW	*	-	-	*

Table 54. Overview of statistically significant differences for sociocultural survey questions by city, age, and sex: Comparison of z-score normalized responses by main effects of primary factors; * indicates *p = <.01 and* ** indicates *p=<.001*.

5.4.2 National and municipal pride

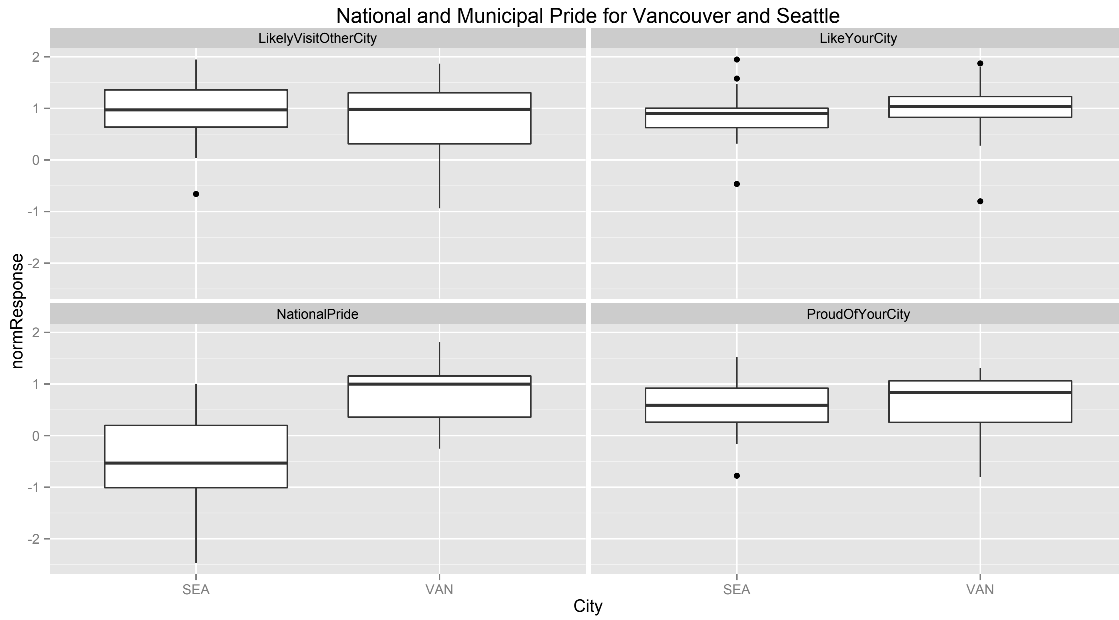

Figure 37. National and municipal pride for Seattle and Vancouver: National and municipal pride for Seattle and Vancouver with medians and standard deviations for z-score normalized responses

There was a highly significant difference between Seattle and Vancouver speakers with respect to national pride. Vancouver participants responded with significantly higher ratings of their national pride, and the effect size of this difference was substantial (t-value 3.29, *p=.003*). A significant main effect of sex also emerged for municipal pride ratings: men responded with lower ratings of municipal pride than females.

5.4.3 Local purchasing

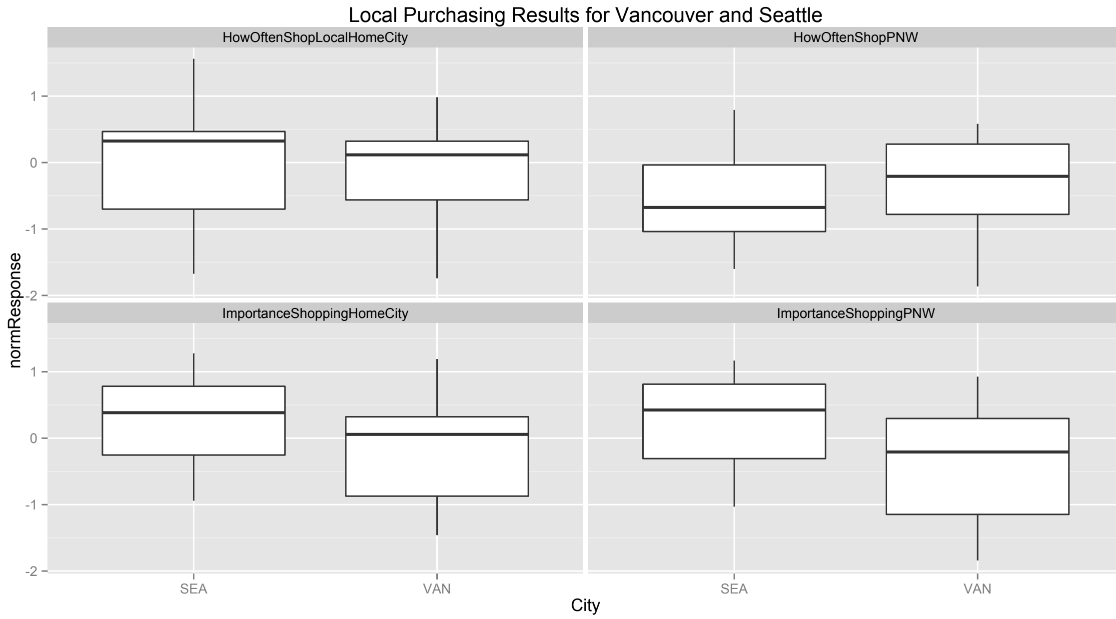

Figure 38. Local Purchasing Results for Seattle and Vancouver: Local Purchasing in Vancouver and Seattle with medians and standard deviations for z-score normalized responses

For three of the questions about purchasing habits and commitments, there were no significant differences between Seattle and Vancouver. One significant difference emerged with respect to the importance of buying goods and services from the Pacific Northwest region: Seattle respondents rated the importance of buying from the Pacific Northwest more highly than Vancouver respondents (t-value = -2.5, *p=.02*). In fact, Seattle speakers tended to respond more positively to questions about local purchasing across the board, despite not reaching significance levels for some questions.

5.4.4 Municipal investment

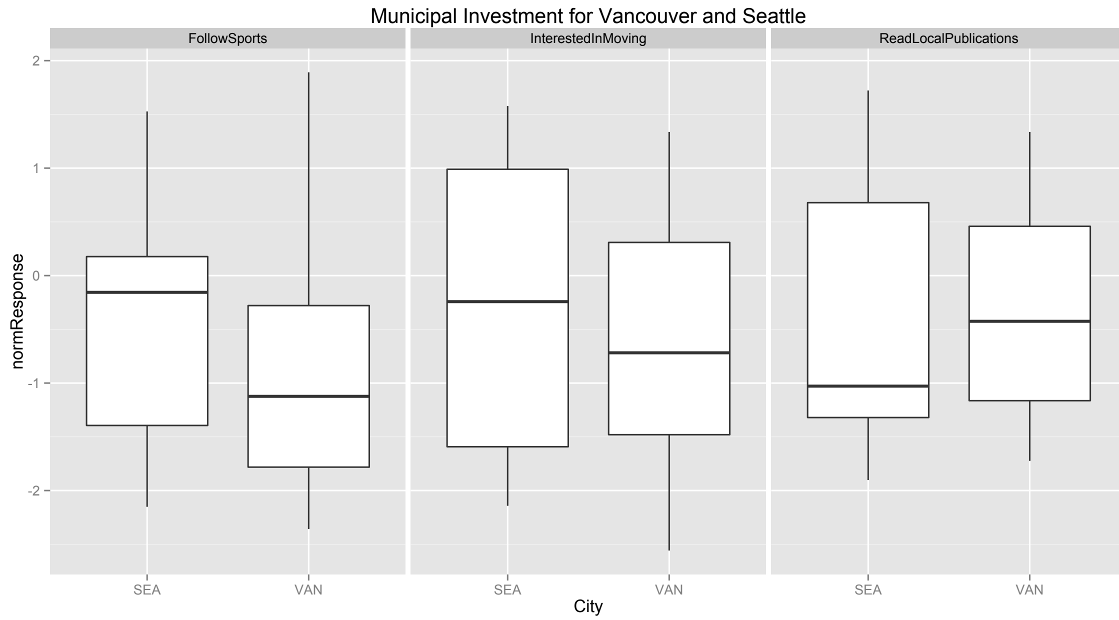

Figure 39. Municipal investment for Seattle and Vancouver

Municipal Investment for Vancouver and Seattle with medians and standard deviations for z-score normalized responses

There were no significant differences between Seattle and Vancouver with respect to municipal investment questions. However, age was found to be a significant predictor of participants likeliness to visit the other city (Seattle for Vancouver participants and Vancouver for Seattle participants) with Group 2 speakers rating themselves as more likely to make this trip (t-value=2.25, $p=.03$). This may be to related factors not assessed here such as access to transportation or work-related requirements for regional travel.

5.4.5 City similarities judgments

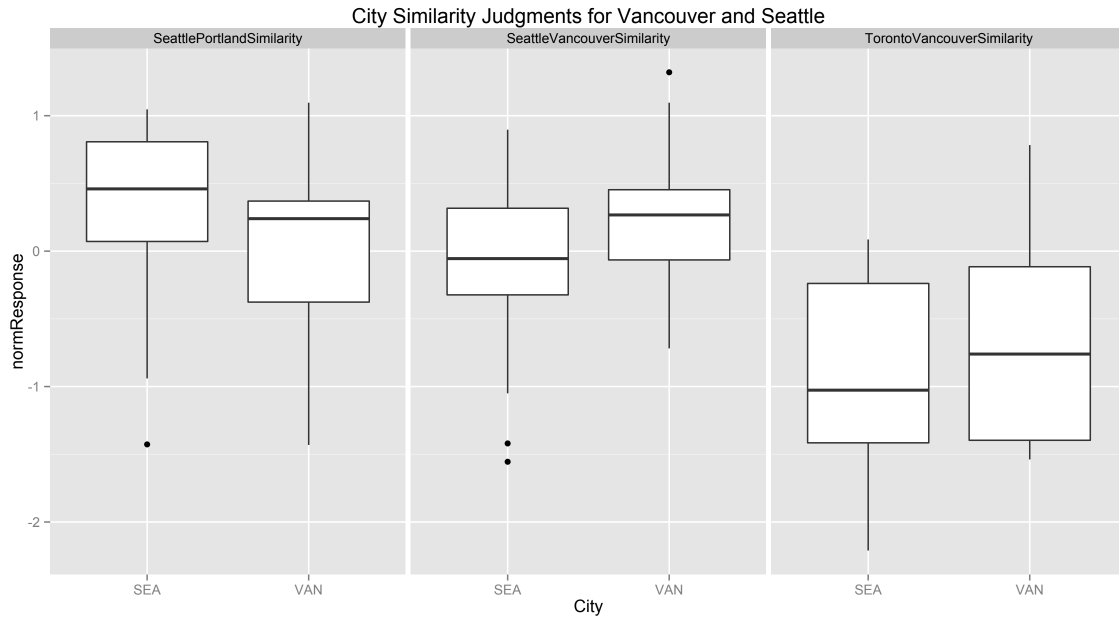

Figure 40. City similarity judgments for Seattle and Vancouver: City Similarity Judgments for Vancouver and Seattle with medians and standard deviations for z-score normalized responses

In general, men judged Seattle and Portland to be significantly more similar than women with a t-value of 2.27 above the baseline at -1.68 (*p=.03)*. Vancouver participants rated Seattle and Vancouver as significantly more similar than Seattle participants (t-value = 2.4, *p=.03*). Middle class participants rated Toronto and Vancouver as significantly more similar (t-value=2.75, *p=.01*). As the table above displays, the two cities did not present any other significant main effects with respect any other questions.

Interestingly, Vancouver and Seattle respondents differed in the pairs of cities they judged to be the most similar. Vancouver participants rated Seattle and Vancouver to be significantly more similar than Seattle participants (t-value = 2.4, *p=.03*). Seattle respondents, on the other hand, judged Seattle and Portland to be more similar, though this difference was not statistically significant. There was no significant difference between the ratings respondents provided for Toronto and Vancouver, though middle class participants had significantly higher ratings of Toronto and Vancouver's similarity (t-value=2.75, *p=.01*).

5.5 Discussion: Similarities and Differences

In general, the sample populations from Vancouver and Seattle were similar in terms of their ages, levels of education, occupations, gender identities, and sexual orientation. The Vancouver sample includes more participants than the Seattle group who identified with an ethnic group other than "White," though this was not an explicitly goal of the researcher. There were more respondents in the Vancouver sample who had been born in Canada to first-generation Asian immigrants, or who had been born abroad and had come to the U.S. with their parents as very young children. These speakers still identified English as their native language, but shared to some extent a cultural background with family or social networks outside of Canada.

5.5.1 Regional background more salient than nationality

Both Vancouver and Seattle speakers expressed that their regional identity was more tangible and had a greater impact on their lives than their national identity. Respondents from both groups described the uniqueness of the Pacific Northwest region relative to the rest of the country and the difficulty they had in identifying with other geographic and cultural groups within their own country.

5.5.2 Aspects of regional identity: Cascadia is real

Seattle and Vancouver respondents painted a picture of Pacific Northwest culture and values that was largely consistent regardless of which side of the national border it was viewed from. Participants from both cities viewed the Pacific Northwest as more progressive than other parts of the continent in terms of the socially and environmental awareness of its inhabitants. Vancouverites view themselves as generally less conservative than folks from other parts of Canada; Seattlites view themselves similarly with respect to other regions of U.S. They both mentioned interest in the outdoors, a strong connection with nature, the region's climate, and geography in their definitions of what unifies the Pacific Northwest.

5.5.3 Struggle to conceptualize the middle class in Seattle

While participants often mentioned the similarly high cost of living in both cities, respondents from both cities acknowledged that Vancouver was the more expensive of the two. There also seemed to be different tendencies for how the young adults in this study handled the challenges of developing as young adults in their respective cities. Seattle speakers were very explicit about the challenges they faced in finding stable employment, covering their costs of living, and making progress toward their financial goals of providing for themselves and eventually a family. This raises an interesting analytical challenge as these descriptions would likely be associated with the working class. Yet, given the level of education and types of employment held by these respondents and their relative financial positions, it calls into question the typical class associations of occupations and livelihoods with socioeconomic status. In essence, what would traditionally be considered White-collar occupations and livelihoods seem to yield the income and lack of financial stability more characteristically associated with the upper working class.

5.5.4 Delayed home-leaving in Vancouver

Another difference between Vancouver natives and Seattle natives was the tendency for Vancouver natives to be living with their parents. Fewer respondents in the Vancouver sample lived on their own or with roommates than in the Seattle sample. This may be related, in part, to the higher cost of living in Vancouver, but an important larger trend documents the importance of ethnic background in shaping homeleaving among Canadian young adults. In comparing homeleaving practices of Canadians age 19 to 36, Mitchell, Wister, and Gee (2004) found ethnocultural factors to be significant predictors for timing and pathways of homeleaving. In particular, Indo, Chinese, and Southern European ethnic groups all exhibited delayed first homeleaving in comparison to the British group.

5.5.5 Higher national pride for Vancouverites

In general, Vancouver participants expressed much greater national pride than Seattle participants. Among other reasons for this, they frequently cited Canada's reputation in terms of global affairs and the safety net it provided for its citizens through legislation and the provision of healthcare, maternity/paternity leaves, etc. Seattle participants did not express pride in the reputation of the U.S. in international affairs, nor did they express pride in the social services provided by the U.S. government. To a great extent than Vancouver respondents, Seattle participants seemed to differentiate themselves as being more "progressive" and "liberal," which they viewed as being in contrast with the rest of the country. They also seemed dissatisfied with the conceptualizations of patriotism and nationality that they felt were embraced by the rest of the country.

5.5.6 Friendliness as a highly variable trait

Whether participants perceived residents of their own city or the other city to be friendly proved to be variable and conflicting. Many participants responded that inhabitants of their own city were not overtly friendly or were "shut off" or "reserved." Some extended this view to inhabitants of the other city, while others judged the other city to be friendlier. When asked to give their impressions of people from both cities, Seattle respondents tended to describe Canadians and people from Vancouver as friendlier than people from Seattle.

5.5.7 Who's watching whom? City similarity judgments

Given that Vancouver respondents judged Seattle and Vancouver to be significantly more similar than Seattle respondents, who perceived themselves in turn to be more similar to Portland, a question is raised about the extent to which inhabitants of one city are aware of or revere the cultural habits of the other cities. This may suggest that Vancouver residents are more informed and interested about the culture in Seattle than Seattlites are in the culture in Vancouver. Seattle, in turn, is preoccupied with Portland, which may indicate the same type of interest in emulating or competing with Portland's culture. This might also be accurately described in terms of rivalry: Participants' responses explain that Vancouver feels a need to differentiate itself from the States, while Seattle feels a need to differentiate itself not from Vancouver but from Portland.

5.5.8 The "'Eh?" stereotype

While the use of 'eh' was a stereotype of Canadian English very frequently cited by both Seattle and Vancouver respondents, there was not a single Vancouver speaker who made extensive use of this feature. This presents an interesting case of a stereotype that, at least within this sample population, outlives its acoustic reality.

5.5.9 Vancouver shows less interest in shopping local

Vancouver natives generally described less interest in shopping from local Vancouver-based business and Pacific Northwest businesses. This may be connected to the fact that most speakers live at home with other parents who do their shopping.

5.6 Asymmetrical Language Ideologies

Vancouver and Seattle participants were distinguished by their perceptions of linguistic and cultural similarity with the other city. In addition to significant differences between their scaled (1 to 7) ratings of the city's similarities, they also differed significantly with respect to whether they used terms like *similarity* or *just the same* in their verbal descriptions of the other city. Fourteen out of 19 Vancouver participants embraced an ideology of cultural and linguistic sameness toward Seattle; eight out of 20 Seattle participants embraced an ideology of sameness toward Vancouver. Seattle participants felt much more certain than Vancouver participants that they could identify a talker from the opposite city if they heard them talking. Sixteen out of 20 Seattle participants thought they could identify a speaker as being from Vancouver if they overheard them. In contrast, only seven Vancouver participants thought they could identify a Seattle talker based on their speech. Vancouver speakers elaborated ideologies of *erasure* with respect to the differences between Seattle and Vancouver. Seattle speakers embraced ideologies of *fractal recursivity*. They constructed a contrasting perception of Vancouver based on nationality and projected this ideology of contrast to other levels, such as their perceptions of linguistic differences.

5.7 Summary of Findings

All Vancouver and Seattle respondents reported that they identified as Pacific Northwesterners and defined the identity of the region very consistently, though they displayed asymmetrical ideologies in their perceptions of the opposite city. Among the consistent and fundamental defining features for the Pacific Northwest as a region were a shared geography and climate, an appreciation for nature and the outdoors, and progressive social and environmental awareness. While Vancouver and Seattle respondents conceived of their regional identity similarly, they also display differences in sociocultural values. Beyond passion for football and for hockey respectively, Seattle and Vancouver natives also show differences in their municipal and national pride with Vancouver residents more apt to express positive attributes associated with their national identity than Seattlites. Seattle respondents rated their municipal pride very highly, on the other hand, and described a stronger interest and importance in purchasing from local Seattle-based business than Vancouver respondents. While participants from both cities viewed high costs of living as a challenge, more Vancouver respondents continued to live with their parents through university and young adulthood than their Seattle counterparts. Seattle respondents living on their own, on the other hand, expressed greater financial struggle and instability than Vancouver participants.

Seattle and Vancouver participants do share many of the same attitudes and beliefs about speech in the Pacific Northwest, including the existence of a larger dialect region to which both Seattle and Vancouver belong, although some believe that they would be able to identify the nationality of a talker from the other city. Seattle speakers most commonly reference the stereotypical Canadian Raising as an identifiable feature of

Vancouver speakers, while Vancouver speakers rarely mention this as an identifying feature of speakers from their own city, nor do they associate a lack of raising with Seattle speakers. With respect to pre-velar /æ/ raising, speakers from both cities reference pre-velar raising of /æ/, but mentions of this feature occurred among several lay participants in Seattle, whereas it was mentioned only by a few participants in Vancouver who had taken linguistics courses. Both cities also discuss 'eh?' as a stereotype of Vancouver speakers. Neither speakers from Vancouver, nor speakers from Seattle make mention of /æ/ retraction as a feature of Vancouver English.

Chapter 6

6 DISCUSSION

This chapter summarizes the findings from the production study and the sociocultural identity survey presented in Chapters 4 and 5, respectively, and discusses themes that emerge from these findings and their theoretical implications. One goal of the current project is to reach a deeper understanding of phonetic and phonological processes taking place in Pacific Northwest English and to fill an empirical gap by providing information about two under-studied urban centers of the dialect region: Seattle and Vancouver. These phonetic or phonological features were examined in terms of their distributional ability to unite the Pacific Northwest region, setting it apart from other varieties of North American English, or to differentiate Seattle and Vancouver as part of their proposed dialect areas: the West and Canada, respectively. The findings have theoretical implications related to criteria for dialect differentiation, terminological and methodological conflicts between linguistic sub-fields, a description of the relationship between conventionalization of phonetic processes and social meaning, and the role speakers' ideologies and attitudes play in sound change.

6.1 Summary: Overview of Research Questions

A brief summary of key findings for each research question is provided below.

6.1.1 /æg/ raising in Seattle and Vancouver

Are Seattle speakers raising /æ/ in pre-velar environments? How do Vancouver speakers compare?

Seattle speakers are raising (and fronting) /æ/ in voiced pre-velar environments. Raising is generally stronger among Group 2 speakers and male speakers. Vancouver speakers are also raising and fronting /æ/ before /g/, and their tokens are significantly higher and fronter than Seattle speakers. This suggests that pre-velar raising may be a marker of the Pacific Northwest dialect region. On the other hand, there are different trends for pre-velar raising in Seattle and Vancouver. In general, Group 1 speakers are engaging in more raising in Vancouver, and Group 2 speakers are leading raising in Seattle. Group 1 women in Seattle in particular engage in pre-velar raising to a lesser extent than men or Group 2 Seattle speakers. This suggests that the socio-evaluative meaning of raised /æg/ may differ in the two cities.

6.1.2 /æn/ in Seattle and Vancouver

Are Seattle and Vancouver speakers raising /æ/ before /n/?

Seattle speakers show very strong phonologized raising of /æn/ while Vancouver speakers show coarticulatory raising of /æ/ before /n/. For Seattle speakers, /æn/ tokens are very high and front at onset, far exceeding the height of /æg/ tokens; for Vancouver speakers, /æn/ is not strongly raised and fronted at onset, and its height is lower than /æg/. The “raising” involved in pre-nasal environments is qualitatively different from /æg/ raising, highlighting the need for time-sensitive analyses to avoid terminological confusion. The varying allophonic behavior of /æ/ before /n/ emerges as one of the greatest differentiators between Seattle and Vancouver speakers, as will be discussed in more detail below.

6.1.3 /æ/ retraction in Seattle and Vancouver

Are Vancouver speakers retracting /æ/ in environments besides those which are pre-nasal and pre-velar? How do Seattle speakers compare?

Vancouver speakers show greater retraction before laterals than before fricatives and greater retraction before fricatives than stops. While laterals are associated with lower F2 values among both Seattle and Vancouver speakers, and this is expected due to coarticulation, Vancouver speakers also show significantly backer realizations of /æ/ before fricatives than before stops, which is not necessarily motivated by coarticulation. These differences between the two cities manifest as significant differences in normalized F2 values and significant differences in the shapes of the F2 trajectories across the duration of the vowel. Seattle speakers appear to engage in a coarticulatorily driven process of retraction, while Vancouver speakers seem to exaggerate retraction in both coarticulatorily predictable environments (before laterals) as well as phonetic environments that do not lend a strong coarticulatory motivation favoring retraction (before fricatives). This suggests a greater degree of phonologization for /æ/ retraction in Vancouver possibly in combination with a socio-historical difference for /æ/ before fricatives due to the TRAP-BATH split in the dialects of its founding settlers. In general, Vancouver speakers also showed more back realizations of /æ/ than Seattle speakers. The height dimension is not affected in /æ/ retraction.

6.1.4 /aʊ/ raising in Seattle and Vancouver

How do Vancouver and Seattle speakers compare with respect to pre-voiceless raising of /aʊ/?

Seattle speakers show some coarticulatory raising before tautosyllabic voiceless consonants, and this significantly affects primarily the F1 dimensions for /aʊT/ as compared to /aʊD/. Voicing of the following phoneme is not a significant predictor of F2 values, but does interact with duration to produce a small effect on F2. While there are some significant differences between /aʊT/ and /aʊD/, the size of the difference is very small. For Seattle speakers, /aʊT/ raising is very slight throughout the onset and midpoint and increases in degree at offset. Vancouver speakers show significant and much more sizeable differences on the F1 and F2 dimensions between /aʊT/ and /aʊD. These differences between /aʊT/ and /aʊD/ are present and large from onset, suggesting more than just hyperarticulatory raising before the voiceless consonant. Pre-voiceless /aʊT/ raising is robust and stable across age and sex sub-groups of the Vancouver population, with a subtle increase among Group 1 speakers. Vancouver speakers, in contrast to Seattle speakers, show more exaggerated and phonologized raising. In general, the difference between /aʊ/ realizations in Seattle and Vancouver is greater than the difference between /aɪ/ realizations.

6.1.5 /aɪ/ raising in Seattle and Vancouver

How do Vancouver and Seattle speakers compare with respect to pre-voiceless raising of /aɪ/?

Both Seattle and Vancouver talkers participate in /aɪ/ raising on the basis of significant differences on the F1 and F2 dimensions between their /aɪT/ and /aɪD/ tokens. Vancouver talkers show significant differences for both F1 and F2 between their /aɪT/ and /aɪD/ tokens. Group 1 women show more differentiation of these phonetic contexts than other Age and Sex sub-groups. The differences between /aɪT/ and /aɪD/ are evident at onset prior to the anticipated effect of hyperarticulation predicted before a voiceless consonant. For Seattle talkers, both F1 and F2 values for /aɪ/ are significantly affected by the pre-voiceless environment, but sub-groups may vary in the degree to which allophonic contrasts manifest on F1 or F2. For example, Group 1 women show more fronting before voiceless consonants, whereas other Age and Sex sub-groups show more raising. In other words, sub-sections of the population may use different strategies in processes like "raising." These differences do manifest at onset, suggesting that they are not only an effect of hyperarticulation. Still, there are significant differences between Seattle and Vancouver talkers in their degree of pre-voiceless /aɪ/ raising. Vancouver speakers have significantly lower F1 values and significantly higher F2 values for /aɪ/ as well as significantly steeper trajectories for these segments. While both cities seem to engage in more than the expected hyperarticulatory raising, Vancouver shows still more exaggeration and a greater degree of phonologization for these effects.

6.1.6 Meta-linguistic commentary about dialect features

Are these dialect features subject to meta-linguistic commentary by Seattle and Vancouver speakers?

No participants from Vancouver or Seattle mentioned retracted /æ/ as a feature of Vancouver English in their sociocultural survey responses. Raised pre-velar /æ/ was mentioned by several respondents in each city as a speech feature of their own city, though not necessarily the other city, raising a question about whether speakers conceptualized of raised /æg/ as *iconic* of the Pacific Northwest region and whether this *iconicity* extends inclusivity to their trans-border neighbors. More participants in Seattle commented on raised /æg/, though this may have been influenced by the exposure some participants had had to linguistics courses and even an NPR interview describing speech patterns of the Pacific Northwest (Wassink, et al. 2014). Pre-nasal raising (or lack of it) was not mentioned or described by any participants in either city. The traditional Canadian Raising diphthong /aʊ/ was often mentioned by Seattle respondents as *iconic* of the Canadian speakers, though /aɪ/ went entirely unmentioned.

6.1.7 Sociocultural (regional and national) identity and language ideology

What do the sociocultural identities of Seattle and Vancouver speakers suggest about their regional and national identities and their language attitudes?

Seattle and Vancouver speakers engage similarly with their regional pride and identity. They cite similar qualities of the Pacific Northwest and its inhabitants and express similarly strong connections to the region. Seattle and Vancouver subjects differ significantly with respect to their attachment to their national identity and sense of national pride. Vancouver speakers have both a strong sense of regional pride and an equally strong sense of national pride. Seattle subjects responded to questions about their national pride and national identity with more negative comments and more detachment from the concept of national identity. Seattle and Vancouver subjects also patterned differently with respect to questions about whether they perceive inhabitants of the other city to be similar or different to them. Vancouver subjects often described Seattle inhabitants as being very similar or "just the same" as them, and they typically stated that they would not be able to identify someone as being from Seattle if they overheard them talking. Seattle subjects, on the other hand, were quicker to say that they could identify someone as being from Vancouver and that they often noticed that Vancouver speakers sounded different than they did. In short, in their responses to questions about language attitudes, Vancouver speakers emphasized the trans-border similarities while Seattle speakers emphasized the trans-border differences. To use Gal & Irvine (1995)'s taxonomy, Vancouver speakers engaged more in ideologies of *erasure* while Seattle speakers engaged more in ideologies of *recursivity*, projecting the difference in nationality to distinctions at other levels of the system. The theoretical implications of this finding will be further discussed in the subsequent section about the asymmetrical language ideologies at the border.

6.1.8 Indexical relationship of phonetic and phonological features to social identities

How do phonetic and phonological features among Seattle and Vancouver speakers index overlapping regional, national or other local social identities?

Seattle and Vancouver speakers engage in some of the same phonetic processes such as /æg/ raising, but they are also differentiated by their participation in other phonetic processes such as pre-nasal raising, Canadian Raising of /aʊ/ and /aɪ/, and /æ/ retraction. From a distributional perspective, /æg/ raising is *iconic* of the Pacific Northwest region including both Seattle and Vancouver speakers, phonologized Canadian Raising and /æ/ retraction distinguish Vancouver speakers from Seattle speakers, and phonologized pre-nasal raising distinguishes Seattle speakers from Vancouver speakers. Seattle and Vancouver speakers manifest participation in phonetic processes that distributionally index their overlapping regional identities as well as distinctive processes associated with their national identity. This does not mean that the social meaning speakers associate with each of these features directly indexes regional or national identity.

6.1.9 Vowel formant trajectories for diagnostic dialect features

What can dynamic information like vowel formant trajectories explain about the conventionalization of phonetic processes and what does this say, in turn, about the *iconic* relationships of social meaning?

With respect to their differentiating features (pre-nasal /æ/ raising, /æ/ retraction, and Canadian Raising), Vancouver and Seattle speakers are distinguished not only by their normalized mean F1 and F2 values, but also by the vowel formant trajectories they exhibit. In these three cases, one city may be differentiated from the other by a more exaggerated trajectory (often steeper slope or parabolic shape) and an effect to F1 or F2 that manifests in a temporally earlier position. In other words, the cities contrast in terms of the degree of phonologization of the phonetic process. For pre-nasal raising, vowel trajectory comparisons reveal more phonologization for Seattle speakers. For /æ/ retraction, Vancouver speakers show more advanced phonologization. For the raising of diphthongs /aʊ/ and /aɪ/, vowel trajectories display a more exaggerated phonologized effect from onset among Vancouver speakers. These findings will be discussed further under Conventionalization of Social Meaning and Phonologization.

6.1.10 Language ideologies, border effects and phonetic features

Finally, how do Seattle and Vancouver speakers illustrate the processes of *erasure* and *fractal recursivity*? How does these affect their linguistic production? What does this suggest about the importance of ideology to language change around a national border?

Distributionally, raised /æg/ is a marker of a shared Pacific Northwest regional identity, while raising /æn/ occurs for Seattle speakers, and retracted /æ/ and raised /aʊ/ and /aɪ/ distinguish Vancouver speakers. It is not necessarily the case that Seattle and Vancouver residents index these traits to macro-sociological categories like "American" or "Canadian." Indeed, these phonetic processes are assumed to have locally-constructed and locally salient indexical meanings that may indirectly index their regional or national group membership (Eckert 2008). Furthermore, based on previous studies of social meaning by Campbell-Kibler (2005 and 2007), Seattle and Vancouver speakers are likely to show variation with respect to the social meanings they associate with these phonetic features, though this remains an area for future work.

Subjects' ideologies about the linguistic "sameness" of speakers of the other city were significant predictors of their realizations of /æ/ for analyses of retraction and raising. For Vancouver speakers as well as for Seattle speakers, speakers who perceived the other city as more linguistically similar to their own had a higher realization of /æ/ in the vowel space, less in-keeping with the predictions of the Canadian Shift. Seattle speakers who had higher ratings of perceived linguistic similarity of Vancouver residents also had more front realizations of /æg/, corresponding with more "raising." In other words, Seattle speakers who engage in ideological constructions of sameness are more participatory in this regional phonetic process common to both of the cities. In both cities, ideological constructions of sameness were also associated with less participation in the process of lowering believed to accompany retraction in the Canadian Shift.

6.2 Theoretical Implications

6.2.1 Dialect differentiation: the West and Canada

An underlying question of this work is to discover what features differentiate the dialect of English spoken by Seattle residents from that spoken just a few hours north, across the national border in Vancouver, B.C. This work identifies and addresses the shortcomings of previous analyses (namely, the ANAE) in which Canadian Raising and /æ/ retraction are cited as the dialect differentiators of Canada from the West. While Labov, Ash, & Boberg (2006) recognize that the West and Canada may be differentiated by quantitative differences in sound change participation, their methodology limits the insights they are able to offer. Findings from this study discuss Boberg's (2000) assertion that Seattle and

Vancouver have "identical phonological systems" and shed light on what the ANAE calls a difficult task of differentiating "the West" as a dialect region from "Canada." The current findings raise questions about the usefulness of traditional methods for dialect identification to sociolinguists interested in social meaning and argues for the vital role of dynamic vowel formant trajectories in describing dialectal differences, especially for dialects with largely similar phonological systems.

The most robust differentiators of Seattle and Vancouver speakers in this study are strong pre-nasal /æ/ raising among Seattleites and strong pre-voiceless raising of /aʊ/ and /aɪ/ among Vancouverites. Retraction of /æ/ in Vancouver is another differentiator, though this difference may be less striking than for pre-nasal raising and pre-voiceless Canadian Raising. While there are some statistically significant differences between the two cities with respect to /æg/ raising, they can be said to pattern more similarly than differently overall. In this sense, the findings are roughly consistent with the observations made in the ANAE (2006), which look primarily to /æ/ retraction and /aʊ/ and /aɪ/ raising as differentiators. Yet, the results of this research refute the over-simplified representation of dialectal features as binary features in which speakers of a geographical region either participate or do not participate in a particular phonological process. It is simply not accurate or sufficient to depict Vancouver speakers as participating in Canadian Raising, while Seattle speakers do not, nor is it sufficient to characterize Seattle speakers as participating in pre-nasal raising of /æ/ while Canadian speakers do not. As Labov, Ash and Boberg (2006) note, the differences between the two dialects are largely quantitative, but methods and findings from the current work reveal that may also be qualitative in nature. Recall Table 51 in Chapter 4 showing that Pacific Northwest speakers of Canadian English and American English "participate" in many of the same phonetic and allophonic processes. For instance, in the within city analyses, Seattle shows significant differences between the /aʊD/ and /aʊT/ environments and Vancouver shows significant differences between the /æd/ and /æn/ environments. Why, then, is it not accurate to say that Seattle speakers participate in Canadian Raising and Vancouver speakers participate in pre-nasal /æ/ raising? The answer lies in their degree of participation, which is a concept far more complex than the mean Hertz difference they show between mid-point measurements of /aʊD/ and /aʊT/ and midpoint measurements of /æd/ and /æn/, respectively. The degree of their participation is defined not only by the degree of allophonic contrast, but also by the subgroups of their populations showing the greatest participation in the processes, and, especially, the qualitative acoustic/articulatory patterns that emerge in their dynamic phonetic processes.

In one sense, what appears to be a quantitative difference between two dialects for a feature like pre-nasal raising (based on smaller allophonic /æd/ ~ /æn/ contrasts of midpoint measurements in one dialect than the other) is part of an underlying qualitative difference (distinctly different formant trajectory shapes for /æn/ in the two dialects), which traditional methods in dialectology have not been sufficient to discern, but which is certainly audible to a listener. Seattle speakers have a tense at onset and sharply in-gliding variant of /æn/, while Vancouver speakers have a much less tense realization, that is slightly up-gliding. With a clearer picture of qualitatively different acoustic manifestations of /æn/ "raising," it is no longer accurate to describe their differences as only "quantitative" in nature. This problem may be especially relevant when considering differentiators for dialects that have predominantly similar "phonologies" and rely on allophonic splits as differentiators, like Canadian and American English in the Pacific Northwest. It is not that Canadian speakers engage in Canadian Raising of /aʊ/ and /aɪ/ while American speakers do not; it is not only that Canadian speakers in the Pacific Northwest engage in raising of /aʊ/ and /aɪ/ to a quantitatively greater extent than American speakers in the Pacific Northwest, it is that they also do so in a qualitatively different way. On the other hand, it is not accurate to declare that Canadian speakers in the Pacific Northwest do not engage in pre-nasal raising, but their pre-nasal raising is qualitatively different than the pre-nasal raising of American speakers in the Pacific Northwest, and also manifests some quantitative differences.

The differentiation of Seattle and Vancouver English takes root in these qualitative differences that may appear to be quantitative differences when analyses do not distinguish the vowel's phonetic environment and consider only a single measurement point in a vowel's trajectory. Yet, research has shown that these qualitative and gradient differences are perceptually salient enough to provide contrasts that may be indexed to social meaning (Koops 2010a, 2010b). While Labov, Ash, and Boberg (2006) acknowledge this gradient difference, their methodology does not employ techniques for analyzing the potential qualitative differences visible at the level of vowel-inherent spectral change. Furthermore, they seem to imply that these gradient differences do not, in and of themselves, constitute distinct "phonological" systems that merit the division of a dialect. This may be true if the concept of a dialect area serves only as an abstract concept for linguists who want to describe macro-level patterns of sound change, but how useful is this notion of a "phonological" system, if it does not correspond with the contrasts that exist acoustically and the socio-indexical meaning speakers attribute to them? Sociolinguists have long relied on macro-level descriptive studies of abstract phonological systems, but also cite as a critical distinguishing factor the allophonic (deemed "phonetic") behavior of certain vowels like /æ/, in particular. Indeed for the current sample, the allophonic behavior of /æ/ with respect to retraction and pre-nasal raising plays a major role in differentiating Vancouver from Seattle speakers. Failure to privilege allophonic variation as part of the abstract "phonological" system results in dialect areas that are excessively large and do not capture the salient qualitative allophonic differences that listeners draw on in their social judgments and perceptions. The current findings make clear that describing Seattle and Vancouver as part of a "Third Dialect" area based on their "identical phonologies" does not do justice to the variation between them. Macro-level dialectal studies may hold some value, but for sociolinguists who are more focused on understanding socio-indexical meaning and specific processes involved in sound change, both the qualitative and quantitative contrasts are vital and must be considered. The most critical way to incorporate these qualitative differences between allophonic processes into dialect differentiation is to use vowel-inherent spectral change information to consider the degree of conventionalization or phonologization that they exhibit for the "allophonic" features in question and to use this information to establish which allophonic features should be included as phonological ones.

6.2.2 Vowel-inherent spectral change in dialectal and social variation

Seattle and Vancouver speakers show significant differences in the vowel formant trajectories for pre-nasal /æ/ as well as diphthongs /aʊ/ and /aɪ/ and /æ/ before fricatives and laterals. For some features, age and sex sub-groups in the within-city analyses patterned differently from their within-city counterparts with respect to vowel-inherent spectral change. These findings are in-keeping with work by variationist sociolinguists who have illustrated differences in vowel-inherent spectral change across speakers of different dialects and across different ethnic, generational or gender groups of the same dialects (DeDecker & Nycz 2006, Fox & Jacewicz 2009, Scanlon & Wassink 2010, Koops 2010a, Koops 2010b, Holt 2011, Jacewicz & Fox 2012, Risdal & Kohn 2014). For Seattle and Vancouver speakers, these formant trajectories represent qualitative differences between the dialects primarily by capturing the degree of phonologization that these allophonic processes exhibit in the two dialects. Findings from the phonetic analyses demonstrate the various phases involved in the conventionalization of a phonetic process and how these may relate to socioindexical meaning and sound change. The results highlight the complexity of assessing phonetic processes such as pre-nasal, pre-velar, and pre-voiceless "raising" and the need for precise terminology. To accurately comment on these distinct acoustic processes (all lumped under the same name) and their degrees of phonologization, dynamic analyses are imperative. Specifically, the analyses of the three raising phenomena confirm Wassink (2015a)'s finding that speakers may vary within and across communities with respect to their strategies and realizations of a "conventionalized" phonetic effect. The three phonetic processes taking place in each city illustrate the discrepant outcomes of a "phonetic universal" in two different communities while simultaneously showing, in a within-city comparison, the different stages of development that may exist in the conventionalization of a phonetic process or, as Wassink calls it, "going public."

6.2.3 Phonetic vs. conventionalized vs. phonologized

In each of the cases examined here the phonetic effect is conditioned by the following consonant, so conventionalization or phonologization is evident the more this exaggerated phonetic effect alters the portion of the vowel preceding the mid-point. For instance, if a following nasal triggers a lowering of F1 values for the preceding vowel, the lowering of the vowel from onset *prior to* any coarticulatory effect of the nasal at offset, then Hyman's first diagnostic for "phonologization" is satisfied. When this pattern holds across some substantial portion of the population, the phonetic effect is said to be phonologized. Findings from the phonetic analyses in Seattle and Vancouver align with three levels of phonologization: phonetic universals, conventionalized patterns and phonologized ones.

Within the Seattle community, then, pre-nasal and pre-velar raising are both at least conventionalized patterns, while pre-voiceless raising of diphthongs /aʊ/ and /aɪ/ remains a phonetic effect. Yet, as the trajectory analyses show, pre-velar and pre-nasal raising in Seattle do not share the exact same status. Pre-nasal raising exhibits a greater degree of phonologization across the community than pre-velar raising as evidenced by the pre-nasal degree of raising (lower F1 and higher F2 values), the earlier temporal location of the effect, and the consistency or lack of variation it exhibits across the population. In the Vancouver community, on the other hand, pre-voiceless raising of diphthongs /aʊ/ and /aɪ/ and pre-velar raising are at least conventionalized patterns, while pre-nasal raising is realized more like a phonetic universal. Like pre-nasal raising in Seattle, diphthongs /aʊ/ and /aɪ/ in pre-voiceless position for Vancouver speakers show greater changes to F1 and F2, greater temporal distance from the conditioning environment and consistency across the population. It is no surprise that they are labeled as phonologized processes. The status of these phonetic/phonological processes are summarized below:

	PHONOLOGIZED		CONVENTIONALIZED		PHONETIC
SEA	Pre-nasal raising	>>	Pre-velar raising	>>	Pre-vcls raising
VAN	Pre-vcls raising	>>	Pre-velar raising	>>	Pre-nasal raising

Figure 41. Phonologization of diagnostic dialect features in Seattle and Vancouver

While it is clear that pre-nasal raising among Seattle speakers and pre-voiceless diphthongal raising among Vancouver speakers are phonologized in their respective communities, it is equally clear that pre-velar raising of /æ/ does not quite reach this status in either community. It seems to meet some of the criteria for phonologization, but perhaps not to the same degree as the phonologized processes discussed above. Pre-velar /æ/ raising in both communities is exaggerated beyond what could be considered a universal phonetic effect and its phonetic effect is observed as temporally distant from its trigger, though not entirely disconnected from it. Furthermore, the degree of consistency for /æg/ raising across the populations is less stable for Seattle than the consistency of /æn/ raising and less consistent in Vancouver than is /aʊ/ and /aɪ/ raising. For the synchronic window of observation available at present, it seems appropriate to deem pre-velar raising a conventionalized process in both Seattle and Vancouver.

At the other end of the spectrum, each city provides a case illustrating the presence of a phonetic effect that does not seem to be conventionalized or phonologized. These processes are typically considered to be automatic and not under speaker control. In Seattle, pre-voiceless tokens of /aʊ/ and /aɪ/ do have lower F1 values at offset than their pre-voiced counterparts, but the degree of this difference is relatively small and it does not temporally extend toward onset of the segment. In Vancouver, pre-nasal realizations of /æ/ raise temporally as they approach offset illustrating the coarticulatory effect of the following consonant. The effect is not, however, temporally distant from the conditioning consonant, nor is the effect anywhere near as great as that observed for /æg/ in contrast to /æk/. These two phonetic processes provide excellent contrast to the aforementioned conventionalized and phonologized processes. Speaking diachronically, conventionalization and phonologization of phonetic processes occur over time and may even follow a cycle. As findings from the current study show, there is a wide gray area between the characterization of phonetic processes and phonologized ones, again necessarily involving dynamic formant analyses, and this variation may itself establish a contrast between two dialects.

6.2.4 Methodological issues and terminological discrepancies between subfields

The contrast discussed above between coarticulatory phonetic effects and phonologized processes also reveals a differential use of terminology by linguists of different subfields and argues strongly for precise descriptions based on dynamic analyses of formant trajectories. In a sense, the issue lies in the inherent complexity of variation, and the restricted meaning this has come to have in sociolinguistic inquiry. A vowel (or any segment) may exhibit 1) variation over the duration of the segment, 2) allophonic variation in a certain conditioning phonetic environment, 3) diachronic variation over time between younger and older speakers, and 4) diatopic variation across geography between speakers from two different dialects. To further complicate matters, phoneticians tend to place more emphasis on the first two types of variation mentioned while sociolinguists or sociophoneticians may place more emphasis on the second two types. As a result, conventional terms for phonetic or phonological processes may be interpreted differently by researchers of different sub-fields.

To illustrate, terms used to label phonological processes like "raising" or "retraction" can have at least four distinct interpretations:

1) "Raising" may refer to changes over the vowel's duration in a physiologically driven coarticulatory way with specific movements at offset that manifest this. For instance, "/æ/ is raising before voiced velars" means that /æ/ is showing a lower F1 value at offset and sharper lowering of F1 before /g/ as compared to before other phonetic environments, including /k/.

2) "Raising" may also refer to changes from onset of a vowel in a particular phonetic context that indicate a phonologized or exaggerated realization of a coarticulatory effect. For example, /æn/ is strongly "raised" for Seattle speakers, but not for Vancouver speakers means that from onset, /æn/ has a higher & fronter position in the vowel space with high F2 and low F1 values *before* the anticipated effect of coarticulation affects the offset of the segment.

3) "Raising" may also refer to changes in apparent time to the vowel space position of particular sub-groups of speakers such as older speakers or younger speakers. For example, "/æ/ is raised among younger speakers" could mean that /æ/ is higher in the vowel space now than it used to be without the effect of any particular conditioning environment. This observation might be used by sociolinguists as evidence of a change in progress.

4) Finally, the same type of difference between speakers different geographic

locations is often used to distinguish dialects as in "American speakers have a raised /æ/ as compared to Canadian speakers." The polysemous nature of "raising" in these four distinct examples is problematic in the sense that none of the four meanings of "raising" (or "raised") entails any of the other three interpretations. Furthermore, each of the four meanings for "raising" requires distinct methods and analyses to be established.

In addition, the contrast between two of the polysemous meanings of "raising" reveals a paradox of the phonologization process: when a phonetic, coarticulatory effect is lost in favor of an exaggerated and conventionalized realization, the terms used to describe it in the first place may cease to be, strictly-speaking, accurate, or may involve a semantic shift of sorts. For instance, what is labeled as pre-nasal "raising" among Seattle speakers now actually describes an acoustic falling and backing of the segment over its duration as it approaches the following nasal. In this case, the phonologized process likely began as a coarticulatory process by which a lowering of the velum produced a lower F1 value for the vowel preceding a nasal consonant. During some past stage, a pre-nasal vowel was synchronically raising in the vowel space over its duration, much the way the Vancouver /æn/ is realized now. Through subsequent reanalysis, the raising effect began earlier and earlier in the vowel segment and became increasingly exaggerated until, as our current analysis shows, the Seattle /æn/ vowel began in such a high and front position that it could only back and fall over its duration toward its so-called "phonetic" trigger. The singular use of "raising" then refers to two completely different processes among Seattle speakers on one hand and Vancouver speakers on the other. This highlights the need for precise language and temporally-sensitive analyses in teasing apart the differences between these types of changes too often labeled similarly and monolithically as “raising” or “retraction." Terms like *phonologized raising* may be more accurate to describe pre-nasal raising in Seattle, while *phonetic* or *coarticulatory raising* may more accurately describe pre-nasal raising in Vancouver.

6.2.5 Relationship between phonetic form and social meaning

What does this matter to the sociolinguist and what can it say about sound change? Besides the obvious cautionary word for sociolinguists to ensure that their language is accurate and consistent with that of phoneticians, sociolinguists find here additional motivation to better understand the dynamic temporal properties of a segment given the evidence they provide for the various phases of sound change.

Wassink (2015) speaks to the “conventionalization” of a universal phonetic pattern occurring in pre-velar raising among Seattle speakers. She also observes that different speakers in a community use distinct strategies to phonetically and acoustically realize a target that becomes increasingly a question of transitional formant trajectories and less a question of midpoint values as conventionalization progresses. Likewise, Wassink & Riebold (2013) explain that when a phonetic process is no longer phonetically predictable, it becomes conventionalized and may serve to differentiate styles and registers, ages, sexes, or dialect groups (Wassink & Riebold 2013). These socio-indexical uses may in turn be subject to changes in socio-evaluative meaning.

In a sense, a phonologized pattern may hold less appeal for a sociolinguist than a conventionalized one. A phonologized pattern with consistency across the population provides evidence for a macro-level dialect differentiation, but may offer less information about a change in progress and may be a less salient carrier of social meaning within a community because it ceases to entail a contrast with another local group of speakers. For example, a strongly phonologized pattern stable across the population such as pre-nasal /æ/ raising in Seattle or Canadian Raising of diphthongs in Vancouver may hold meaning as a dialect marker to the outside group, but may not be indexed in socially meaningful ways for the in-group to perceived local contrasts. An intermediary feature like raised /æg/ that shows conventionalization, yet more variation across the population, may serve as a better carrier of locally-contrastive social meaning. In the progressive stages of phonologization, if in the following generations /æg/ raising continued to become more exaggerated, earlier in the segment and more stably distributed across all sub-groups of the population, it might lose its value as an index of locally-contrastive social meaning. It would hold value as a dialect marker, as /æn/ does currently, perhaps identifying the Pacific Northwest as a whole but would be less apt to index contrasts within Seattle or Vancouver. The social meanings currently associated with conventionalized /æg/ will be addressed in the subsequent sections.

6.3 The Role of Language Ideologies in Sound Change

6.3.1 Asymmetrical Language Ideologies at the Border

A central question of this work is to determine to what extent phonological processes and developments on either side of the U.S.-Canadian border in the Pacific Northwest parallel one another, to better understand the social identities of speakers in either city, and to determine how social identities and language ideologies relate to linguistic production for Seattle and Vancouver speakers. The strong sense of regional solidarity is evident in speakers' descriptions of the other city and the characteristics and qualities they describe about the region and its inhabitants are very consistent. Despite the solidarity and similarly articulated social identities for Seattle and Vancouver speakers, the findings reveal an asymmetry in their language ideologies. Vancouver speakers view themselves as more similar linguistically and culturally to Seattle than Seattle views itself as similar to Vancouver. It should be noted that culturally, this was not accompanied by negative implications about the differences, though this may be less the case for their language ideologies. Seattle speakers identified many positive differentiators for Vancouver in terms of culture, especially the ideas of being more inclusive with respect to diversity, more international and more cosmopolitan. On the other hand, their responses, comments and stereotypes about the linguistic characteristics of Vancouver speakers revealed ideologies of perceived difference. Vancouver speakers saw and described far fewer differences linguistically between their own speech and the speech of Seattle speakers, almost never commenting on the features that truly differentiate Seattle speakers from them such as pre-nasal /æ/ raising. They embraced ideologies of perceived sameness. This is not surprising given that in the prevailing social order dialects of American English spoken in the U.S. are more likely to carry the status of a continental, and even global, standard and that Canadian speakers are much more likely to have exposure to Standard American English than American speakers are to Canadian English. Nonetheless, it is an important reminder that language ideologies in border contexts may be asymmetrical and may not involve the same degree of perceived difference for those on each side. In cases where these asymmetrical ideologies exist, they can be important predictors of directionality for a change in progress.

6.3.2 Language ideologies as a predictor of participation in regional sound change

As both Auer (2005) and Irvine & Gal (2000) suggest, the social psychological and cognitive processes of identifying speakers on the other side of the border as "different" are predictive of linguistic behavior. Results from the current study confirm that language ideologies of sameness do significantly predict participation in local sound changes. In this case, Seattle subjects' ratings of perceived sameness of Vancouver talkers are associated with greater participation in a regionally-defining phonetic process: (/æg/ fronting). With respect to /æ/ in all non-nasal environments, both cities show a similar effect of perceived sameness on the height of /æ/. For both Vancouver and Seattle speakers, declarations of the other city's perceived sameness were associated with higher /æ/ vowels (lower F1 values). Given that retraction and lowering of /æ/ are documented aspects of the Canadian Shift, this implies that perceived sameness entails less participation in the Canadian Shift among Vancouver speakers as well as Seattle speakers. Again, this finding seems to imply an asymmetrical enactment of perceived sameness on either side of the border. While *sameness* is associated with the salient defining trans-border feature of the region (/æg/ raising) for Seattle speakers, it is negatively associated with the proto-typically cited Canadian change in progress for /æ/ among both populations. This suggests that while perceived sameness is related to increased use of regional dialect markers that unify Vancouver and Seattle, the underlying standard does pull toward the Seattle side, or a more "American" pronunciation. Of course, this similar effect of perceived sameness in the Seattle and Vancouver populations could also have independent explanations or contrasts based on more localized social meanings that were not discovered here. Perhaps the association between perceived sameness with Seattle and higher /æ/ position for Vancouver speakers actually entails a contrast with speakers of other Canadian dialects, namely those in which the Canadian Shift is more advanced, such as Toronto. In this sense, the results do not confirm that perceived sameness with Seattle speakers entails directly a resistance to "Canadian" features in favor of "American" ones. More research is needed to better understand the socio-indexical values of these features in their local contexts.

It is also important to note here that perceived sameness is not a significant predictor of other phonetic features, most notably those that operate on the basis of coarticulatory phonetic universals, nor is it a predictor of those that are strongly phonologized in the respective populations. This supports the idea proposed above that *conventionalized* patterns which still vary and display signs of a change in progress throughout the population are better candidates for locally-contrastive socio-indexical meaning than either the phonetic universals or the phonologized features. If language ideologies like *fractal recursivity* and *erasure* are indeed motivators of language change in border situations, they are expected to affect phonetic features currently exhibiting variation in the population or changes in progress.

6.3.3 Linguistic and cultural convergence at the U.S.-Canadian border?

Despite their asymmetrical ideologies and the reported association of sameness with a seemingly less Canadian-shifted realization of /æ/ for Canadian speakers, the findings do not support what could accurately be called "convergence" of one dialect toward the other. Canadian linguists have been concerned for some time about the loss of distinctively Canadian English features (Zeller 1993, Woods 1993, Chambers 1998, Nylvek 1992, Warkentyne 1971 and Scargill 1957 & 1974). Findings from the current work suggest that in regions with strong trans-border solidarity, such as the Pacific Northwest, Canadian and U.S. English dialects may share certain phonological features as dialect markers, but this does not entail wholesale linguistic or cultural "convergence" on the part of Canadians with their American neighbors south of the border. Even in this region with strong solidarity and trans-border affinity, Vancouver speakers continue to differentiate themselves through the robust presence of "Canadian" features like pre-voiceless /aʊ/ and /aɪ/ raising and /æ/ retraction. Predictions of wholesale convergence are missing the critical social function of language to both *unite* and *differentiate*. The observed presence of /æg/ raising throughout the Pacific Northwest does not necessarily entail the "convergence" of Canadian English with American English.

It should also be noted that there is no definitively established direction of change for pre-velar raising in Seattle and Vancouver, and they may have had a similar origin based on settlement patterns. That is to say, it is almost certainly not the case that this feature was directly borrowed from Seattle by Vancouver speakers. While /æg/ raising in Seattle has been the subject of more sociolinguistic inquiries in recent years, it has also been previously mentioned for B.C. and attested in other parts of Alberta and Saskatchewan. Yet, findings from the current study also discover more extreme /æg/ raising than previously reported for Vancouver, as well as a sharp increase among Group 1, female speakers suggesting that this trend has recently been intensified. Given distinct methods of analyses, though, and little availability of longitudinal or apparent-time data, this is somewhat difficult to confirm. Again, it is difficult to pinpoint whether the recent intensification of /æg/ raising among Vancouver speakers is related to its prevalence among Seattle speakers. Regardless of its origins, it may be more likely that raised /æg/ has different socio-indexical values for Vancouver and Seattle speakers, as the following section will discuss.

6.3.4 Variation between emically-defined age groups and direction of change

The current study does not pretend to employ sampling methods sufficient to truly document apparent time changes in progress as it collects data from young adults speakers belonging to only two age brackets (18-25 and 26-36). These do not constitute generations of speakers by traditional definitions, but do represent two different groups in terms of life experience. Most notably, Group 1 speakers could be described as collegiate speakers who had not yet started their own families. Group 2 speakers would more accurately be described as working young adults, many of whom had also started their own families. The findings confirm that speakers in a community who do not show large differences in their chronological ages may still show meaningful variation in usage that correspond with their social experiences and emically-defined age categories. Quantitative and qualitative differences emerge in the participation of the two groups with respect to the five phonological processes examined. These differences emerge both within cities as well as across cities and are audible to the listener. For /æn/ raising, in particular, Seattle speakers produce a sharply in-gliding variant, while Vancouver speakers produce a more retracted, slightly upgliding variant. For Vancouver, pre-velar and pre-voiceless raising phenomena are high among Group 1 speakers. Group 1 speakers show higher pre-velar /æg/ raising as well as greater differentiation of the diphthongs /aʊ/ and /aɪ/ in pre-voiceless environments than their Group 2 Vancouver counterparts. The difference between the groups is quite sizable for /æg/ raising and more subtle for /aʊ/ and /aɪ/ raising. For Seattle, raising phenomena (other than pre-nasal raising) are very low among Group 1 speakers, and in particular, among women. Group 1 speakers show less pre-velar /æg/ raising than their Group 2 counterparts, and Group 1 women show this very strikingly. These findings are complex and may parallel those found by Freeman (2013), though Freeman considers data from a more expansive group of speakers in terms of age. While there are quantitative differences in the degree of raising exhibited by Group 1 Seattle females and their male and Group 2 counterparts, it is not accurate to state that females are not participating in raising. Significant differences in the pre-velar and non-pre-velar phonetic environments persist, which do not seem to be driven by coarticulatory processes. It is more accurate to say that Group 1 Seattle females show significantly less raising with respect to other sub-groups of their city's population, while the opposite is true for Group 1 Vancouver women. In both cities, Group 1 speakers tend to show larger standard deviations for their means than Group 2 speakers.

The contrasting developments in /æg/ raising with respect to age and sex sub-group may not necessarily indicate long-term sound change. Instead, they may evidence the variable way in which experientially-defined age groups make use of the sociolinguistic resources in the community. The variation between Group 1 and Group 2 patterns comparing Seattle and Vancouver suggests that the social meanings of raised /æg/ are distinct for these speakers. For Group 1 females in Vancouver, /æg/ and /aʊ/ raising seem to relate to an expression of a locally-salient identity, while this seems less the case for young Seattle females. The greater extent of /æg/ raising among Group 1 Vancouver females may also be indicative of more vernacular usage and less pressure to follow a pronunciation norm than for Group 2 Vancouver speakers. Given these patterns and the meta-linguistic commentary attributed to it in sociocultural interviews, it may be that /æg/ has acquired a more negative socio-evaluative meaning among Seattle speakers than it has among Vancouver speakers. Riebold (2015) also suggests that this may be the case for Seattle speakers. Socio-cultural interviews from the current work also reveal greater meta-linguistic awareness among the Seattle population as compared to Vancouver. The socio-indexical meanings speakers from each city construct for /æg/ raising will be an important subject for future inquiry.

It is not entirely clear how the variation observed between these two emically-defined groups relates to long-term sound change. The patterns do raise a question about whether Seattle and Vancouver speakers may be headed in different directions with /æg/ raising. Given the belief that women often lead sound change (Labov 2001), the fact that young women in Seattle and Vancouver display contrasting trends with respect to pre-velar raising brings up questions about the direction of change that may be transpiring in the respective cities. That is, if young females are expected to lead language change, this predicts a future increase in raising among Vancouver speakers and a reduction in raising among Seattle speakers. On the other hand, pre-velar raising in Seattle has been steady and noted for well over half a century, and it is plausible that a situation of stable sociolinguistic variation has existed throughout this time and will persist in the future. As aforementioned, detailed historical data documenting pre-velar raising are not readily available for Seattle or Vancouver, so it is difficult to say whether a situation of sociolinguistic variation has existed or been stable over time. Boberg (2010) reports that B.C. speakers are raising /æg/ and /æn/ to the same extent, which is not consistent with the findings from this study. If Boberg's observations of B.C. are taken at face value despite the methodological differences with the current study, it appears that there has been a more recent surge in /æg/ raising among younger (Group 1) female speakers in particular. Whether the synchronic variation in these two emically-defined groups will be sustained as a long-term sound change requires ongoing documentation.

Overall, findings from the current study suggest that language ideologies and social identities should be considered as a potential predictor of sound change in cross-border scenarios. With data from Detroit, MI and Windsor, ON, Boberg (2000) describes the inability of typical models of sound change like Trudgill's (1974) gravity model to account for resistance to language change across a national border. He proposes that a "border" factor needs to be incorporated to account for the resistance created by the national border. This may well be so, but the national border is not a monolithic entity, which argues for the further inclusion of a term specifying the strength and history of trans-border regional solidarity and language ideologies of residents for the area in question. The shared affinity and solidarity Pacific Northwest speakers have for their region has linguistic parallels and may lead to distinct outcomes as compared to a situation in which speakers lack a strong regional identity or hold a potentially hostile view of their trans-border counterparts. While it may not be entirely accurate to represent /æg/ raising as a case of trans-border linguistic borrowing, the strong use of /æg/ raising among both Vancouver and Seattle speakers at present illustrates the existence of a trans-border dialect marker whose usage and distribution is associated with this specific region of the continent.

Chapter 7

7 CONCLUSION

7.1 Summary

This dissertation presents phonetic analyses from five diagnostic variables of English spoken by Seattle, WA and Vancouver, B.C. natives in the Pacific Northwest (/æg/ raising, /æn/ raising, /æ/ retraction, /aʊ/ and /aɪ/ raising), illustrating that these features serve to both unite and distinguish the dialects spoken on either side of the U.S.-Canadian border. This work shows relative consistency between Seattle and Vancouver speakers with respect to /æg/ raising, while /æn/ raising, /aʊ/ and /aɪ/ raising, and /æ/ retraction emerge as contrasting features of the dialects. Vancouver and Seattle speakers show asymmetrical language ideologies that significantly affect their participation in conventionalized local sound changes. These findings reveal that the dialectal differences between Seattle and Vancouver English are not limited to quantitative differences based on their participation in the same sound changes, but that this quantitative difference is itself in some cases, an underlying qualitative difference. This argues strongly for incorporating allophonic differences into dialect differentiation by using time-sensitive formant analyses to identify the degree of phonologization diagnostic variables exhibit. Conventionalized patterns (those residing between phonetic universals and phonologized features) play a major role in dialect variation and are prime candidates for the construction of socio-indexical meaning. All in all, this work illustrates the complexity of local to macro-levels of identity and identifies their distributional linguistic parallels.

7.2 Future Directions

In the interest of understanding how sociophonetic variation indexes social meaning, these findings seem to leave more yet to do than has already been done. First, it would be useful to conduct social meaning studies to better understand the locally-constructed socio-evaluative meanings associated with the phonetic processes described here for speakers of Seattle and Vancouver English. This might be aptly combined along with more 3rd-wave style studies; observing the variable situational use of phonetic features would be valuable in understanding their socioindexical meaning and further clarifying the role between regional and stylistic variation. Secondly, given the critical importance of dynamic vowel formant trajectory information in establishing these as conventionalized or coarticulatorily motivated processes, it would be enlightening to explore the value of the formant trajectory to the perception of socioindexical meaning. If conventionalization of a phonetic process entails a change in the vowel trajectory, and if conventionalization of the process makes it available for use as an sociolinguistic marker, the perception of its meaning must be dependent on a listener's access to the trajectory. Again, more studies are needed to establish the role of the formant trajectory in social meaning. Finally, the role of Vancouver's sizable population of ethnic speakers in the observed sound changes and phonetic processes remains to be explored in detail.

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Appendix A.

Word List Reading Task

Thank you for agreeing to participate in this research study of speech in the Pacific Northwest. The study is being conducted by Julia Thomas Swan, Ph.D. candidate at the University of Chicago, under the supervision of Alan Yu (IRB13-0041). Your participation is entirely voluntary and you may stop at any time. The task will take approximately one hour. In Part A, you will be asked to read a short list of words three times each. In Part B, you will be asked to read a longer list of words 3 times. After each repetition of the list, you will be asked a few questions about your thoughts and experiences living in Seattle/Vancouver.

Part A

Please read each of the following words aloud one at a time in the sentence “Say X again.” You will be asked to repeat the list 3 times.

Example:
dog
“Say dog again.”

heed	hard	who’d
hid	hair	hood
hayed	hired	hoed
head	hide	hawed
had	how	hod
hud	ahoy	
herd	hued	

Part B

Please read each of the following words aloud one at a time in the sentence “Say X again.” You will be asked to repeat the list a total of 3 times.

Example:
dog
“Say dog again.”

devout	kite	tag
calves	drape	tokens
growl	path	cat

hate
line
bout
pine
pace
pays
keg
height
Stout
bat
tail
Abe
head
adapt
browse
bath
addition
paid
death
tight
pies
Bethesda
tap
gap
stayed
eighth
aim
bide
blaze
Rep
time
stripe
jive
nebulous
Kate
ate
staff
spies
tied
pipe
bake
type
fade
gent
South
finnagle

debt
tack
neck
state
pain
beg
bait
cage
dyke
typist
album
evergreen
gape
night
bible
stallion
Bagdad
bagel
Ace
pail
theft
housed
Dad
haggle
loud
as
tightest
pile
dame
bad
stat
ice
Kyle
fan
vague
heck
plows
bowed
leapt
said
plague
base
let
left
made
desert

bounds
ties
check
pen
ebb
guide
owl
access
deck
side
cab
pack
strife
den
dab
couch
crowed
cake
bowels
deaf
peg
tape
imbibe
hybrid
back
Gabe
paddle
lake
ask
aisle
ape
tan
pet
fowl
dice
kept
pound
typer
hat
endeavor
tax
tile
tribe
clowns
pebble
kale

set
sign
Meg
eyes
waif
mouth
out
gouge
athlete
stab
bile
Ben
age
help
had
depth
pad
A’s
talc
Deb
dagger
spell
cane
cap
babe
peck
cape
foust
cashmere
tab
add
allowed
heaven
tribal
egg
spouse
bet
take
aid
title
town
wipe
psych
travels
table
bounce

pan
pike
Labe
bite
tyke
lead
denied
fathom
bag
at
Dell
bell
mouthed
calcium
spice
dead
towels
can
scribe
ache
tend
wave
ale
stain
shroud
nice
hype
lab
pal
bike
flout
accept
tell
Dale
kind
hack
February
apt
bed
load
road

Appendix B.

Sociocultural Identity Survey

Do you identify as male or female?
How old are you?
Where are you from?
Where were you born and where did you grow up?
Where were your folks born? Your grandparents?
What is your native language?
Do you speak any other languages?
Do your parents speak any other languages?
What city do you live in? What neighborhood?
What is your occupation or livelihood?
Would you consider your upbringing working class, middle class or upper class?
Would you consider yourself currently working class, middle class or upper class?
What is the highest level of education you have completed?
Have you ever lived away from Seattle [Vancouver]? If so, where and for how long?
Do you feel that you have a national identity? If so, what is it?
Do you consider yourself a Pacific Northwesterner?
How do you think Seattle and Vancouver are similar? How are they different?
On a scale of 1 to 7, how similar do you think Seattle and Vancouver are? (1 =not very, 7=very)
On a scale of 1 to 7, how similar do you think Vancouver and Toronto are? (1 = not very, 7 = very)
On a scale of 1 to 7, how similar do you think Seattle and Portland are? (1 = not very, 7 = very)
Do you think social, economic and environmental policies should allow for sharing of resources and capital between Seattle and Vancouver?
On a scale of 1 to 7, how much do you like the city you live in? (1=not very much, 7 = very much)
On a scale of 1 to 7, how interested would you be in moving elsewhere? If so, where? (1=not very, 7 = very)
On a scale of 1 to 7, how proud do you feel of the city you currently live in? (1=not very, 7 = very)
On a scale of 1 to 7, how likely would you be to visit [other city]? (1=least likely, 7 = most)
On a scale of 1 to 7, how closely do you follow sports in Seattle [Vancouver]? (1=not very, 7 = very)
What types of sports do you follow? As a kid, did you play any sports?
On a scale of 1 to 7, how often do you read local publications like newspapers, magazines or event guides in Seattle [Vancouver]? (1= not very, 7 = very)
Which ones do you read?
Are you a member of any clubs or groups in Seattle [Vancouver]? Which ones?
On a scale of 1 to 7, how often do you purchase goods or services from local businesses? (1= not very often, 7 = very often)
On a scale of 1 to 7, how important is it to you to buy from Seattle [Vancouver]-based businesses? (1=not very, 7 = very)

On a scale of 1 to 7, how often do you purchase goods or services from the Pacific Northwest outside of the city where you reside? (1=not very often, 7 = very often)
On a scale of 1 to 7, how important is it to you to buy from Pacific Northwest-based businesses? (1=not very, 7 = very)
Do you every notice that people from Vancouver [Seattle] speak differently than you do? What do you notice about their speech?
Do you notice anything in particular about the way people speak in Seattle [Vancouver]?
Who are the members of your immediate family? Where do they live?
Who do you live with?
Who do you text, call or correspond with on a daily basis outside of work? Where do they live?
Are there other folks you correspond with regularly for work? Where do they live?
If you needed personal advice about a problem, name 3 people you would you call for help. Where do they live?

This is the end of the task. Thank you for your participation in this study.

Appendix C.

Mixed-Effects Linear Regression Models and Results

Pre-velar Raising

F1

```
F1.lmerG <- lmer(normF1 ~ FollowingPhone*as.factor(AgeGroup)*Sex +
Position.ord*FollowingPhone*Sex*normdurms + (1 + Position.ord | Name) + (1|Word),
data=SEAae1)
```

Table 55. Full F1 model of /æg/ vs. /æk/ in Seattle

	Estimate	Std..Error	t.value	p
(Intercept)	0.662	0.12	5.31	< 1e-04
FollowingPhonek	0.487	0.07	7.05	< 1e-04
as.factor(AgeGroup)2	-0.434	0.15	-2.81	0.005
SexM	-0.470	0.17	-2.83	0.005
Position.ord.L	-0.927	0.07	-12.61	< 1e-04
Position.ord.Q	-0.533	0.05	-9.82	< 1e-04
Position.ord.C	0.055	0.05	1.21	0.227
Position.ord^4	0.021	0.04	0.48	0.633
normdurms	-0.001	0.02	-0.04	0.965
FollowingPhonek:as.factor(AgeGroup)2	0.702	0.05	14.49	< 1e-04
FollowingPhonek:SexM	0.467	0.05	8.65	< 1e-04
as.factor(AgeGroup)2:SexM	0.236	0.22	1.07	0.282
FollowingPhonek:Position.ord.L	0.757	0.06	12.69	< 1e-04
FollowingPhonek:Position.ord.Q	0.317	0.06	5.31	< 1e-04
FollowingPhonek:Position.ord.C	0.105	0.06	1.76	0.078
FollowingPhonek:Position.ord^4	0.011	0.06	0.19	0.848
SexM:Position.ord.L	0.105	0.10	1.00	0.316
SexM:Position.ord.Q	0.113	0.08	1.46	0.145
SexM:Position.ord.C	0.001	0.06	0.01	0.988
SexM:Position.ord^4	0.010	0.06	0.16	0.871
Position.ord.L:normdurms	0.143	0.04	3.84	0.000
Position.ord.Q:normdurms	-0.086	0.04	-2.31	0.021
Position.ord.C:normdurms	-0.057	0.04	-1.54	0.125
Position.ord^4:normdurms	-0.006	0.04	-0.17	0.868
FollowingPhonek:normdurms	-0.069	0.03	-2.18	0.029
SexM:normdurms	0.004	0.02	0.15	0.879
FollowingPhonek:as.factor(AgeGroup)2:SexM	-0.250	0.07	-3.56	0.000
FollowingPhonek:SexM:Position.ord.L	-0.155	0.09	-1.80	0.071

Table 55. (continued)

FollowingPhonek:SexM:Position.ord.Q	-0.218	0.09	-2.54	0.011
FollowingPhonek:SexM:Position.ord.C	-0.139	0.09	-1.62	0.106
FollowingPhonek:SexM:Position.ord^4	-0.028	0.09	-0.33	0.745
FollowingPhonek:Position.ord.L:normdurms	-0.222	0.06	-3.54	0.000
FollowingPhonek:Position.ord.Q:normdurms	0.018	0.06	0.29	0.769
FollowingPhonek:Position.ord.C:normdurms	0.092	0.06	1.49	0.137
FollowingPhonek:Position.ord^4:normdurms	0.015	0.06	0.24	0.810
SexM:Position.ord.L:normdurms	-0.177	0.05	-3.48	0.001
SexM:Position.ord.Q:normdurms	0.054	0.05	1.07	0.286
SexM:Position.ord.C:normdurms	0.008	0.05	0.16	0.869
SexM:Position.ord^4:normdurms	-0.011	0.05	-0.22	0.828
FollowingPhonek:SexM:normdurms	0.148	0.04	3.35	0.001
FollowingPhonek:SexM:Position.ord.L:normdurms	0.280	0.10	2.89	0.004
FollowingPhonek:SexM:Position.ord.Q:normdurms	-0.096	0.10	-1.00	0.317
FollowingPhonek:SexM:Position.ord.C:normdurms	-0.041	0.10	-0.43	0.667
FollowingPhonek:SexM:Position.ord^4:normdurms	-0.010	0.10	-0.11	0.913

F2

F2.lmerH <- lmer(normF2 ~ FollowingPhone*Sex*as.factor(AgeGroup)*normdurms + Position.ord + Sameness + normImportanceShoppingHomeCity + (1 + Position.ord | Name) + (1|Word), data=SEAae1)

Table 56. Full F2 model of /æg/ vs. /æk/ in Seattle

	Estimate	Std.Error	t.value	p
(Intercept)	-0.25	0.08	-3.21	0
FollowingPhonek	-0.01	0.04	-0.15	0.88
SexM	0.21	0.09	2.46	0.01
as.factor(AgeGroup)2	0.48	0.08	5.88	<1e-04
normdurms	0.16	0.02	6.59	<1e-04
Position.ord.L	0.2	0.03	6.3	<1e-04
Position.ord.Q	0.16	0.02	6.95	<1e-04
Position.ord.C	0	0.02	0.22	0.82
Position.ord^4	-0.02	0.02	-1.02	0.31
normImportanceShoppingHomeCity	-0.18	0.03	-5.36	<1e-04
SamenessY	0.27	0.06	4.23	<1e-04
FollowingPhonek:SexM	-0.44	0.05	-8.29	<1e-04
FollowingPhonek:as.factor(AgeGroup)2	-0.49	0.05	-10.73	<1e-04
SexM:as.factor(AgeGroup)2	0.17	0.12	1.42	0.16
FollowingPhonek:normdurms	-0.06	0.04	-1.7	0.09
SexM:normdurms	-0.15	0.03	-4.57	<1e-04
as.factor(AgeGroup)2:normdurms	-0.09	0.03	-2.88	0
FollowingPhonek:SexM:as.factor(AgeGroup)2	0.32	0.07	4.61	<1e-04
FollowingPhonek:SexM:normdurms	0.06	0.06	1.01	0.31
FollowingPhonek:as.factor(AgeGroup)2:normdurms	-0.02	0.05	-0.34	0.74
SexM:as.factor(AgeGroup)2:normdurms	0.06	0.04	1.42	0.16
FollowingPhonek:SexM:as.factor(AgeGroup)2:normdurms	0.14	0.08	1.72	0.09

Vancouver
F1

F1.lmerI <- lmer(normF1 ~ Position.ord*FollowingPhone*normdurms + FollowingPhone*Sex + FollowingPhone*as.factor(AgeGroup) + (1 + Position.ord | Name) + (1|Word), data=VANae1)

Table 57. Full F1 model of /æg/ vs. /æk/ in Vancouver

	Estimate	Std..Error	t.value	p
(Intercept)	-0.217	0.07	-2.94	0.003
Position.ord.L	-0.710	0.06	-12.84	<1e-04
Position.ord.Q	-0.356	0.04	-8.83	<1e-04
Position.ord.C	0.043	0.03	1.28	0.202
Position.ord^4	0.020	0.03	0.64	0.520
FollowingPhonek	1.469	0.06	23.99	<1e-04
normdurms	0.082	0.02	5.42	<1e-04
SexM	-0.177	0.07	-2.47	0.014
as.factor(AgeGroup)2	0.233	0.07	3.24	0.001
Position.ord.L:FollowingPhonek	0.487	0.04	11.12	<1e-04
Position.ord.Q:FollowingPhonek	0.001	0.04	0.02	0.982
Position.ord.C:FollowingPhonek	-0.012	0.04	-0.28	0.781
Position.ord^4:FollowingPhonek	-0.008	0.04	-0.18	0.855
Position.ord.L:normdurms	0.040	0.03	1.54	0.125
Position.ord.Q:normdurms	-0.061	0.03	-2.33	0.020
Position.ord.C:normdurms	-0.037	0.03	-1.42	0.154
Position.ord^4:normdurms	0.025	0.03	0.94	0.346
FollowingPhonek:normdurms	-0.134	0.02	-5.43	<1e-04
FollowingPhonek:SexM	0.189	0.04	5.36	<1e-04
FollowingPhonek:as.factor(AgeGroup)2	-0.249	0.04	-7.06	<1e-04
Position.ord.L:FollowingPhonek:normdurms	0.057	0.05	1.21	0.227
Position.ord.Q:FollowingPhonek:normdurms	-0.071	0.05	-1.51	0.131
Position.ord.C:FollowingPhonek:normdurms	0.058	0.05	1.24	0.214
Position.ord^4:FollowingPhonek:normdurms	-0.013	0.05	-0.28	0.780

F2

```
F2.lmerD <- lmer(normF2 ~ FollowingPhone*Position.ord*Sex*as.factor(AgeGroup) +
normdurms +  normSeattleVancouverSimilarity + (1 + Position.ord | Name) + (1|Word),
data=VANae1)
```

Table 58. Full F2 model of /æg/ vs. /æk/ in Vancouver

	Estimate	Std..Error	t.value	p
(Intercept)	0.749	0.08	9.90	< 1e-04
FollowingPhonek	-1.288	0.05	-24.86	< 1e-04
Position.ord.L	0.297	0.07	4.33	< 1e-04
Position.ord.Q	0.025	0.05	0.46	0.644
Position.ord.C	0.013	0.05	0.25	0.801
Position.ord^4	-0.014	0.05	-0.29	0.773
SexM	0.226	0.10	2.30	0.021
as.factor(AgeGroup)2	-0.234	0.10	-2.40	0.016
normdurms	-0.035	0.01	-3.60	0.000
normSeattleVancouverSimilarity	0.093	0.04	2.54	0.011
FollowingPhonek:Position.ord.L	-0.283	0.07	-4.34	< 1e-04
FollowingPhonek:Position.ord.Q	0.109	0.07	1.67	0.094
FollowingPhonek:Position.ord.C	-0.008	0.07	-0.13	0.900
FollowingPhonek:Position.ord^4	-0.001	0.07	-0.02	0.982
FollowingPhonek:SexM	-0.027	0.04	-0.68	0.495
Position.ord.L:SexM	0.085	0.10	0.89	0.373
Position.ord.Q:SexM	0.098	0.07	1.31	0.190
Position.ord.C:SexM	-0.004	0.07	-0.05	0.958
Position.ord^4:SexM	-0.007	0.07	-0.10	0.920
FollowingPhonek:as.factor(AgeGroup)2	0.296	0.04	7.30	< 1e-04
Position.ord.L:as.factor(AgeGroup)2	-0.045	0.10	-0.47	0.639
Position.ord.Q:as.factor(AgeGroup)2	0.060	0.07	0.80	0.426
Position.ord.C:as.factor(AgeGroup)2	0.092	0.07	1.33	0.184
Position.ord^4:as.factor(AgeGroup)2	0.016	0.07	0.23	0.814
SexM:as.factor(AgeGroup)2	-0.115	0.14	-0.82	0.412
FollowingPhonek:Position.ord.L:SexM	0.017	0.09	0.19	0.848
FollowingPhonek:Position.ord.Q:SexM	-0.062	0.09	-0.68	0.494
FollowingPhonek:Position.ord.C:SexM	0.028	0.09	0.31	0.756
FollowingPhonek:Position.ord^4:SexM	0.015	0.09	0.17	0.867
FollowingPhonek:Position.ord.L:as.factor(AgeGroup)2	0.065	0.09	0.72	0.470
FollowingPhonek:Position.ord.Q:as.factor(AgeGroup)2	-0.041	0.09	-0.46	0.649
FollowingPhonek:Position.ord.C:as.factor(AgeGroup)2	-0.086	0.09	-0.95	0.344
FollowingPhonek:Position.ord^4:as.factor(AgeGroup)2	-0.035	0.09	-0.39	0.695
FollowingPhonek:SexM:as.factor(AgeGroup)2	0.016	0.06	0.27	0.791
Position.ord.L:SexM:as.factor(AgeGroup)2	0.197	0.14	1.42	0.156

Table 58. Full F2 model of /æg/ vs. /æk/ in Vancouver (continued)

Position.ord.Q:SexM:as.factor(AgeGroup)2	0.058	0.11	0.53	0.594
Position.ord.C:SexM:as.factor(AgeGroup)2	-0.099	0.10	-0.99	0.323
Position.ord^4:SexM:as.factor(AgeGroup)2	-0.010	0.10	-0.10	0.918
FollowingPhonek:Position.ord.L:SexM:as.factor(AgeGroup)2	-0.314	0.13	-2.40	0.016
FollowingPhonek:Position.ord.Q:SexM:as.factor(AgeGroup)2	-0.110	0.13	-0.84	0.401
FollowingPhonek:Position.ord.C:SexM:as.factor(AgeGroup)2	0.047	0.13	0.36	0.718
FollowingPhonek:Position.ord^4:SexM:as.factor(AgeGroup)2	0.010	0.13	0.08	0.939

Comparison of Seattle and Vancouver

F1

```
F1.lmerC <- lmer(normF1 ~ FollowingPhone*Position.ord*normdurms +
City*FollowingPhone*Sex*(as.factor(AgeGroup)) + (1 + Position.ord | Name) + (1|Word),
data=ae1)
```

Table 59. Full F1 model of /æg/ comparing Seattle and Vancouver

	Estimate	Std..Error	t.value	p
(Intercept)	0.601	0.10	5.86	< 1e-04
FollowingPhonek	0.527	0.06	8.96	< 1e-04
Position.ord.L	-0.794	0.04	-21.31	< 1e-04
Position.ord.Q	-0.423	0.03	-15.34	< 1e-04
Position.ord.C	0.049	0.02	2.11	0.035
Position.ord^4	0.024	0.02	1.08	0.282
normdurms	0.039	0.01	3.55	0.000
CityVAN	-0.833	0.14	-6.17	< 1e-04
SexM	-0.403	0.13	-2.99	0.003
as.factor(AgeGroup)2	-0.443	0.13	-3.32	0.001
FollowingPhonek:Position.ord.L	0.584	0.03	18.88	< 1e-04
FollowingPhonek:Position.ord.Q	0.114	0.03	3.68	0.000
FollowingPhonek:Position.ord.C	0.014	0.03	0.47	0.642
FollowingPhonek:Position.ord^4	-0.006	0.03	-0.18	0.858
FollowingPhonek:normdurms	-0.070	0.02	-3.94	< 1e-04
Position.ord.L:normdurms	0.045	0.02	2.44	0.015
Position.ord.Q:normdurms	-0.059	0.02	-3.21	0.001
Position.ord.C:normdurms	-0.045	0.02	-2.47	0.013
Position.ord^4:normdurms	0.005	0.02	0.27	0.784
FollowingPhonek:CityVAN	0.926	0.05	18.41	< 1e-04
CityVAN:SexM	0.278	0.19	1.46	0.145
FollowingPhonek:SexM	0.403	0.05	8.05	< 1e-04
CityVAN:as.factor(AgeGroup)2	0.779	0.19	4.10	< 1e-04
FollowingPhonek:as.factor(AgeGroup)2	0.691	0.05	14.43	< 1e-04
SexM:as.factor(AgeGroup)2	0.243	0.19	1.28	0.201
FollowingPhonek:Position.ord.L:normdurms	-0.018	0.03	-0.52	0.604
FollowingPhonek:Position.ord.Q:normdurms	-0.048	0.03	-1.43	0.151
FollowingPhonek:Position.ord.C:normdurms	0.066	0.03	1.96	0.050
FollowingPhonek:Position.ord^4:normdurms	0.001	0.03	0.02	0.981
FollowingPhonek:CityVAN:SexM	-0.206	0.07	-2.91	0.004
FollowingPhonek:CityVAN:as.factor(AgeGroup)2	-0.932	0.07	-13.42	< 1e-04
CityVAN:SexM:as.factor(AgeGroup)2	-0.356	0.27	-1.30	0.192
FollowingPhonek:SexM:as.factor(AgeGroup)2	-0.234	0.07	-3.36	0.001
FollowingPhonek:CityVAN:SexM:as.factor(AgeGroup)2	0.212	0.10	2.10	0.035

F2

```
F2.lmerC <- lmer(normF2 ~ FollowingPhone*Position.ord*City*normdurms + City*FollowingPhone*Sex*(as.factor(AgeGroup)) + normProudOfYourCity + (1 + Position.ord | Name) + (1|Word), data=ae1)
```

Table 60. Full F2 model of /æg/ comparing Seattle and Vancouver

	Estimate	Std..Error	t.value	p
(Intercept)	-0.104	0.09	-1.22	0.224
FollowingPhonek	-0.086	0.04	-1.97	0.049
Position.ord.L	0.265	0.03	7.62	< 1e-04
Position.ord.Q	0.121	0.03	4.31	< 1e-04
Position.ord.C	-0.014	0.03	-0.56	0.578
Position.ord^4	-0.017	0.03	-0.68	0.497
CityVAN	0.848	0.12	7.31	< 1e-04
normdurms	0.057	0.01	5.15	< 1e-04
SexM	0.374	0.12	3.15	0.002
as.factor(AgeGroup)2	0.259	0.11	2.26	0.024
normProudOfYourCity	-0.073	0.03	-2.28	0.022
FollowingPhonek:Position.ord.L	-0.131	0.04	-3.71	0.000
FollowingPhonek:Position.ord.Q	0.052	0.04	1.48	0.139
FollowingPhonek:Position.ord.C	0.015	0.04	0.42	0.677
FollowingPhonek:Position.ord^4	0.000	0.04	0.00	0.997
FollowingPhonek:CityVAN	-1.198	0.04	-27.80	< 1e-04
Position.ord.L:CityVAN	0.090	0.05	1.78	0.075
Position.ord.Q:CityVAN	0.000	0.04	0.00	0.997
Position.ord.C:CityVAN	0.034	0.04	0.93	0.352
Position.ord^4:CityVAN	0.001	0.04	0.01	0.988
FollowingPhonek:normdurms	-0.009	0.02	-0.45	0.650
Position.ord.L:normdurms	0.037	0.02	1.77	0.077
Position.ord.Q:normdurms	0.050	0.02	2.41	0.016
Position.ord.C:normdurms	0.020	0.02	0.98	0.326
Position.ord^4:normdurms	0.000	0.02	0.02	0.986
CityVAN:normdurms	-0.103	0.01	-7.52	< 1e-04
CityVAN:SexM	-0.183	0.16	-1.13	0.258
FollowingPhonek:SexM	-0.277	0.04	-6.67	< 1e-04
CityVAN:as.factor(AgeGroup)2	-0.409	0.16	-2.49	0.013
FollowingPhonek:as.factor(AgeGroup)2	-0.400	0.04	-10.06	< 1e-04
SexM:as.factor(AgeGroup)2	0.026	0.16	0.16	0.874
FollowingPhonek:Position.ord.L:CityVAN	-0.173	0.05	-3.36	0.001
FollowingPhonek:Position.ord.Q:CityVAN	0.002	0.05	0.04	0.965
FollowingPhonek:Position.ord.C:CityVAN	-0.021	0.05	-0.41	0.680

Table 60. Full F2 model of /æg/ comparing Seattle and Vancouver (continued)

FollowingPhonek:Position.ord^4:CityVAN	-0.008	0.05	-0.15	0.882
FollowingPhonek:Position.ord.L:normdurms	-0.006	0.04	-0.16	0.872
FollowingPhonek:Position.ord.Q:normdurms	-0.035	0.04	-0.90	0.370
FollowingPhonek:Position.ord.C:normdurms	-0.041	0.04	-1.07	0.286
FollowingPhonek:Position.ord^4:normdurms	0.005	0.04	0.12	0.902
FollowingPhonek:CityVAN:normdurms	0.031	0.03	1.22	0.221
Position.ord.L:CityVAN:normdurms	-0.031	0.03	-1.02	0.310
Position.ord.Q:CityVAN:normdurms	-0.067	0.03	-2.20	0.028
Position.ord.C:CityVAN:normdurms	0.011	0.03	0.36	0.715
Position.ord^4:CityVAN:normdurms	0.011	0.03	0.36	0.718
FollowingPhonek:CityVAN:SexM	0.250	0.06	4.26	< 1e-04
FollowingPhonek:CityVAN:as.factor(AgeGroup)2	0.696	0.06	12.08	< 1e-04
CityVAN:SexM:as.factor(AgeGroup)2	-0.121	0.23	-0.52	0.606
FollowingPhonek:SexM:as.factor(AgeGroup)2	0.153	0.06	2.66	0.008
FollowingPhonek:Position.ord.L:CityVAN:normdurms	0.009	0.06	0.16	0.870
FollowingPhonek:Position.ord.Q:CityVAN:normdurms	0.118	0.06	2.13	0.034
FollowingPhonek:Position.ord.C:CityVAN:normdurms	0.021	0.06	0.39	0.698
FollowingPhonek:Position.ord^4:CityVAN:normdurms	-0.026	0.06	-0.47	0.636
FollowingPhonek:CityVAN:SexM:as.factor(AgeGroup)2	-0.139	0.08	-1.66	0.096

Pre-nasal /æ/ Raising

Seattle

F1

F1.lmerC <- lmer(normF1 ~ FollowingPhone*Position.ord*Sex + normdurms + (1 + Position.ord | Name) + (1|Word), data=SEAae2)

Table 61. Full F1 model of /æn/ vs. /æd/ in Seattle

	Estimate	Std..Error	t.value	p
(Intercept)	0.938	0.10	9.17	< 1e-04
FollowingPhonen	-0.981	0.14	-7.20	< 1e-04
Position.ord.L	-0.655	0.06	-11.01	< 1e-04
Position.ord.Q	-0.411	0.04	-9.87	< 1e-04
Position.ord.C	-0.009	0.03	-0.28	0.778
Position.ord^4	0.005	0.03	0.17	0.865
SexM	-0.045	0.07	-0.63	0.530
normdurms	0.040	0.01	3.86	0.000
FollowingPhonen:Position.ord.L	0.922	0.05	17.82	< 1e-04
FollowingPhonen:Position.ord.Q	0.271	0.05	5.24	< 1e-04
FollowingPhonen:Position.ord.C	-0.094	0.05	-1.82	0.069
FollowingPhonen:Position.ord^4	-0.056	0.05	-1.08	0.280
FollowingPhonen:SexM	0.115	0.03	3.41	0.001
Position.ord.L:SexM	0.251	0.08	2.97	0.003
Position.ord.Q:SexM	0.049	0.06	0.81	0.416
Position.ord.C:SexM	-0.051	0.05	-1.08	0.279
Position.ord^4:SexM	-0.034	0.05	-0.75	0.452
FollowingPhonen:Position.ord.L:SexM	-0.372	0.08	-4.95	< 1e-04
FollowingPhonen:Position.ord.Q:SexM	0.038	0.08	0.51	0.611
FollowingPhonen:Position.ord.C:SexM	0.104	0.08	1.38	0.167
FollowingPhonen:Position.ord^4:SexM	0.023	0.08	0.31	0.759

F2

```
F2.lmerT <- lmer(normF2 ~ FollowingPhone*Position.ord*Sex + normdurms +
normHowOftenShopPNW + (1 + Position.ord | Name) + (1|Word), data=SEAae2)
```

Table 62. Full F2 model of /æn/ vs. /æd/ in Seattle

	Estimate	Std..Error	t.value	p
(Intercept)	-0.399	0.05	-8.44	<1e-04
FollowingPhonen	0.720	0.06	11.15	<1e-04
Position.ord.L	-0.001	0.06	-0.01	0.993
Position.ord.Q	0.085	0.05	1.80	0.072
Position.ord.C	0.026	0.04	0.70	0.485
Position.ord^4	0.003	0.04	0.08	0.934
SexM	0.243	0.04	5.90	<1e-04
normdurms	0.039	0.01	3.32	0.001
normHowOftenShopPNW	-0.062	0.02	-3.12	0.002
FollowingPhonen:Position.ord.L	-0.925	0.06	-15.18	<1e-04
FollowingPhonen:Position.ord.Q	-0.236	0.06	-3.88	0.000
FollowingPhonen:Position.ord.C	0.127	0.06	2.09	0.037
FollowingPhonen:Position.ord^4	-0.100	0.06	-1.64	0.102
FollowingPhonen:SexM	-0.192	0.04	-4.87	<1e-04
Position.ord.L:SexM	-0.231	0.09	-2.60	0.009
Position.ord.Q:SexM	-0.051	0.07	-0.75	0.455
Position.ord.C:SexM	0.027	0.05	0.50	0.617
Position.ord^4:SexM	-0.009	0.05	-0.16	0.870
FollowingPhonen:Position.ord.L:SexM	0.190	0.09	2.15	0.031
FollowingPhonen:Position.ord.Q:SexM	-0.079	0.09	-0.90	0.371
FollowingPhonen:Position.ord.C:SexM	0.004	0.09	0.05	0.961
FollowingPhonen:Position.ord^4:SexM	0.099	0.09	1.12	0.263

Vancouver

F1

```
F1.lmerD <- lmer(normF1 ~ FollowingPhone*Position.ord*(as.factor(AgeGroup))*Sex +
normdurms + normSeattlePortlandSimilarity + (1 + Position.ord | Name) + (1|Word),
data=VANae2)
```

Table 63. Full F1 model of /æn/ vs. /æd/ in Vancouver

	Estimate	Std..Error	t.value	p
(Intercept)	0.939	0.11	8.24	< 1e-04
FollowingPhonen	-0.638	0.18	-3.53	0.000
Position.ord.L	-0.517	0.06	-8.60	< 1e-04
Position.ord.Q	-0.480	0.04	-11.08	< 1e-04
Position.ord.C	-0.059	0.04	-1.54	0.124
Position.ord^4	0.004	0.04	0.10	0.918
as.factor(AgeGroup)2	0.031	0.05	0.63	0.527
SexM	-0.076	0.05	-1.62	0.105
normdurms	-0.023	0.01	-2.53	0.012
normSeattlePortlandSimilarity	-0.044	0.02	-2.46	0.014
FollowingPhonen:Position.ord.L	0.395	0.07	5.97	< 1e-04
FollowingPhonen:Position.ord.Q	0.331	0.07	5.00	< 1e-04
FollowingPhonen:Position.ord.C	0.042	0.07	0.63	0.528
FollowingPhonen:Position.ord^4	-0.037	0.07	-0.57	0.572
FollowingPhonen:as.factor(AgeGroup)2	0.020	0.04	0.50	0.620
Position.ord.L:as.factor(AgeGroup)2	-0.089	0.08	-1.05	0.292
Position.ord.Q:as.factor(AgeGroup)2	0.034	0.06	0.56	0.578
Position.ord.C:as.factor(AgeGroup)2	0.047	0.05	0.88	0.378
Position.ord^4:as.factor(AgeGroup)2	-0.025	0.05	-0.46	0.643
FollowingPhonen:SexM	0.441	0.04	10.67	< 1e-04
Position.ord.L:SexM	-0.008	0.08	-0.09	0.925
Position.ord.Q:SexM	-0.048	0.06	-0.80	0.424
Position.ord.C:SexM	0.015	0.05	0.28	0.779
Position.ord^4:SexM	-0.013	0.05	-0.25	0.806
as.factor(AgeGroup)2:SexM	-0.014	0.07	-0.21	0.836
FollowingPhonen:Position.ord.L:as.factor(AgeGroup)2	0.153	0.09	1.67	0.095
FollowingPhonen:Position.ord.Q:as.factor(AgeGroup)2	-0.054	0.09	-0.59	0.555
FollowingPhonen:Position.ord.C:as.factor(AgeGroup)2	-0.013	0.09	-0.14	0.891
FollowingPhonen:Position.ord^4:as.factor(AgeGroup)2	0.042	0.09	0.46	0.644
FollowingPhonen:Position.ord.L:SexM	0.060	0.09	0.65	0.518
FollowingPhonen:Position.ord.Q:SexM	-0.155	0.09	-1.68	0.093
FollowingPhonen:Position.ord.C:SexM	-0.062	0.09	-0.67	0.505
FollowingPhonen:Position.ord^4:SexM	0.028	0.09	0.31	0.760
FollowingPhonen:as.factor(AgeGroup)2:SexM	-0.116	0.06	-1.86	0.063
Position.ord.L:as.factor(AgeGroup)2:SexM	0.139	0.13	1.08	0.279
Position.ord.Q:as.factor(AgeGroup)2:SexM	0.044	0.09	0.48	0.634
Position.ord.C:as.factor(AgeGroup)2:SexM	-0.066	0.08	-0.81	0.418
Position.ord^4:as.factor(AgeGroup)2:SexM	-0.004	0.08	-0.05	0.958
FollowingPhonen:Position.ord.L:as.factor(AgeGroup)2:SexM	-0.379	0.14	-2.71	0.007

Table 63. Full F1 model of /æn/ vs. /æd/ in Vancouver (continued)

FollowingPhonen:Position.ord.Q:as.factor(AgeGroup)2:SexM	-0.003	0.14	-0.02	0.983
FollowingPhonen:Position.ord.C:as.factor(AgeGroup)2:SexM	0.063	0.14	0.45	0.654
FollowingPhonen:Position.ord^4:as.factor(AgeGroup)2:SexM	-0.069	0.14	-0.49	0.624

F2

F2.lmerN <- lmer(normF2 ~ FollowingPhone*Position.ord*as.factor(AgeGroup)*Sex + normdurms*FollowingPhone + YearsEducation + normMunicipalInvestment + normReadLocalPublications + (1 + Position.ord | Name) + (1|Word), data=VANae2)

Table 64. Full F2 model of /æn/ vs. /æd/ in Vancouver

	Estimate	Std..Error	t.value	p
(Intercept)	0.201	0.20	1.00	0.320
FollowingPhonen	0.533	0.12	4.41	< 1e-04
Position.ord.L	-0.010	0.06	-0.19	0.850
Position.ord.Q	0.129	0.04	3.15	0.002
Position.ord.C	-0.004	0.04	-0.12	0.901
Position.ord^4	-0.003	0.04	-0.09	0.927
as.factor(AgeGroup)2	-0.073	0.08	-0.88	0.379
SexM	0.158	0.08	1.92	0.055
normdurms	-0.009	0.01	-0.94	0.348
YearsEducation	-0.031	0.01	-2.64	0.008
normMunicipalInvestment	0.227	0.04	5.15	< 1e-04
normReadLocalPublications	-0.131	0.04	-3.46	0.001
FollowingPhonen:Position.ord.L	-0.300	0.06	-4.91	< 1e-04
FollowingPhonen:Position.ord.Q	-0.202	0.06	-3.31	0.001
FollowingPhonen:Position.ord.C	0.035	0.06	0.58	0.564
FollowingPhonen:Position.ord^4	0.008	0.06	0.13	0.895
FollowingPhonen:as.factor(AgeGroup)2	-0.213	0.04	-5.59	< 1e-04
Position.ord.L:as.factor(AgeGroup)2	0.006	0.08	0.08	0.935
Position.ord.Q:as.factor(AgeGroup)2	-0.016	0.06	-0.29	0.774
Position.ord.C:as.factor(AgeGroup)2	0.031	0.05	0.62	0.535
Position.ord^4:as.factor(AgeGroup)2	-0.022	0.05	-0.44	0.659
FollowingPhonen:SexM	-0.200	0.04	-5.23	< 1e-04
Position.ord.L:SexM	-0.070	0.08	-0.90	0.368
Position.ord.Q:SexM	-0.029	0.06	-0.51	0.611
Position.ord.C:SexM	-0.005	0.05	-0.11	0.916
Position.ord^4:SexM	-0.012	0.05	-0.25	0.802
as.factor(AgeGroup)2:SexM	-0.172	0.12	-1.41	0.160
FollowingPhonen:normdurms	0.081	0.02	4.00	< 1e-04
FollowingPhonen:Position.ord.L:as.factor(AgeGroup)2	-0.115	0.09	-1.35	0.178

Table 64. Full F2 model of /æn/ vs. /æd/ in Vancouver (continued)

FollowingPhonen:Position.ord.Q:as.factor(AgeGroup)2	0.184	0.09	2.16	0.031
FollowingPhonen:Position.ord.C:as.factor(AgeGroup)2	0.034	0.09	0.40	0.689
FollowingPhonen:Position.ord^4:as.factor(AgeGroup)2	-0.018	0.09	-0.21	0.834
FollowingPhonen:Position.ord.L:SexM	0.011	0.09	0.12	0.902
FollowingPhonen:Position.ord.Q:SexM	0.155	0.09	1.82	0.069
FollowingPhonen:Position.ord.C:SexM	-0.017	0.09	-0.20	0.839
FollowingPhonen:Position.ord^4:SexM	-0.014	0.09	-0.16	0.872
FollowingPhonen:as.factor(AgeGroup)2:SexM	0.237	0.06	4.30	< 1e-04
Position.ord.L:as.factor(AgeGroup)2:SexM	-0.036	0.11	-0.31	0.753
Position.ord.Q:as.factor(AgeGroup)2:SexM	0.034	0.08	0.41	0.684
Position.ord.C:as.factor(AgeGroup)2:SexM	-0.008	0.07	-0.11	0.910
Position.ord^4:as.factor(AgeGroup)2:SexM	0.008	0.07	0.11	0.911
FollowingPhonen:Position.ord.L:as.factor(AgeGroup)2:SexM	0.271	0.12	2.20	0.028
FollowingPhonen:Position.ord.Q:as.factor(AgeGroup)2:SexM	-0.270	0.12	-2.19	0.028
FollowingPhonen:Position.ord.C:as.factor(AgeGroup)2:SexM	-0.024	0.12	-0.19	0.848
FollowingPhonen:Position.ord^4:as.factor(AgeGroup)2:SexM	0.042	0.12	0.34	0.732

Comparing Seattle and Vancouver

F1

F1.lmerH <- lmer(normF1 ~ FollowingPhone*Position.ord*normdurms*City + City*as.factor(AgeGroup)*Sex*FollowingPhone + normNationalPride + (1 + Position.ord | Name) + (1|Word), data=ae2)

Table 65. Full F1 model of /æn/ comparing Seattle and Vancouver

	Estimate	**Std..Error**	**t.value**	**p**
(Intercept)	0.683	0.14	4.83	< 1e-04
FollowingPhonen	-0.816	0.21	-3.94	< 1e-04
Position.ord.L	-0.533	0.04	-14.57	< 1e-04
Position.ord.Q	-0.387	0.03	-14.73	< 1e-04
Position.ord.C	-0.034	0.02	-1.57	0.115
Position.ord^4	-0.011	0.02	-0.52	0.603
normdurms	0.000	0.01	-0.04	0.968
CityVAN	0.184	0.07	2.58	0.010
as.factor(AgeGroup)2	0.196	0.07	2.84	0.005
SexM	0.158	0.07	2.13	0.033
normNationalPride	0.052	0.02	2.22	0.026
FollowingPhonen:Position.ord.L	0.743	0.04	21.14	< 1e-04
FollowingPhonen:Position.ord.Q	0.289	0.04	8.23	< 1e-04

Table 65. Full F1 model of /æn/ comparing Seattle and Vancouver (continued)

FollowingPhonen:Position.ord.C	-0.043	0.04	-1.23	0.220
FollowingPhonen:Position.ord^4	-0.045	0.04	-1.27	0.203
FollowingPhonen:normdurms	0.068	0.02	3.30	0.001
Position.ord.L:normdurms	0.066	0.02	3.42	0.001
Position.ord.Q:normdurms	-0.020	0.02	-1.03	0.303
Position.ord.C:normdurms	-0.044	0.02	-2.31	0.021
Position.ord^4:normdurms	-0.030	0.02	-1.56	0.118
FollowingPhonen:CityVAN	0.244	0.05	5.37	< 1e-04
Position.ord.L:CityVAN	-0.008	0.05	-0.16	0.872
Position.ord.Q:CityVAN	-0.097	0.04	-2.62	0.009
Position.ord.C:CityVAN	-0.010	0.03	-0.34	0.734
Position.ord^4:CityVAN	-0.001	0.03	-0.04	0.971
normdurms:CityVAN	-0.002	0.01	-0.15	0.884
CityVAN:as.factor(AgeGroup)2	-0.274	0.10	-2.70	0.007
CityVAN:SexM	-0.305	0.10	-2.96	0.003
as.factor(AgeGroup)2:SexM	-0.217	0.10	-2.20	0.028
FollowingPhonen:as.factor(AgeGroup)2	-0.044	0.04	-1.00	0.317
FollowingPhonen:SexM	0.103	0.05	2.26	0.024
FollowingPhonen:Position.ord.L:normdurms	0.041	0.04	0.99	0.320
FollowingPhonen:Position.ord.Q:normdurms	0.049	0.04	1.19	0.236
FollowingPhonen:Position.ord.C:normdurms	-0.022	0.04	-0.53	0.598
FollowingPhonen:Position.ord^4:normdurms	0.039	0.04	0.94	0.345
FollowingPhonen:Position.ord.L:CityVAN	-0.324	0.05	-6.45	< 1e-04
FollowingPhonen:Position.ord.Q:CityVAN	-0.042	0.05	-0.83	0.407
FollowingPhonen:Position.ord.C:CityVAN	0.068	0.05	1.35	0.176
FollowingPhonen:Position.ord^4:CityVAN	0.029	0.05	0.57	0.566
FollowingPhonen:normdurms:CityVAN	-0.106	0.03	-3.74	0.000
Position.ord.L:normdurms:CityVAN	-0.030	0.03	-1.11	0.269
Position.ord.Q:normdurms:CityVAN	-0.018	0.03	-0.68	0.498
Position.ord.C:normdurms:CityVAN	0.038	0.03	1.42	0.156
Position.ord^4:normdurms:CityVAN	0.017	0.03	0.63	0.527
CityVAN:as.factor(AgeGroup)2:SexM	0.292	0.14	2.04	0.042
FollowingPhonen:CityVAN:as.factor(AgeGroup)2	0.065	0.06	1.04	0.297
FollowingPhonen:CityVAN:SexM	0.338	0.06	5.30	< 1e-04
FollowingPhonen:as.factor(AgeGroup)2:SexM	0.016	0.06	0.25	0.803
FollowingPhonen:Position.ord.L:normdurms:CityVAN	-0.045	0.06	-0.74	0.457
FollowingPhonen:Position.ord.Q:normdurms:CityVAN	-0.033	0.06	-0.54	0.589
FollowingPhonen:Position.ord.C:normdurms:CityVAN	0.042	0.06	0.70	0.485
FollowingPhonen:Position.ord^4:normdurms:CityVAN	-0.027	0.06	-0.45	0.653
FollowingPhonen:CityVAN:as.factor(AgeGroup)2:SexM	-0.247	0.09	-2.74	0.006

F2

F2.lmerW <- lmer(normF2 ~ Position.ord*City*FollowingPhone + City*as.factor(AgeGroup)*Sex*FollowingPhone + normdurms + normFollowSports + (1 + Position.ord | Name) + (1|Word), data=ae2)

Table 66. Full F2 model of /æn/ comparing Seattle and Vancouver

	Estimate	Std..Error	t.value	p
(Intercept)	-0.389	0.08	-4.62	< 1e-04
Position.ord.L	-0.113	0.04	-2.93	0.003
Position.ord.Q	0.059	0.03	2.10	0.036
Position.ord.C	0.039	0.02	1.70	0.090
Position.ord^4	-0.001	0.02	-0.06	0.952
CityVAN	-0.024	0.08	-0.29	0.771
FollowingPhonen	0.535	0.11	4.98	< 1e-04
as.factor(AgeGroup)2	0.045	0.07	0.62	0.534
SexM	0.401	0.08	4.84	< 1e-04
normdurms	0.021	0.01	2.91	0.004
normFollowSports	0.052	0.02	2.34	0.019
Position.ord.L:CityVAN	0.065	0.05	1.19	0.236
Position.ord.Q:CityVAN	0.055	0.04	1.39	0.164
Position.ord.C:CityVAN	-0.033	0.03	-1.03	0.305
Position.ord^4:CityVAN	-0.017	0.03	-0.51	0.608
Position.ord.L:FollowingPhonen	-0.835	0.04	-22.04	< 1e-04
Position.ord.Q:FollowingPhonen	-0.274	0.04	-7.23	< 1e-04
Position.ord.C:FollowingPhonen	0.129	0.04	3.41	0.001
Position.ord^4:FollowingPhonen	-0.053	0.04	-1.39	0.165
CityVAN:FollowingPhonen	-0.065	0.05	-1.32	0.185
CityVAN:as.factor(AgeGroup)2	0.021	0.10	0.21	0.835
CityVAN:SexM	-0.237	0.12	-2.00	0.046
as.factor(AgeGroup)2:SexM	-0.201	0.11	-1.86	0.063
FollowingPhonen:as.factor(AgeGroup)2	0.143	0.05	3.05	0.002
FollowingPhonen:SexM	-0.128	0.05	-2.61	0.009
Position.ord.L:CityVAN:FollowingPhonen	0.542	0.05	10.02	< 1e-04
Position.ord.Q:CityVAN:FollowingPhonen	0.177	0.05	3.27	0.001
Position.ord.C:CityVAN:FollowingPhonen	-0.091	0.05	-1.67	0.094
Position.ord^4:CityVAN:FollowingPhonen	0.055	0.05	1.01	0.314
CityVAN:as.factor(AgeGroup)2:SexM	0.121	0.15	0.81	0.416
CityVAN:FollowingPhonen:as.factor(AgeGroup)2	-0.352	0.07	-5.24	< 1e-04
CityVAN:FollowingPhonen:SexM	-0.065	0.07	-0.95	0.341
FollowingPhonen:as.factor(AgeGroup)2:SexM	-0.117	0.07	-1.72	0.085
CityVAN:FollowingPhonen:as.factor(AgeGroup)2:SexM	0.349	0.10	3.59	0.000

/æ/ Retraction

Seattle
F1

F1.lmerD <- lmer(normF1 ~ Manner*Position.ord*Sex + normdurms +Sameness + (1 + Position.ord | Name) + (1|Word), data=SEAback3)

Table 67. Full F1 model of /æ/ retraction in Seattle

	Estimate	Std..Error	t.value	p
(Intercept)	0.95	0.13	7.35	< 1e-04
Mannerlateral	0.04	0.22	0.2	0.84
Mannerstop	0.07	0.14	0.46	0.65
Position.ord.L	-0.51	0.06	-9.22	< 1e-04
Position.ord.Q	-0.37	0.03	-10.99	< 1e-04
Position.ord.C	0.1	0.03	3.63	0
Position.ord^4	0	0.03	-0.08	0.94
SexM	0.03	0.05	0.59	0.55
normdurms	0.02	0.01	3.66	0
SamenessY	-0.09	0.04	-2.07	0.04
Mannerlateral:Position.ord.L	0.09	0.05	1.81	0.07
Mannerstop:Position.ord.L	0.11	0.03	3.71	0
Mannerlateral:Position.ord.Q	0.1	0.05	2.18	0.03
Mannerstop:Position.ord.Q	-0.01	0.03	-0.39	0.7
Mannerlateral:Position.ord.C	-0.02	0.05	-0.36	0.72
Mannerstop:Position.ord.C	-0.06	0.03	-2.08	0.04
Mannerlateral:Position.ord^4	0.02	0.05	0.34	0.74
Mannerstop:Position.ord^4	0.02	0.03	0.54	0.59
Mannerlateral:SexM	0.06	0.03	1.92	0.06
Mannerstop:SexM	-0.1	0.02	-4.92	< 1e-04
Position.ord.L:SexM	0.22	0.08	2.7	0.01
Position.ord.Q:SexM	0.06	0.05	1.24	0.21
Position.ord.C:SexM	-0.06	0.04	-1.36	0.17
Position.ord^4:SexM	0.01	0.04	0.32	0.75
Mannerlateral:Position.ord.L:SexM	-0.14	0.07	-1.91	0.06
Mannerstop:Position.ord.L:SexM	-0.09	0.05	-2.03	0.04
Mannerlateral:Position.ord.Q:SexM	0.02	0.07	0.21	0.83
Mannerstop:Position.ord.Q:SexM	-0.02	0.05	-0.46	0.65
Mannerlateral:Position.ord.C:SexM	0.02	0.07	0.31	0.76
Mannerstop:Position.ord.C:SexM	0.01	0.05	0.22	0.83
Mannerlateral:Position.ord^4:SexM	0.01	0.07	0.09	0.93
Mannerstop:Position.ord^4:SexM	-0.02	0.05	-0.47	0.64

F2

F2.lmerE <- lmer(normF2 ~ Manner*Position.ord*(as.factor(AgeGroup))*Sex + normdurms + normImportanceShoppingPNW + (1 + Position.ord | Name) + (1|Word), data=SEAback3)

Table 68. Full F2 model for /æ/ retraction in Seattle

	Estimate	Std..Error	t.value	p
(Intercept)	-0.397	0.08	-4.70	< 1e-04
Mannerlateral	-0.515	0.12	-4.37	< 1e-04
Mannerstop	0.137	0.08	1.79	0.073
Position.ord.L	-0.099	0.06	-1.57	0.118
Position.ord.Q	0.068	0.04	1.73	0.083
Position.ord.C	0.032	0.04	0.87	0.384
Position.ord^4	-0.033	0.04	-0.90	0.369
as.factor(AgeGroup)2	-0.048	0.07	-0.64	0.522
SexM	0.037	0.08	0.47	0.635
normdurms	0.028	0.01	4.84	< 1e-04
normImportanceShoppingPNW	-0.106	0.03	-3.36	0.001
Mannerlateral:Position.ord.L	-0.530	0.06	-8.33	< 1e-04
Mannerstop:Position.ord.L	0.061	0.04	1.46	0.143
Mannerlateral:Position.ord.Q	-0.074	0.06	-1.16	0.245
Mannerstop:Position.ord.Q	0.036	0.04	0.86	0.388
Mannerlateral:Position.ord.C	0.017	0.06	0.27	0.785
Mannerstop:Position.ord.C	-0.044	0.04	-1.06	0.290
Mannerlateral:Position.ord^4	0.023	0.06	0.36	0.722
Mannerstop:Position.ord^4	0.021	0.04	0.50	0.620
Mannerlateral:as.factor(AgeGroup)2	0.102	0.04	2.59	0.010
Mannerstop:as.factor(AgeGroup)2	0.052	0.03	2.05	0.041
Position.ord.L:as.factor(AgeGroup)2	-0.053	0.09	-0.60	0.549
Position.ord.Q:as.factor(AgeGroup)2	0.069	0.05	1.28	0.199
Position.ord.C:as.factor(AgeGroup)2	0.017	0.05	0.34	0.733
Position.ord^4:as.factor(AgeGroup)2	0.026	0.05	0.52	0.601
Mannerlateral:SexM	0.122	0.04	3.00	0.003
Mannerstop:SexM	0.100	0.03	3.75	0.000
Position.ord.L:SexM	-0.264	0.09	-2.93	0.003
Position.ord.Q:SexM	-0.074	0.06	-1.32	0.187
Position.ord.C:SexM	-0.007	0.05	-0.14	0.887
Position.ord^4:SexM	0.029	0.05	0.55	0.582
as.factor(AgeGroup)2:SexM	0.153	0.11	1.45	0.148
Mannerlateral:Position.ord.L:as.factor(AgeGroup)2	0.117	0.09	1.33	0.183
Mannerstop:Position.ord.L:as.factor(AgeGroup)2	0.019	0.06	0.34	0.733
Mannerlateral:Position.ord.Q:as.factor(AgeGroup)2	-0.005	0.09	-0.06	0.951

Table 68. Full F2 model for /æ/ retraction in Seattle (continued)

Mannerstop:Position.ord.Q:as.factor(AgeGroup)2	-0.074	0.06	-1.30	0.193
Mannerlateral:Position.ord.C:as.factor(AgeGroup)2	0.017	0.09	0.20	0.843
Mannerstop:Position.ord.C:as.factor(AgeGroup)2	0.001	0.06	0.02	0.985
Mannerlateral:Position.ord^4:as.factor(AgeGroup)2	-0.003	0.09	-0.04	0.971
Mannerstop:Position.ord^4:as.factor(AgeGroup)2	-0.022	0.06	-0.39	0.700
Mannerlateral:Position.ord.L:SexM	0.245	0.09	2.69	0.007
Mannerstop:Position.ord.L:SexM	0.133	0.06	2.23	0.025
Mannerlateral:Position.ord.Q:SexM	0.076	0.09	0.83	0.404
Mannerstop:Position.ord.Q:SexM	-0.011	0.06	-0.18	0.856
Mannerlateral:Position.ord.C:SexM	0.030	0.09	0.33	0.741
Mannerstop:Position.ord.C:SexM	0.042	0.06	0.70	0.482
Mannerlateral:Position.ord^4:SexM	-0.037	0.09	-0.40	0.688
Mannerstop:Position.ord^4:SexM	-0.021	0.06	-0.35	0.725
Mannerlateral:as.factor(AgeGroup)2:SexM	-0.320	0.06	-5.64	< 1e-04
Mannerstop:as.factor(AgeGroup)2:SexM	-0.047	0.04	-1.29	0.198
Position.ord.L:as.factor(AgeGroup)2:SexM	0.086	0.13	0.68	0.493
Position.ord.Q:as.factor(AgeGroup)2:SexM	-0.018	0.08	-0.22	0.822
Position.ord.C:as.factor(AgeGroup)2:SexM	0.001	0.07	0.01	0.992
Position.ord^4:as.factor(AgeGroup)2:SexM	-0.008	0.07	-0.11	0.911
Mannerlateral:Position.ord.L:as.factor(AgeGroup)2:SexM	-0.259	0.13	-2.04	0.041
Mannerstop:Position.ord.L:as.factor(AgeGroup)2:SexM	-0.047	0.08	-0.57	0.566
Mannerlateral:Position.ord.Q:as.factor(AgeGroup)2:SexM	-0.023	0.13	-0.18	0.855
Mannerstop:Position.ord.Q:as.factor(AgeGroup)2:SexM	0.068	0.08	0.83	0.409
Mannerlateral:Position.ord.C:as.factor(AgeGroup)2:SexM	0.003	0.13	0.03	0.978
Mannerstop:Position.ord.C:as.factor(AgeGroup)2:SexM	-0.007	0.08	-0.09	0.928
Mannerlateral:Position.ord^4:as.factor(AgeGroup)2:SexM	0.007	0.13	0.05	0.958
Mannerstop:Position.ord^4:as.factor(AgeGroup)2:SexM	-0.003	0.08	-0.04	0.967

Vancouver

F1

```
F1.lmerH <- lmer(normF1 ~ Manner*Position.ord*Sex*normdurms +
(as.factor(AgeGroup))*Sex*Manner + PrecedingPhone + Sameness + normFollowSports + (1 +
Position.ord | Name) + (1|Word), data=VANback3)
```

Table 69. Full F1 model of /æ/ retraction in Vancouver

	Estimate	Std..Error	t.value	p
(Intercept)	1.05	0.36	2.88	0.00
Mannerlateral	-0.11	0.36	-0.3	0.77
Mannerstop	0.19	0.34	0.55	0.58
Position.ord.L	-0.48	0.05	-9.11	< 1e-04
Position.ord.Q	-0.39	0.03	-11.33	< 1e-04
Position.ord.C	0.02	0.03	0.74	0.46
Position.ord^4	-0.01	0.03	-0.35	0.73
SexM	-0.06	0.06	-1.04	0.30
normdurms	0.05	0.02	2.99	0.00
as.factor(AgeGroup)2	0.06	0.06	1.06	0.29
PrecedingPhoned	-0.3	0.16	-1.9	0.06
PrecedingPhoneeƒ»	0.17	0.21	0.81	0.42
PrecedingPhonef	-0.28	0.49	-0.57	0.57
PrecedingPhoneg	0.49	0.27	1.83	0.07
PrecedingPhoneh	0.08	0.26	0.29	0.77
PrecedingPhonek	0.07	0.27	0.25	0.80
PrecedingPhonel	0.11	0.47	0.24	0.81
PrecedingPhonep	0.29	0.24	1.2	0.23
PrecedingPhoner	-0.24	0.47	-0.52	0.61
PrecedingPhonet	0.18	0.2	0.89	0.37
normFollowSports	0.09	0.02	3.69	0.00
SamenessY	-0.17	0.06	-2.86	0.00
Placeinterdental	0.27	0.4	0.69	0.49
Placelabial	-0.06	0.18	-0.3	0.77
Placelabiodental	-0.01	0.44	-0.02	0.98
Placepalatal	-0.27	0.56	-0.49	0.62
Placevelar	-0.48	0.16	-3.06	0.00
Mannerlateral:Position.ord.L	0.06	0.08	0.73	0.46
Mannerstop:Position.ord.L	0.15	0.03	4.83	< 1e-04
Mannerlateral:Position.ord.Q	-0.07	0.08	-0.91	0.36
Mannerstop:Position.ord.Q	-0.01	0.03	-0.17	0.86
Mannerlateral:Position.ord.C	0.06	0.08	0.81	0.42
Mannerstop:Position.ord.C	-0.02	0.03	-0.71	0.48
Mannerlateral:Position.ord^4	0.03	0.08	0.43	0.67
Mannerstop:Position.ord^4	0	0.03	0.1	0.92
Mannerlateral:SexM	-0.04	0.05	-0.74	0.46
Mannerstop:SexM	-0.1	0.03	-3.73	0.00
Position.ord.L:SexM	0.18	0.08	2.32	0.02
Position.ord.Q:SexM	-0.01	0.05	-0.17	0.86
Position.ord.C:SexM	-0.01	0.04	-0.13	0.90

Table 69. Full F1 model of /æ/ retraction in Vancouver (continued)

Position.ord^4:SexM	0.01	0.04	0.18	0.86
Mannerlateral:normdurms	-0.07	0.03	-2.21	0.03
Mannerstop:normdurms	-0.04	0.02	-2.14	0.03
Position.ord.L:normdurms	0	0.03	-0.13	0.90
Position.ord.Q:normdurms	-0.06	0.03	-2.09	0.04
Position.ord.C:normdurms	-0.02	0.03	-0.83	0.41
Position.ord^4:normdurms	-0.01	0.03	-0.3	0.77
SexM:normdurms	-0.01	0.02	-0.55	0.58
SexM:as.factor(AgeGroup)2	-0.08	0.08	-0.98	0.33
Mannerlateral:as.factor(AgeGroup)2	-0.04	0.04	-0.93	0.35
Mannerstop:as.factor(AgeGroup)2	-0.01	0.03	-0.21	0.84
Mannerlateral:Position.ord.L:SexM	0.01	0.1	0.06	0.95
Mannerstop:Position.ord.L:SexM	-0.15	0.04	-3.39	0.00
Mannerlateral:Position.ord.Q:SexM	0.09	0.1	0.87	0.39
Mannerstop:Position.ord.Q:SexM	-0.01	0.04	-0.2	0.84
Mannerlateral:Position.ord.C:SexM	-0.09	0.1	-0.85	0.39
Mannerstop:Position.ord.C:SexM	-0.01	0.04	-0.28	0.78
Mannerlateral:Position.ord^4:SexM	-0.02	0.1	-0.19	0.85
Mannerstop:Position.ord^4:SexM	0	0.04	-0.06	0.95
Mannerlateral:Position.ord.L:normdurms	-0.04	0.06	-0.75	0.45
Mannerstop:Position.ord.L:normdurms	0	0.03	-0.01	0.99
Mannerlateral:Position.ord.Q:normdurms	-0.13	0.06	-2.29	0.02
Mannerstop:Position.ord.Q:normdurms	-0.03	0.03	-1.05	0.30
Mannerlateral:Position.ord.C:normdurms	0.02	0.06	0.36	0.72
Mannerstop:Position.ord.C:normdurms	0.01	0.03	0.4	0.69
Mannerlateral:Position.ord^4:normdurms	0.01	0.06	0.14	0.89
Mannerstop:Position.ord^4:normdurms	0.02	0.03	0.71	0.48
Mannerlateral:SexM:normdurms	0.09	0.04	2.32	0.02
Mannerstop:SexM:normdurms	-0.02	0.02	-1.15	0.25
Position.ord.L:SexM:normdurms	-0.05	0.04	-1.37	0.17
Position.ord.Q:SexM:normdurms	0	0.04	-0.02	0.98
Position.ord.C:SexM:normdurms	-0.01	0.04	-0.2	0.84
Position.ord^4:SexM:normdurms	0	0.04	0.03	0.98
Mannerlateral:SexM:as.factor(AgeGroup)2	0.25	0.06	3.96	< 1e-04
Mannerstop:SexM:as.factor(AgeGroup)2	0.1	0.04	2.53	0.01
Mannerlateral:Position.ord.L:SexM:normdurms	0.14	0.08	1.83	0.07
Mannerstop:Position.ord.L:SexM:normdurms	-0.01	0.05	-0.11	0.91
Mannerlateral:Position.ord.Q:SexM:normdurms	0.05	0.08	0.64	0.52
Mannerstop:Position.ord.Q:SexM:normdurms	0	0.05	-0.07	0.94
Mannerlateral:Position.ord.C:SexM:normdurms	-0.03	0.08	-0.4	0.69
Mannerstop:Position.ord.C:SexM:normdurms	-0.02	0.05	-0.41	0.68

Table 69. Full F1 model of /æ/ retraction in Vancouver (continued)

Mannerlateral:Position.ord^4:SexM:normdurms	-0.01	0.08	-0.19	0.85
Mannerstop:Position.ord^4:SexM:normdurms	-0.03	0.05	-0.76	0.45

F2

```
F2.lmerG <- lmer(normF2 ~ Manner*as.factor(AgeGroup)*Sex +
Manner*Position.ord*normdurms + PrecedingPhone + normSeattleVancouverSimilarity + (1 +
Position.ord | Name) + (1|Word), data=VANback3)
```

Table 70. Full F2 model of /æ/ retraction in Vancouver

	Estimate	Std..Error	t.value	p
(Intercept)	-0.152	0.20	-0.77	0.439
Mannerlateral	-0.285	0.22	-1.29	0.197
Mannerstop	0.265	0.16	1.61	0.107
as.factor(AgeGroup)2	0.157	0.05	3.06	0.002
SexM	0.133	0.05	2.56	0.010
Position.ord.L	-0.232	0.02	-10.17	< 1e-04
Position.ord.Q	0.067	0.02	3.89	0.000
Position.ord.C	0.025	0.02	1.50	0.134
Position.ord^4	-0.002	0.02	-0.11	0.915
normdurms	0.081	0.01	7.00	< 1e-04
PrecedingPhoned	-0.538	0.03	-16.46	< 1e-04
PrecedingPhoneeɪ	-0.493	0.17	-2.84	0.005
PrecedingPhonef	-0.556	0.44	-1.27	0.204
PrecedingPhoneg	-0.331	0.23	-1.46	0.143
PrecedingPhoneh	-0.287	0.23	-1.23	0.219
PrecedingPhonek	-0.589	0.21	-2.80	0.005
PrecedingPhonel	-0.879	0.41	-2.13	0.033
PrecedingPhonep	-0.632	0.21	-2.94	0.003
PrecedingPhoner	-0.961	0.35	-2.76	0.006
PrecedingPhonet	-0.474	0.17	-2.80	0.005
normSeattleVancouverSimilarity	0.058	0.02	2.74	0.006
Mannerlateral:as.factor(AgeGroup)2	-0.067	0.04	-1.79	0.074
Mannerstop:as.factor(AgeGroup)2	-0.138	0.02	-5.94	< 1e-04
Mannerlateral:SexM	-0.197	0.04	-5.29	< 1e-04
Mannerstop:SexM	0.037	0.02	1.60	0.109
as.factor(AgeGroup)2:SexM	-0.157	0.07	-2.13	0.033
Mannerlateral:Position.ord.L	-0.496	0.04	-11.38	< 1e-04
Mannerstop:Position.ord.L	0.134	0.02	7.12	< 1e-04
Mannerlateral:Position.ord.Q	-0.039	0.04	-0.91	0.365
Mannerstop:Position.ord.Q	0.035	0.02	1.89	0.059
Mannerlateral:Position.ord.C	0.016	0.04	0.38	0.705
Mannerstop:Position.ord.C	-0.013	0.02	-0.67	0.501

Table 70. Full F2 model of /æ/ retraction in Vancouver (continued)

Mannerlateral:Position.ord^4	0.015	0.04	0.34	0.735
Mannerstop:Position.ord^4	-0.014	0.02	-0.74	0.458
Mannerlateral:normdurms	-0.090	0.02	-4.28	< 1e-04
Mannerstop:normdurms	-0.082	0.01	-6.20	< 1e-04
Position.ord.L:normdurms	0.001	0.02	0.04	0.971
Position.ord.Q:normdurms	0.064	0.02	3.69	0.000
Position.ord.C:normdurms	0.007	0.02	0.40	0.691
Position.ord^4:normdurms	0.000	0.02	-0.01	0.988
Mannerlateral:as.factor(AgeGroup)2:SexM	0.104	0.05	1.96	0.050
Mannerstop:as.factor(AgeGroup)2:SexM	0.065	0.03	1.94	0.052
Mannerlateral:Position.ord.L:normdurms	-0.089	0.03	-2.63	0.009
Mannerstop:Position.ord.L:normdurms	-0.007	0.02	-0.37	0.712
Mannerlateral:Position.ord.Q:normdurms	-0.059	0.03	-1.74	0.081
Mannerstop:Position.ord.Q:normdurms	-0.045	0.02	-2.30	0.022
Mannerlateral:Position.ord.C:normdurms	-0.031	0.03	-0.91	0.365
Mannerstop:Position.ord.C:normdurms	-0.003	0.02	-0.13	0.893
Mannerlateral:Position.ord^4:normdurms	0.012	0.03	0.37	0.712
Mannerstop:Position.ord^4:normdurms	0.002	0.02	0.10	0.918

Comparison of Seattle and Vancouver

F1

```
F1.lmerC <- lmer(normF1 ~ Manner*Position.ord*normdurms +
 Manner*(as.factor(AgeGroup))*Sex*City + PrecedingPhone + (1 + Position.ord | Name) +
 (1|Word), data=back3)
```

Table 71. Full F1 model for /æ/ retraction comparing Seattle and Vancouver

	Estimate	**Std..Error**	**t.value**	**p**
(Intercept)	0.802	0.20	3.93	< 1e-04
Mannerlateral	0.017	0.26	0.07	0.946
Mannerstop	0.049	0.18	0.27	0.786
Position.ord.L	-0.390	0.03	-14.04	< 1e-04
Position.ord.Q	-0.368	0.02	-20.46	< 1e-04
Position.ord.C	0.044	0.01	3.03	0.002
Position.ord^4	0.003	0.01	0.25	0.806
normdurms	0.038	0.01	3.84	0.000
as.factor(AgeGroup)2	0.102	0.07	1.48	0.139
SexM	0.046	0.07	0.66	0.509
CityVAN	0.095	0.07	1.38	0.169
PrecedingPhoned	0.127	0.03	3.71	0.000

Table 71. Full F1 model for /æ/ retraction comparing Seattle and Vancouver (continued)

PrecedingPhoneeeɪ	0.058	0.14	0.40	0.689
PrecedingPhonef	-0.021	0.51	-0.04	0.967
PrecedingPhoneg	0.458	0.23	1.95	0.051
PrecedingPhoneh	-0.105	0.25	-0.42	0.672
PrecedingPhonek	0.007	0.22	0.03	0.974
PrecedingPhonel	0.253	0.48	0.52	0.600
PrecedingPhonep	0.369	0.24	1.54	0.123
PrecedingPhoner	-0.253	0.40	-0.64	0.524
PrecedingPhonet	0.148	0.17	0.86	0.387
Mannerlateral:Position.ord.L	-0.010	0.04	-0.27	0.789
Mannerstop:Position.ord.L	0.065	0.02	4.10	< 1e-04
Mannerlateral:Position.ord.Q	-0.005	0.04	-0.14	0.889
Mannerstop:Position.ord.Q	-0.016	0.02	-0.99	0.324
Mannerlateral:Position.ord.C	0.012	0.04	0.33	0.743
Mannerstop:Position.ord.C	-0.041	0.02	-2.58	0.010
Mannerlateral:Position.ord^4	0.012	0.04	0.34	0.734
Mannerstop:Position.ord^4	0.001	0.02	0.04	0.971
Mannerlateral:normdurms	-0.037	0.02	-2.09	0.036
Mannerstop:normdurms	-0.034	0.01	-3.00	0.003
Position.ord.L:normdurms	-0.066	0.01	-4.64	< 1e-04
Position.ord.Q:normdurms	-0.044	0.01	-3.09	0.002
Position.ord.C:normdurms	-0.010	0.01	-0.72	0.474
Position.ord^4:normdurms	-0.026	0.01	-1.85	0.064
Mannerlateral:as.factor(AgeGroup)2	-0.166	0.04	-3.95	< 1e-04
Mannerstop:as.factor(AgeGroup)2	-0.058	0.03	-2.13	0.033
Mannerlateral:SexM	0.091	0.04	2.10	0.036
Mannerstop:SexM	-0.116	0.03	-4.07	< 1e-04
as.factor(AgeGroup)2:SexM	-0.056	0.10	-0.58	0.564
Mannerlateral:CityVAN	-0.096	0.04	-2.16	0.031
Mannerstop:CityVAN	-0.116	0.03	-4.08	< 1e-04
as.factor(AgeGroup)2:CityVAN	-0.120	0.10	-1.23	0.219
SexM:CityVAN	-0.039	0.10	-0.40	0.690
Mannerlateral:Position.ord.L:normdurms	0.023	0.03	0.82	0.414
Mannerstop:Position.ord.L:normdurms	-0.003	0.02	-0.19	0.852
Mannerlateral:Position.ord.Q:normdurms	-0.090	0.03	-3.20	0.001
Mannerstop:Position.ord.Q:normdurms	-0.042	0.02	-2.57	0.010
Mannerlateral:Position.ord.C:normdurms	0.003	0.03	0.11	0.914
Mannerstop:Position.ord.C:normdurms	-0.020	0.02	-1.22	0.221
Mannerlateral:Position.ord^4:normdurms	0.018	0.03	0.66	0.512
Mannerstop:Position.ord^4:normdurms	0.016	0.02	0.98	0.325
Mannerlateral:as.factor(AgeGroup)2:SexM	0.002	0.06	0.03	0.973

Table 71. Full F1 model for /æ/ retraction comparing Seattle and Vancouver (continued)

Mannerstop:as.factor(AgeGroup)2:SexM	0.041	0.04	1.04	0.301
Mannerlateral:as.factor(AgeGroup)2:CityVAN	0.139	0.06	2.26	0.024
Mannerstop:as.factor(AgeGroup)2:CityVAN	0.054	0.04	1.39	0.166
Mannerlateral:SexM:CityVAN	-0.203	0.06	-3.24	0.001
Mannerstop:SexM:CityVAN	0.014	0.04	0.34	0.734
as.factor(AgeGroup)2:SexM:CityVAN	0.032	0.14	0.23	0.821
Mannerlateral:as.factor(AgeGroup)2:SexM:CityVAN	0.236	0.09	2.66	0.008
Mannerstop:as.factor(AgeGroup)2:SexM:CityVAN	0.056	0.06	0.99	0.320

F2

F2.lmerG <- lmer(normF2 ~ Manner*Position.ord*City*normdurms + PrecedingPhone + normHowOftenShopLocalHomeCity + (1 + Position.ord | Name) + (1|Word), data=back3)

Table 72. Full F2 model for /æ/ retraction comparing Seattle and Vancouver

	Estimate	Std..Error	t.value	p
(Intercept)	-0.225	0.13	-1.70	0.089
Mannerlateral	-0.419	0.16	-2.62	0.009
Mannerstop	0.163	0.11	1.46	0.144
Position.ord.L	-0.230	0.03	-7.95	<1e-04
Position.ord.Q	0.059	0.02	3.06	0.002
Position.ord.C	0.037	0.02	2.06	0.040
Position.ord^4	-0.005	0.02	-0.29	0.770
CityVAN	-0.146	0.04	-3.72	0.000
normdurms	0.047	0.01	4.49	<1e-04
SexM	0.131	0.04	3.61	0.000
PrecedingPhoned	-0.314	0.03	-10.08	<1e-04
PrecedingPhoneeeɪ	-0.175	0.11	-1.65	0.099
PrecedingPhonef	-0.272	0.31	-0.86	0.388
PrecedingPhoneg	-0.048	0.18	-0.26	0.796
PrecedingPhoneh	-0.075	0.16	-0.48	0.632
PrecedingPhonek	-0.243	0.14	-1.74	0.082
PrecedingPhonel	-0.608	0.30	-2.03	0.042
PrecedingPhonep	-0.333	0.15	-2.19	0.028
PrecedingPhoner	-0.667	0.26	-2.61	0.009
PrecedingPhonet	-0.215	0.12	-1.84	0.066
normHowOftenShopLocalHomeCity	-0.038	0.02	-2.12	0.034
Mannerlateral:Position.ord.L	-0.420	0.04	-9.54	<1e-04
Mannerstop:Position.ord.L	0.121	0.02	5.95	<1e-04
Mannerlateral:Position.ord.Q	-0.059	0.04	-1.34	0.181
Mannerstop:Position.ord.Q	0.012	0.02	0.59	0.555

Table 72. Full F2 model for /æ/ retraction comparing Seattle and Vancouver (continued)

Mannerlateral:Position.ord.C	0.008	0.04	0.19	0.850
Mannerstop:Position.ord.C	-0.025	0.02	-1.21	0.225
Mannerlateral:Position.ord^4	0.002	0.04	0.05	0.961
Mannerstop:Position.ord^4	-0.004	0.02	-0.18	0.853
Mannerlateral:CityVAN	0.009	0.03	0.30	0.761
Mannerstop:CityVAN	0.108	0.01	8.23	<1e-04
Position.ord.L:CityVAN	-0.002	0.04	-0.06	0.954
Position.ord.Q:CityVAN	0.009	0.03	0.31	0.758
Position.ord.C:CityVAN	-0.011	0.03	-0.44	0.659
Position.ord^4:CityVAN	0.003	0.03	0.13	0.893
Mannerlateral:normdurms	0.017	0.02	0.89	0.373
Mannerstop:normdurms	-0.038	0.01	-3.15	0.002
Position.ord.L:normdurms	-0.018	0.02	-1.06	0.291
Position.ord.Q:normdurms	0.024	0.02	1.40	0.160
Position.ord.C:normdurms	0.006	0.02	0.33	0.742
Position.ord^4:normdurms	-0.010	0.02	-0.60	0.547
CityVAN:normdurms	0.049	0.01	4.19	<1e-04
Mannerlateral:Position.ord.L:CityVAN	-0.076	0.07	-1.17	0.243
Mannerstop:Position.ord.L:CityVAN	0.013	0.03	0.45	0.654
Mannerlateral:Position.ord.Q:CityVAN	0.019	0.07	0.29	0.769
Mannerstop:Position.ord.Q:CityVAN	0.023	0.03	0.81	0.420
Mannerlateral:Position.ord.C:CityVAN	0.006	0.07	0.09	0.926
Mannerstop:Position.ord.C:CityVAN	0.012	0.03	0.41	0.683
Mannerlateral:Position.ord^4:CityVAN	0.012	0.07	0.19	0.852
Mannerstop:Position.ord^4:CityVAN	-0.010	0.03	-0.35	0.726
Mannerlateral:Position.ord.L:normdurms	0.017	0.04	0.48	0.629
Mannerstop:Position.ord.L:normdurms	0.000	0.02	0.01	0.992
Mannerlateral:Position.ord.Q:normdurms	-0.041	0.04	-1.17	0.242
Mannerstop:Position.ord.Q:normdurms	-0.009	0.02	-0.44	0.658
Mannerlateral:Position.ord.C:normdurms	-0.039	0.03	-1.10	0.270
Mannerstop:Position.ord.C:normdurms	-0.003	0.02	-0.15	0.883
Mannerlateral:Position.ord^4:normdurms	0.010	0.03	0.28	0.777
Mannerstop:Position.ord^4:normdurms	0.011	0.02	0.56	0.572
Mannerlateral:CityVAN:normdurms	-0.101	0.02	-4.37	<1e-04
Mannerstop:CityVAN:normdurms	-0.042	0.01	-3.12	0.002
Position.ord.L:CityVAN:normdurms	0.019	0.03	0.74	0.460
Position.ord.Q:CityVAN:normdurms	0.039	0.03	1.51	0.130
Position.ord.C:CityVAN:normdurms	0.001	0.03	0.03	0.977
Position.ord^4:CityVAN:normdurms	0.010	0.03	0.40	0.692
Mannerlateral:Position.ord.L:CityVAN:normdurms	-0.107	0.05	-2.07	0.039
Mannerstop:Position.ord.L:CityVAN:normdurms	-0.008	0.03	-0.26	0.797
Mannerlateral:Position.ord.Q:CityVAN:normdurms	-0.018	0.05	-0.35	0.726

Table 72. Full F2 model for /æ/ retraction comparing Seattle and Vancouver (continued)

Mannerstop:Position.ord.Q:CityVAN:normdurms	-0.036	0.03	-1.21	0.225
Mannerlateral:Position.ord.C:CityVAN:normdurms	0.007	0.05	0.13	0.893
Mannerstop:Position.ord.C:CityVAN:normdurms	0.001	0.03	0.03	0.975
Mannerlateral:Position.ord^4:CityVAN:normdurms	0.002	0.05	0.04	0.967
Mannerstop:Position.ord^4:CityVAN:normdurms	-0.009	0.03	-0.31	0.753

/aʊ/ Raising

Seattle

F1

F1.lmerH <- lmer(normF1 ~ Voicing*Position.ord*as.factor(AgeGroup)*Sex + PrecedingPhone + normdurms*Voicing*Position.ord + (1 + Position.ord | Name) + (1|Word), data=SEAau)

Table 73. Full F1 model for /aʊT/ vs. /aʊD/ in Seattle

	Estimate	Std..Error	t.value	p
(Intercept)	0.613	0.11	5.58	< 1e-04
Voicingvoiceless	-0.223	0.09	-2.59	0.010
Position.ord.L	-1.084	0.08	-13.75	< 1e-04
Position.ord.Q	-0.358	0.05	-7.16	< 1e-04
Position.ord.C	0.089	0.03	2.72	0.006
Position.ord^4	0.034	0.03	1.13	0.258
as.factor(AgeGroup)2	-0.094	0.09	-1.07	0.285
SexM	-0.035	0.09	-0.40	0.689
PrecedingPhoneeeɪ	0.239	0.14	1.74	0.081
PrecedingPhonef	0.258	0.15	1.67	0.095
PrecedingPhoneg	-0.071	0.17	-0.42	0.671
PrecedingPhoneh	-0.410	0.16	-2.57	0.010
PrecedingPhonek	-0.135	0.21	-0.65	0.515
PrecedingPhonel	-0.032	0.12	-0.27	0.786
PrecedingPhonem	0.178	0.15	1.16	0.248
PrecedingPhonep	0.044	0.15	0.29	0.775
PrecedingPhoner	-0.175	0.12	-1.50	0.134
PrecedingPhones	0.184	0.21	0.89	0.374
PrecedingPhonet	0.017	0.13	0.13	0.900
PrecedingPhonev	0.106	0.21	0.51	0.609
normdurms	-0.007	0.01	-0.96	0.337
Voicingvoiceless:Position.ord.L	0.154	0.05	3.06	0.002
Voicingvoiceless:Position.ord.Q	0.098	0.05	1.95	0.051

Table 73. Full F1 model for /aʊT/ vs. /aʊD/ in Seattle (continued)

Voicingvoiceless:Position.ord.C	0.125	0.05	2.50	0.013
Voicingvoiceless:Position.ord^4	-0.026	0.05	-0.51	0.610
Voicingvoiceless:as.factor(AgeGroup)2	-0.120	0.03	-3.87	0.000
Position.ord.L:as.factor(AgeGroup)2	-0.241	0.11	-2.17	0.030
Position.ord.Q:as.factor(AgeGroup)2	0.019	0.07	0.27	0.786
Position.ord.C:as.factor(AgeGroup)2	0.013	0.05	0.28	0.780
Position.ord^4:as.factor(AgeGroup)2	0.009	0.04	0.22	0.824
Voicingvoiceless:SexM	-0.029	0.03	-0.87	0.385
Position.ord.L:SexM	0.015	0.11	0.14	0.890
Position.ord.Q:SexM	0.095	0.07	1.32	0.185
Position.ord.C:SexM	-0.053	0.05	-1.13	0.260
Position.ord^4:SexM	-0.038	0.04	-0.88	0.380
as.factor(AgeGroup)2:SexM	-0.008	0.12	-0.06	0.952
Voicingvoiceless:normdurms	-0.044	0.01	-2.94	0.003
Position.ord.L:normdurms	-0.144	0.01	-9.79	< 1e-04
Position.ord.Q:normdurms	-0.017	0.01	-1.12	0.261
Position.ord.C:normdurms	0.027	0.01	1.87	0.061
Position.ord^4:normdurms	0.001	0.01	0.04	0.967
Voicingvoiceless:Position.ord.L:as.factor(AgeGroup)2	-0.147	0.07	-2.13	0.034
Voicingvoiceless:Position.ord.Q:as.factor(AgeGroup)2	0.101	0.07	1.47	0.142
Voicingvoiceless:Position.ord.C:as.factor(AgeGroup)2	-0.032	0.07	-0.46	0.646
Voicingvoiceless:Position.ord^4:as.factor(AgeGroup)2	-0.023	0.07	-0.33	0.744
Voicingvoiceless:Position.ord.L:SexM	-0.317	0.07	-4.33	< 1e-04
Voicingvoiceless:Position.ord.Q:SexM	-0.131	0.07	-1.80	0.072
Voicingvoiceless:Position.ord.C:SexM	0.014	0.07	0.19	0.851
Voicingvoiceless:Position.ord^4:SexM	0.045	0.07	0.62	0.538
Voicingvoiceless:as.factor(AgeGroup)2:SexM	0.105	0.05	2.32	0.020
Position.ord.L:as.factor(AgeGroup)2:SexM	0.063	0.16	0.40	0.691
Position.ord.Q:as.factor(AgeGroup)2:SexM	-0.012	0.10	-0.12	0.905
Position.ord.C:as.factor(AgeGroup)2:SexM	0.035	0.07	0.53	0.599
Position.ord^4:as.factor(AgeGroup)2:SexM	-0.010	0.06	-0.17	0.866
Voicingvoiceless:Position.ord.L:normdurms	-0.001	0.03	-0.03	0.973
Voicingvoiceless:Position.ord.Q:normdurms	0.089	0.03	3.04	0.002
Voicingvoiceless:Position.ord.C:normdurms	0.022	0.03	0.76	0.450
Voicingvoiceless:Position.ord^4:normdurms	-0.004	0.03	-0.16	0.876
Voicingvoiceless:Position.ord.L:as.factor(AgeGroup)2:SexM	0.236	0.10	2.35	0.019
Voicingvoiceless:Position.ord.Q:as.factor(AgeGroup)2:SexM	0.070	0.10	0.69	0.487
Voicingvoiceless:Position.ord.C:as.factor(AgeGroup)2:SexM	0.063	0.10	0.62	0.533
Voicingvoiceless:Position.ord^4:as.factor(AgeGroup)2:SexM	0.021	0.10	0.21	0.833

F2

```
F2.lmerJ <- lmer(normF2 ~ Voicing*Position.ord*as.factor(AgeGroup)*Sex +
 normdurms*Position.ord + normdurms*Voicing + (1 + Position.ord | Name) + (1|Word),
 data=SEAau)
```

Table 74. Full F2 model for /aʊT/ vs. /aʊD/ in Seattle

	Estimate	Std..Error	t.value	p
(Intercept)	-1.018	0.09	-11.55	< 1e-04
Voicingvoiceless	0.053	0.07	0.75	0.455
Position.ord.L	-0.571	0.08	-7.06	< 1e-04
Position.ord.Q	0.137	0.04	3.52	0.000
Position.ord.C	0.091	0.04	2.58	0.010
Position.ord^4	0.047	0.03	1.49	0.136
as.factor(AgeGroup)2	-0.047	0.11	-0.42	0.677
SexM	0.002	0.11	0.02	0.984
normdurms	0.003	0.01	0.35	0.727
Voicingvoiceless:Position.ord.L	0.032	0.05	0.59	0.555
Voicingvoiceless:Position.ord.Q	0.066	0.05	1.23	0.220
Voicingvoiceless:Position.ord.C	0.028	0.05	0.52	0.605
Voicingvoiceless:Position.ord^4	-0.011	0.05	-0.21	0.837
Voicingvoiceless:as.factor(AgeGroup)2	-0.017	0.03	-0.52	0.602
Position.ord.L:as.factor(AgeGroup)2	0.020	0.11	0.18	0.858
Position.ord.Q:as.factor(AgeGroup)2	-0.004	0.05	-0.08	0.935
Position.ord.C:as.factor(AgeGroup)2	-0.016	0.05	-0.33	0.739
Position.ord^4:as.factor(AgeGroup)2	-0.046	0.04	-1.06	0.291
Voicingvoiceless:SexM	0.064	0.03	1.82	0.068
Position.ord.L:SexM	-0.108	0.12	-0.94	0.349
Position.ord.Q:SexM	0.010	0.06	0.18	0.859
Position.ord.C:SexM	0.009	0.05	0.19	0.852
Position.ord^4:SexM	-0.055	0.05	-1.19	0.236
as.factor(AgeGroup)2:SexM	-0.136	0.16	-0.85	0.397
Position.ord.L:normdurms	-0.016	0.01	-1.18	0.240
Position.ord.Q:normdurms	0.049	0.01	3.66	0.000
Position.ord.C:normdurms	0.024	0.01	1.80	0.072
Position.ord^4:normdurms	0.005	0.01	0.35	0.724
Voicingvoiceless:normdurms	-0.053	0.02	-3.37	0.001
Voicingvoiceless:Position.ord.L:as.factor(AgeGroup)2	-0.016	0.07	-0.21	0.832
Voicingvoiceless:Position.ord.Q:as.factor(AgeGroup)2	0.028	0.07	0.38	0.706
Voicingvoiceless:Position.ord.C:as.factor(AgeGroup)2	0.009	0.07	0.12	0.907
Voicingvoiceless:Position.ord^4:as.factor(AgeGroup)2	0.016	0.07	0.21	0.832
Voicingvoiceless:Position.ord.L:SexM	-0.112	0.08	-1.44	0.151

Table 74. Full F2 model for /aʊT/ vs. /aʊD/ in Seattle (continued)

Voicingvoiceless:Position.ord.Q:SexM	-0.079	0.08	-1.01	0.311
Voicingvoiceless:Position.ord.C:SexM	0.042	0.08	0.54	0.589
Voicingvoiceless:Position.ord^4:SexM	0.057	0.08	0.73	0.464
Voicingvoiceless:as.factor(AgeGroup)2:SexM	-0.047	0.05	-0.97	0.332
Position.ord.L:as.factor(AgeGroup)2:SexM	-0.199	0.16	-1.22	0.221
Position.ord.Q:as.factor(AgeGroup)2:SexM	0.041	0.08	0.53	0.598
Position.ord.C:as.factor(AgeGroup)2:SexM	0.079	0.07	1.11	0.267
Position.ord^4:as.factor(AgeGroup)2:SexM	0.051	0.06	0.79	0.430
Voicingvoiceless:Position.ord.L:as.factor(AgeGroup)2:SexM	0.243	0.11	2.26	0.024
Voicingvoiceless:Position.ord.Q:as.factor(AgeGroup)2:SexM	0.039	0.11	0.37	0.715
Voicingvoiceless:Position.ord.C:as.factor(AgeGroup)2:SexM	-0.060	0.11	-0.56	0.573
Voicingvoiceless:Position.ord^4:as.factor(AgeGroup)2:SexM	-0.037	0.11	-0.35	0.727

Vancouver

F1

F1.lmerM <- lmer(normF1 ~ Position.ord*as.factor(AgeGroup)*Sex*Voicing + PrecedingPhone + normdurms + normNationalPride + (1 + Position.ord | Name) + (1|Word), data=VANau)

Table 75. Full F1 model for /aʊT/ vs. /aʊD/ in Vancouver

	Estimate	Std.Error	t.value	p
(Intercept)	0.650	0.08	8.30	< 1e-04
Position.ord.L	-0.974	0.07	-14.34	< 1e-04
Position.ord.Q	-0.370	0.04	-8.55	< 1e-04
Position.ord.C	0.128	0.03	4.38	< 1e-04
Position.ord^4	-0.016	0.03	-0.59	0.556
as.factor(AgeGroup)2	-0.122	0.05	-2.42	0.016
SexM	0.048	0.05	0.99	0.320
Voicingvoiceless	-0.762	0.07	-10.55	< 1e-04
PrecedingPhoneeeı	0.033	0.12	0.26	0.793
PrecedingPhonef	0.181	0.12	1.46	0.145
PrecedingPhoneg	-0.436	0.16	-2.72	0.007
PrecedingPhoneh	-0.594	0.14	-4.18	< 1e-04
PrecedingPhonek	-0.244	0.17	-1.45	0.147
PrecedingPhonel	-0.089	0.09	-0.94	0.348
PrecedingPhonem	-0.125	0.12	-1.01	0.313
PrecedingPhonep	-0.134	0.12	-1.08	0.282
PrecedingPhoner	-0.263	0.10	-2.74	0.006
PrecedingPhones	-0.092	0.17	-0.55	0.586
PrecedingPhonet	-0.039	0.11	-0.36	0.720

Table 75. Full F1 model for /aʊT/ vs. /aʊD/ in Vancouver (continued)

PrecedingPhonev	-0.005	0.17	-0.03	0.976
normdurms	-0.019	0.01	-3.20	0.001
normNationalPride	0.039	0.02	2.20	0.028
Position.ord.L:as.factor(AgeGroup)2	-0.138	0.10	-1.44	0.149
Position.ord.Q:as.factor(AgeGroup)2	0.145	0.06	2.38	0.017
Position.ord.C:as.factor(AgeGroup)2	-0.034	0.04	-0.82	0.411
Position.ord^4:as.factor(AgeGroup)2	0.006	0.04	0.15	0.882
Position.ord.L:SexM	-0.007	0.10	-0.08	0.938
Position.ord.Q:SexM	0.017	0.06	0.28	0.780
Position.ord.C:SexM	-0.055	0.04	-1.35	0.176
Position.ord^4:SexM	-0.004	0.04	-0.11	0.912
as.factor(AgeGroup)2:SexM	0.063	0.07	0.88	0.377
Position.ord.L:Voicingvoiceless	0.038	0.05	0.82	0.413
Position.ord.Q:Voicingvoiceless	0.136	0.05	2.95	0.003
Position.ord.C:Voicingvoiceless	0.033	0.05	0.72	0.470
Position.ord^4:Voicingvoiceless	0.007	0.05	0.15	0.884
as.factor(AgeGroup)2:Voicingvoiceless	0.104	0.03	3.63	0.000
SexM:Voicingvoiceless	0.177	0.03	6.18	< 1e-04
Position.ord.L:as.factor(AgeGroup)2:SexM	0.062	0.14	0.44	0.657
Position.ord.Q:as.factor(AgeGroup)2:SexM	-0.165	0.09	-1.87	0.061
Position.ord.C:as.factor(AgeGroup)2:SexM	0.028	0.06	0.48	0.631
Position.ord^4:as.factor(AgeGroup)2:SexM	0.023	0.05	0.42	0.675
Position.ord.L:as.factor(AgeGroup)2:Voicingvoiceless	-0.082	0.06	-1.28	0.199
Position.ord.Q:as.factor(AgeGroup)2:Voicingvoiceless	0.033	0.06	0.51	0.610
Position.ord.C:as.factor(AgeGroup)2:Voicingvoiceless	0.082	0.06	1.29	0.197
Position.ord^4:as.factor(AgeGroup)2:Voicingvoiceless	-0.002	0.06	-0.03	0.974
Position.ord.L:SexM:Voicingvoiceless	0.002	0.06	0.03	0.979
Position.ord.Q:SexM:Voicingvoiceless	-0.011	0.06	-0.17	0.863
Position.ord.C:SexM:Voicingvoiceless	0.088	0.06	1.37	0.169
Position.ord^4:SexM:Voicingvoiceless	0.008	0.06	0.12	0.904
as.factor(AgeGroup)2:SexM:Voicingvoiceless	-0.104	0.04	-2.52	0.012
Position.ord.L:as.factor(AgeGroup)2:SexM:Voicingvoiceless	0.295	0.09	3.19	0.001
Position.ord.Q:as.factor(AgeGroup)2:SexM:Voicingvoiceless	0.163	0.09	1.76	0.078
Position.ord.C:as.factor(AgeGroup)2:SexM:Voicingvoiceless	-0.113	0.09	-1.22	0.221
Position.ord^4:as.factor(AgeGroup)2:SexM:Voicingvoiceless	-0.038	0.09	-0.41	0.682

F2

F2.lmerH <- lmer(normF2 ~ Position.ord*Voicing*Sex + as.factor(AgeGroup)*Position.ord*Voicing + normdurms + (1 + Position.ord | Name) + (1|Word), data=VANau)

Table 76. Full F2 model of /aʊT/ vs. /aʊD/ in Vancouver

	Estimate	Std..Error	t.value	p
(Intercept)	-0.950	0.07	-14.12	< 1e-04
Position.ord.L	-0.598	0.06	-10.63	< 1e-04
Position.ord.Q	0.099	0.03	3.66	0.000
Position.ord.C	0.120	0.02	4.87	< 1e-04
Position.ord^4	0.023	0.02	1.03	0.301
Voicingvoiceless	0.142	0.08	1.76	0.078
SexM	-0.104	0.06	-1.75	0.081
as.factor(AgeGroup)2	0.020	0.06	0.33	0.738
normdurms	-0.030	0.01	-5.42	< 1e-04
Position.ord.L:Voicingvoiceless	-0.100	0.04	-2.71	0.007
Position.ord.Q:Voicingvoiceless	-0.132	0.04	-3.58	0.000
Position.ord.C:Voicingvoiceless	0.022	0.04	0.61	0.543
Position.ord^4:Voicingvoiceless	0.010	0.04	0.26	0.794
Position.ord.L:SexM	-0.050	0.07	-0.75	0.453
Position.ord.Q:SexM	0.013	0.03	0.40	0.689
Position.ord.C:SexM	-0.011	0.03	-0.38	0.702
Position.ord^4:SexM	-0.002	0.03	-0.07	0.948
Voicingvoiceless:SexM	-0.178	0.02	-9.34	< 1e-04
Position.ord.L:as.factor(AgeGroup)2	0.026	0.07	0.40	0.691
Position.ord.Q:as.factor(AgeGroup)2	0.032	0.03	1.02	0.309
Position.ord.C:as.factor(AgeGroup)2	-0.020	0.03	-0.71	0.481
Position.ord^4:as.factor(AgeGroup)2	-0.020	0.03	-0.76	0.450
Voicingvoiceless:as.factor(AgeGroup)2	-0.081	0.02	-4.23	< 1e-04
Position.ord.L:Voicingvoiceless:SexM	0.149	0.04	3.51	0.000
Position.ord.Q:Voicingvoiceless:SexM	0.141	0.04	3.32	0.001
Position.ord.C:Voicingvoiceless:SexM	-0.016	0.04	-0.37	0.713
Position.ord^4:Voicingvoiceless:SexM	-0.034	0.04	-0.79	0.432
Position.ord.L:Voicingvoiceless:as.factor(AgeGroup)2	0.128	0.04	3.01	0.003
Position.ord.Q:Voicingvoiceless:as.factor(AgeGroup)2	0.118	0.04	2.77	0.006
Position.ord.C:Voicingvoiceless:as.factor(AgeGroup)2	0.003	0.04	0.06	0.952
Position.ord^4:Voicingvoiceless:as.factor(AgeGroup)2	0.003	0.04	0.07	0.947

Comparing Seattle and Vancouver

F1

```
F1.lmerH <- lmer(normF1 ~ Voicing*Position.ord*Sex*as.factor(AgeGroup) +
City*Voicing*normdurms + City*Voicing*as.factor(AgeGroup)*Sex + PrecedingPhone + (1 +
Position.ord | Name) + (1|Word), data=BOTHau)
```

Table 77. Full F1 model of /aʊ/ comparing Seattle and Vancouver

	Estimate	Std..Error	t.value	p
(Intercept)	0.700	0.09	7.46	< 1e-04
Voicingvoiceless	-0.217	0.08	-2.63	0.009
Position.ord.L	-1.037	0.06	-17.55	< 1e-04
Position.ord.Q	-0.364	0.03	-11.14	< 1e-04
Position.ord.C	0.109	0.02	5.09	< 1e-04
Position.ord^4	0.010	0.02	0.48	0.634
SexM	-0.020	0.06	-0.32	0.751
as.factor(AgeGroup)2	-0.097	0.06	-1.53	0.126
CityVAN	-0.078	0.05	-1.53	0.125
normdurms	-0.004	0.01	-0.62	0.538
PrecedingPhoneeeɪ	0.161	0.13	1.26	0.209
PrecedingPhonef	0.199	0.15	1.37	0.170
PrecedingPhoneg	-0.134	0.16	-0.85	0.398
PrecedingPhoneh	-0.504	0.14	-3.58	0.000
PrecedingPhonek	-0.206	0.20	-1.05	0.295
PrecedingPhonel	-0.084	0.11	-0.78	0.437
PrecedingPhonem	0.010	0.15	0.07	0.944
PrecedingPhonep	-0.063	0.15	-0.44	0.662
PrecedingPhoner	-0.227	0.11	-2.14	0.032
PrecedingPhones	0.038	0.20	0.19	0.847
PrecedingPhonet	-0.032	0.13	-0.26	0.797
PrecedingPhonev	0.043	0.20	0.22	0.829
Voicingvoiceless:Position.ord.L	0.116	0.03	3.36	0.001
Voicingvoiceless:Position.ord.Q	0.111	0.03	3.21	0.001
Voicingvoiceless:Position.ord.C	0.076	0.03	2.21	0.027
Voicingvoiceless:Position.ord^4	-0.010	0.03	-0.28	0.777
Voicingvoiceless:SexM	-0.030	0.03	-0.95	0.344
Position.ord.L:SexM	-0.009	0.08	-0.11	0.912
Position.ord.Q:SexM	0.051	0.05	1.10	0.272
Position.ord.C:SexM	-0.049	0.03	-1.62	0.106
Position.ord^4:SexM	-0.022	0.03	-0.76	0.447
Voicingvoiceless:as.factor(AgeGroup)2	-0.121	0.03	-4.10	< 1e-04
Position.ord.L:as.factor(AgeGroup)2	-0.197	0.08	-2.37	0.018

Table 77. Full F1 model of /aʊ/ comparing Seattle and Vancouver (continued)

Position.ord.Q:as.factor(AgeGroup)2	0.079	0.05	1.72	0.086
Position.ord.C:as.factor(AgeGroup)2	-0.008	0.03	-0.28	0.780
Position.ord^4:as.factor(AgeGroup)2	0.008	0.03	0.30	0.768
SexM:as.factor(AgeGroup)2	0.023	0.09	0.25	0.803
Voicingvoiceless:CityVAN	-0.589	0.03	-18.44	< 1e-04
CityVAN:normdurms	-0.004	0.01	-0.41	0.684
Voicingvoiceless:normdurms	-0.048	0.01	-3.55	0.000
as.factor(AgeGroup)2:CityVAN	0.016	0.07	0.22	0.824
SexM:CityVAN	0.065	0.07	0.90	0.367
Voicingvoiceless:Position.ord.L:SexM	-0.118	0.05	-2.41	0.016
Voicingvoiceless:Position.ord.Q:SexM	-0.078	0.05	-1.58	0.113
Voicingvoiceless:Position.ord.C:SexM	0.037	0.05	0.76	0.445
Voicingvoiceless:Position.ord^4:SexM	0.027	0.05	0.56	0.575
Voicingvoiceless:Position.ord.L:as.factor(AgeGroup)2	-0.094	0.05	-1.98	0.048
Voicingvoiceless:Position.ord.Q:as.factor(AgeGroup)2	0.063	0.05	1.32	0.186
Voicingvoiceless:Position.ord.C:as.factor(AgeGroup)2	0.017	0.05	0.35	0.729
Voicingvoiceless:Position.ord^4:as.factor(AgeGroup)2	-0.013	0.05	-0.27	0.788
Voicingvoiceless:SexM:as.factor(AgeGroup)2	0.107	0.04	2.50	0.012
Position.ord.L:SexM:as.factor(AgeGroup)2	0.054	0.12	0.45	0.652
Position.ord.Q:SexM:as.factor(AgeGroup)2	-0.078	0.07	-1.18	0.237
Position.ord.C:SexM:as.factor(AgeGroup)2	0.030	0.04	0.69	0.488
Position.ord^4:SexM:as.factor(AgeGroup)2	0.005	0.04	0.13	0.900
Voicingvoiceless:CityVAN:normdurms	0.022	0.02	1.14	0.255
Voicingvoiceless:as.factor(AgeGroup)2:CityVAN	0.226	0.04	5.28	< 1e-04
Voicingvoiceless:SexM:CityVAN	0.207	0.04	4.69	< 1e-04
SexM:as.factor(AgeGroup)2:CityVAN	-0.037	0.10	-0.36	0.721
Voicingvoiceless:Position.ord.L:SexM:as.factor(AgeGroup)2	0.242	0.07	3.49	0.000
Voicingvoiceless:Position.ord.Q:SexM:as.factor(AgeGroup)2	0.103	0.07	1.48	0.139
Voicingvoiceless:Position.ord.C:SexM:as.factor(AgeGroup)2	-0.017	0.07	-0.24	0.808
Voicingvoiceless:Position.ord^4:SexM:as.factor(AgeGroup)2	-0.005	0.07	-0.07	0.941
Voicingvoiceless:SexM:as.factor(AgeGroup)2:CityVAN	-0.213	0.06	-3.43	0.001

F2

```
F2.lmerJ <- lmer(normF2 ~ Voicing*Position.ord*Sex*City + normdurms*Voicing*City + (1 +
Position.ord | Name) + (1|Word), data=BOTHau)
```

Table 78. Full F2 model of /aʊ/ comparing Seattle and Vancouver

	Estimate	Std..Error	t.value	p
(Intercept)	-1.013	0.06	-15.68	< 1e-04
Voicingvoiceless	0.017	0.08	0.21	0.831
Position.ord.L	-0.563	0.05	-11.13	< 1e-04
Position.ord.Q	0.142	0.03	5.64	< 1e-04
Position.ord.C	0.086	0.02	3.90	< 1e-04
Position.ord^4	0.024	0.02	1.19	0.233
SexM	-0.066	0.07	-0.92	0.356
CityVAN	0.092	0.07	1.29	0.197
normdurms	0.004	0.01	0.64	0.523
Voicingvoiceless:Position.ord.L	0.029	0.03	0.89	0.373
Voicingvoiceless:Position.ord.Q	0.062	0.03	1.87	0.061
Voicingvoiceless:Position.ord.C	0.023	0.03	0.70	0.485
Voicingvoiceless:Position.ord^4	-0.005	0.03	-0.14	0.885
Voicingvoiceless:SexM	0.042	0.02	1.91	0.056
Position.ord.L:SexM	-0.212	0.07	-2.94	0.003
Position.ord.Q:SexM	0.040	0.04	1.10	0.273
Position.ord.C:SexM	0.055	0.03	1.72	0.086
Position.ord^4:SexM	-0.027	0.03	-0.93	0.351
Voicingvoiceless:CityVAN	0.062	0.02	2.73	0.006
Position.ord.L:CityVAN	-0.022	0.07	-0.31	0.757
Position.ord.Q:CityVAN	-0.027	0.04	-0.74	0.462
Position.ord.C:CityVAN	0.024	0.03	0.77	0.444
Position.ord^4:CityVAN	-0.011	0.03	-0.37	0.710
SexM:CityVAN	-0.038	0.10	-0.37	0.708
Voicingvoiceless:normdurms	-0.051	0.01	-3.76	0.000
CityVAN:normdurms	-0.032	0.01	-3.41	0.001
Voicingvoiceless:Position.ord.L:SexM	0.021	0.05	0.43	0.664
Voicingvoiceless:Position.ord.Q:SexM	-0.083	0.05	-1.72	0.085
Voicingvoiceless:Position.ord.C:SexM	-0.001	0.05	-0.02	0.985
Voicingvoiceless:Position.ord^4:SexM	0.035	0.05	0.73	0.463
Voicingvoiceless:Position.ord.L:CityVAN	-0.063	0.05	-1.31	0.190
Voicingvoiceless:Position.ord.Q:CityVAN	-0.132	0.05	-2.77	0.006
Voicingvoiceless:Position.ord.C:CityVAN	0.001	0.05	0.01	0.988
Voicingvoiceless:Position.ord^4:CityVAN	0.016	0.05	0.33	0.740
Voicingvoiceless:SexM:CityVAN	-0.215	0.03	-6.87	< 1e-04
Position.ord.L:SexM:CityVAN	0.162	0.10	1.57	0.117

Table 78. Full F2 model of /aʊ/ comparing Seattle and Vancouver (continued)

Position.ord.Q:SexM:CityVAN	-0.030	0.05	-0.57	0.566
Position.ord.C:SexM:CityVAN	-0.064	0.05	-1.40	0.160
Position.ord^4:SexM:CityVAN	0.027	0.04	0.64	0.523
Voicingvoiceless:CityVAN:normdurms	0.043	0.02	2.22	0.027
Voicingvoiceless:Position.ord.L:SexM:CityVAN	0.119	0.07	1.71	0.087
Voicingvoiceless:Position.ord.Q:SexM:CityVAN	0.215	0.07	3.10	0.002
Voicingvoiceless:Position.ord.C:SexM:CityVAN	-0.015	0.07	-0.21	0.834
Voicingvoiceless:Position.ord^4:SexM:CityVAN	-0.069	0.07	-0.99	0.320

/aɪ/ Raising

Seattle

F1

F1.lmerK <- lmer(normF1 ~ Voicing*Position.ord*as.factor(AgeGroup)*Sex + normdurms*Voicing*Position.ord + PrecedingPhone + normSeattleVancouverSimilarity + (1 + Position.ord | Name) + (1|Word), data=SEAaI)

Table 79. Full F1 model of /aɪT/ vs. /aɪD/ in Seattle

	Estimate	Std..Error	t.value	p
(Intercept)	0.405	0.07	5.77	< 1e-04
Voicingvoiceless	-0.579	0.04	-13.00	< 1e-04
Position.ord.L	-1.104	0.07	-15.50	< 1e-04
Position.ord.Q	-0.364	0.06	-6.49	< 1e-04
Position.ord.C	0.141	0.03	5.24	< 1e-04
Position.ord^4	0.023	0.02	0.93	0.352
as.factor(AgeGroup)2	0.006	0.06	0.10	0.922
SexM	0.081	0.06	1.28	0.202
normdurms	0.015	0.01	1.81	0.070
PrecedingPhoned	-0.083	0.12	-0.71	0.478
PrecedingPhonedʒ	-0.028	0.15	-0.18	0.853
PrecedingPhoneeeɪ	0.275	0.09	3.00	0.003
PrecedingPhoneg	0.008	0.15	0.05	0.957
PrecedingPhoneh	-0.055	0.08	-0.67	0.504
PrecedingPhonek	0.019	0.10	0.20	0.843
PrecedingPhonel	-0.034	0.15	-0.23	0.821
PrecedingPhonen	-0.076	0.10	-0.76	0.447
PrecedingPhonep	0.054	0.08	0.71	0.477
PrecedingPhoner	-0.163	0.08	-1.98	0.048
PrecedingPhones	-0.020	0.09	-0.22	0.829

Table 79. Full F1 model of /aɪT/ vs. /aɪD/ in Seattle (continued)

PrecedingPhonet	0.098	0.07	1.40	0.161
PrecedingPhonew	-0.226	0.15	-1.47	0.142
normSeattleVancouverSimilarity	0.039	0.01	3.27	0.001
Voicingvoiceless:Position.ord.L	-0.447	0.04	-11.84	< 1e-04
Voicingvoiceless:Position.ord.Q	0.402	0.04	10.65	< 1e-04
Voicingvoiceless:Position.ord.C	0.131	0.04	3.47	0.001
Voicingvoiceless:Position.ord^4	-0.025	0.04	-0.67	0.505
Voicingvoiceless:as.factor(AgeGroup)2	-0.106	0.02	-5.03	< 1e-04
Position.ord.L:as.factor(AgeGroup)2	-0.137	0.10	-1.37	0.171
Position.ord.Q:as.factor(AgeGroup)2	0.113	0.08	1.44	0.149
Position.ord.C:as.factor(AgeGroup)2	-0.001	0.04	-0.03	0.975
Position.ord^4:as.factor(AgeGroup)2	0.010	0.03	0.30	0.764
Voicingvoiceless:SexM	-0.044	0.02	-1.87	0.062
Position.ord.L:SexM	-0.103	0.11	-0.97	0.333
Position.ord.Q:SexM	-0.008	0.08	-0.09	0.925
Position.ord.C:SexM	-0.037	0.04	-0.93	0.354
Position.ord^4:SexM	0.002	0.04	0.06	0.953
as.factor(AgeGroup)2:SexM	-0.051	0.09	-0.59	0.556
Voicingvoiceless:normdurms	-0.035	0.02	-2.32	0.021
Position.ord.L:normdurms	-0.094	0.01	-7.79	< 1e-04
Position.ord.Q:normdurms	-0.134	0.01	-11.18	< 1e-04
Position.ord.C:normdurms	0.019	0.01	1.57	0.115
Position.ord^4:normdurms	0.016	0.01	1.34	0.180
Voicingvoiceless:Position.ord.L:as.factor(AgeGroup)2	0.137	0.05	2.91	0.004
Voicingvoiceless:Position.ord.Q:as.factor(AgeGroup)2	-0.131	0.05	-2.79	0.005
Voicingvoiceless:Position.ord.C:as.factor(AgeGroup)2	-0.009	0.05	-0.20	0.844
Voicingvoiceless:Position.ord^4:as.factor(AgeGroup)2	-0.064	0.05	-1.36	0.174
Voicingvoiceless:Position.ord.L:SexM	-0.007	0.05	-0.13	0.899
Voicingvoiceless:Position.ord.Q:SexM	-0.263	0.05	-4.97	< 1e-04
Voicingvoiceless:Position.ord.C:SexM	0.070	0.05	1.33	0.184
Voicingvoiceless:Position.ord^4:SexM	-0.021	0.05	-0.39	0.696
Voicingvoiceless:as.factor(AgeGroup)2:SexM	0.124	0.03	3.90	< 1e-04
Position.ord.L:as.factor(AgeGroup)2:SexM	0.088	0.15	0.60	0.546
Position.ord.Q:as.factor(AgeGroup)2:SexM	-0.096	0.12	-0.83	0.405
Position.ord.C:as.factor(AgeGroup)2:SexM	0.051	0.05	0.94	0.348
Position.ord^4:as.factor(AgeGroup)2:SexM	0.007	0.05	0.14	0.889
Voicingvoiceless:Position.ord.L:normdurms	-0.017	0.03	-0.62	0.534
Voicingvoiceless:Position.ord.Q:normdurms	0.021	0.03	0.75	0.455
Voicingvoiceless:Position.ord.C:normdurms	0.126	0.03	4.59	< 1e-04
Voicingvoiceless:Position.ord^4:normdurms	-0.063	0.03	-2.29	0.022
Voicingvoiceless:Position.ord.L:as.factor(AgeGroup)2:SexM	-0.397	0.07	-5.59	< 1e-04

Table 79. Full F1 model of /aɪT/ vs. /aɪD/ in Seattle (continued)

Voicingvoiceless:Position.ord.Q:as.factor(AgeGroup)2:SexM	0.480	0.07	6.74	< 1e-04
Voicingvoiceless:Position.ord.C:as.factor(AgeGroup)2:SexM	-0.056	0.07	-0.79	0.429
Voicingvoiceless:Position.ord^4:as.factor(AgeGroup)2:SexM	0.048	0.07	0.68	0.497

F2

```
F2.lmerP <- lmer(normF2 ~ Voicing*Position.ord*normdurms +
Voicing*Position.ord*as.factor(AgeGroup)*Sex + PrecedingPhone +
normImportanceShoppingHomeCity + (1 + Position.ord | Name) + (1|Word), data=SEAaI)
```

Table 80. Full F2 model of /aɪT/ vs. /aɪD/ in Seattle

	Estimate	Std..Error	t.value	p
(Intercept)	-0.436	0.08	-5.60	<1e-04
Voicingvoiceless	0.570	0.04	13.18	<1e-04
Position.ord.L	0.675	0.08	7.96	<1e-04
Position.ord.Q	-0.041	0.04	-0.92	0.356
Position.ord.C	-0.200	0.03	-5.95	<1e-04
Position.ord^4	-0.001	0.03	-0.03	0.979
normdurms	-0.019	0.01	-1.88	0.060
as.factor(AgeGroup)2	0.005	0.08	0.06	0.952
SexM	0.032	0.08	0.38	0.707
PrecedingPhoned	0.168	0.11	1.56	0.119
PrecedingPhonedʒ	0.131	0.14	0.94	0.346
PrecedingPhoneeeɪ	-0.031	0.09	-0.36	0.718
PrecedingPhoneg	0.279	0.14	2.01	0.045
PrecedingPhoneh	0.063	0.08	0.83	0.408
PrecedingPhonek	-0.025	0.09	-0.28	0.778
PrecedingPhonel	-0.021	0.14	-0.15	0.882
PrecedingPhonen	0.248	0.09	2.72	0.007
PrecedingPhonep	-0.018	0.07	-0.25	0.802
PrecedingPhoner	-0.003	0.08	-0.04	0.970
PrecedingPhones	0.007	0.08	0.08	0.937
PrecedingPhonet	-0.006	0.06	-0.09	0.927
PrecedingPhonew	-0.218	0.14	-1.55	0.122
normImportanceShoppingHomeCity	0.064	0.03	2.38	0.017
Voicingvoiceless:Position.ord.L	0.105	0.05	2.19	0.029
Voicingvoiceless:Position.ord.Q	-0.136	0.05	-2.83	0.005
Voicingvoiceless:Position.ord.C	0.029	0.05	0.59	0.553
Voicingvoiceless:Position.ord^4	0.040	0.05	0.83	0.406
Voicingvoiceless:normdurms	-0.001	0.02	-0.06	0.956

Table 80. Full F2 model of /aɪT/ vs. /aɪD/ in Seattle (continued)

Position.ord.L:normdurms	0.172	0.02	11.41	<1e-04
Position.ord.Q:normdurms	0.122	0.02	8.08	<1e-04
Position.ord.C:normdurms	-0.021	0.02	-1.37	0.170
Position.ord^4:normdurms	-0.014	0.02	-0.91	0.362
Voicingvoiceless:as.factor(AgeGroup)2	0.076	0.03	2.82	0.005
Position.ord.L:as.factor(AgeGroup)2	0.030	0.12	0.26	0.798
Position.ord.Q:as.factor(AgeGroup)2	0.022	0.06	0.35	0.725
Position.ord.C:as.factor(AgeGroup)2	0.066	0.05	1.46	0.145
Position.ord^4:as.factor(AgeGroup)2	0.032	0.04	0.76	0.448
Voicingvoiceless:SexM	-0.045	0.03	-1.60	0.109
Position.ord.L:SexM	0.068	0.12	0.57	0.571
Position.ord.Q:SexM	-0.050	0.06	-0.79	0.431
Position.ord.C:SexM	0.012	0.05	0.25	0.801
Position.ord^4:SexM	0.005	0.04	0.11	0.912
as.factor(AgeGroup)2:SexM	-0.125	0.12	-1.04	0.298
Voicingvoiceless:Position.ord.L:normdurms	0.008	0.03	0.22	0.823
Voicingvoiceless:Position.ord.Q:normdurms	-0.170	0.03	-4.91	<1e-04
Voicingvoiceless:Position.ord.C:normdurms	0.001	0.03	0.02	0.982
Voicingvoiceless:Position.ord^4:normdurms	0.037	0.03	1.07	0.283
Voicingvoiceless:Position.ord.L:as.factor(AgeGroup)2	0.036	0.06	0.59	0.553
Voicingvoiceless:Position.ord.Q:as.factor(AgeGroup)2	-0.068	0.06	-1.14	0.255
Voicingvoiceless:Position.ord.C:as.factor(AgeGroup)2	-0.018	0.06	-0.30	0.766
Voicingvoiceless:Position.ord^4:as.factor(AgeGroup)2	-0.021	0.06	-0.35	0.723
Voicingvoiceless:Position.ord.L:SexM	0.205	0.06	3.24	0.001
Voicingvoiceless:Position.ord.Q:SexM	0.021	0.06	0.33	0.742
Voicingvoiceless:Position.ord.C:SexM	-0.020	0.06	-0.32	0.747
Voicingvoiceless:Position.ord^4:SexM	-0.020	0.06	-0.32	0.749
Voicingvoiceless:as.factor(AgeGroup)2:SexM	-0.014	0.04	-0.35	0.725
Position.ord.L:as.factor(AgeGroup)2:SexM	0.118	0.17	0.70	0.484
Position.ord.Q:as.factor(AgeGroup)2:SexM	0.020	0.09	0.22	0.823
Position.ord.C:as.factor(AgeGroup)2:SexM	-0.057	0.07	-0.87	0.386
Position.ord^4:as.factor(AgeGroup)2:SexM	-0.074	0.06	-1.18	0.237
Voicingvoiceless:Position.ord.L:as.factor(AgeGroup)2:SexM	-0.207	0.09	-2.36	0.018
Voicingvoiceless:Position.ord.Q:as.factor(AgeGroup)2:SexM	-0.020	0.09	-0.23	0.821
Voicingvoiceless:Position.ord.C:as.factor(AgeGroup)2:SexM	0.002	0.09	0.02	0.986
Voicingvoiceless:Position.ord^4:as.factor(AgeGroup)2:SexM	0.082	0.09	0.94	0.349

Vancouver
F1

```
F1.lmerR <- lmer(normF1 ~ Voicing*Position.ord*as.factor(AgeGroup)*Sex +
normdurms*Voicing*Position.ord + normInterestedInMoving +
normTorontoVancouverSimilarity +  normHowOftenShopPNW +
normImportanceShoppingPNW + (1 + Position.ord | Name) + (1|Word), data=VANaI)
```

Table 81. Full F1 model for /aɪT/ vs. /aɪD/ in Vancouver

	Estimate	Std..Error	t.value	p
(Intercept)	0.505	0.04	11.84	< 1e-04
Voicingvoiceless	-0.931	0.05	-19.47	< 1e-04
Position.ord.L	-0.959	0.08	-12.38	< 1e-04
Position.ord.Q	-0.460	0.06	-8.03	< 1e-04
Position.ord.C	0.096	0.04	2.73	0.006
Position.ord^4	0.021	0.03	0.78	0.435
as.factor(AgeGroup)2	-0.076	0.04	-1.76	0.078
SexM	0.080	0.04	1.79	0.073
normdurms	-0.069	0.01	-7.95	< 1e-04
normInterestedInMoving	0.054	0.01	4.08	< 1e-04
normTorontoVancouverSimilarity	0.019	0.01	1.95	0.051
normHowOftenShopPNW	0.057	0.02	3.82	0.000
normImportanceShoppingPNW	-0.047	0.02	-2.87	0.004
Voicingvoiceless:Position.ord.L	-0.500	0.04	-11.79	< 1e-04
Voicingvoiceless:Position.ord.Q	0.197	0.04	4.66	< 1e-04
Voicingvoiceless:Position.ord.C	0.159	0.04	3.76	0.000
Voicingvoiceless:Position.ord^4	-0.025	0.04	-0.58	0.563
Voicingvoiceless:as.factor(AgeGroup)2	0.141	0.02	6.39	< 1e-04
Position.ord.L:as.factor(AgeGroup)2	0.001	0.11	0.01	0.990
Position.ord.Q:as.factor(AgeGroup)2	0.059	0.08	0.73	0.463
Position.ord.C:as.factor(AgeGroup)2	-0.009	0.05	-0.18	0.859
Position.ord^4:as.factor(AgeGroup)2	0.059	0.04	1.68	0.094
Voicingvoiceless:SexM	0.080	0.02	3.41	0.001
Position.ord.L:SexM	0.152	0.12	1.32	0.186
Position.ord.Q:SexM	-0.031	0.08	-0.37	0.710
Position.ord.C:SexM	-0.064	0.05	-1.26	0.207
Position.ord^4:SexM	0.013	0.04	0.34	0.732
as.factor(AgeGroup)2:SexM	0.174	0.06	2.68	0.007
Voicingvoiceless:normdurms	0.050	0.02	2.63	0.009
Position.ord.L:normdurms	-0.076	0.01	-5.61	< 1e-04
Position.ord.Q:normdurms	-0.083	0.01	-6.10	< 1e-04

Table. 81 Full F1 model for /aɪT/ vs. /aɪD/ in Vancouver (continued)

Position.ord.C:normdurms	0.028	0.01	2.08	0.038
Position.ord^4:normdurms	0.011	0.01	0.80	0.426
Voicingvoiceless:Position.ord.L:as.factor(AgeGroup)2	-0.144	0.05	-2.92	0.004
Voicingvoiceless:Position.ord.Q:as.factor(AgeGroup)2	0.126	0.05	2.55	0.011
Voicingvoiceless:Position.ord.C:as.factor(AgeGroup)2	0.061	0.05	1.24	0.217
Voicingvoiceless:Position.ord^4:as.factor(AgeGroup)2	-0.124	0.05	-2.51	0.012
Voicingvoiceless:Position.ord.L:SexM	-0.278	0.05	-5.31	< 1e-04
Voicingvoiceless:Position.ord.Q:SexM	0.006	0.05	0.12	0.908
Voicingvoiceless:Position.ord.C:SexM	0.115	0.05	2.19	0.029
Voicingvoiceless:Position.ord^4:SexM	-0.004	0.05	-0.08	0.935
Voicingvoiceless:as.factor(AgeGroup)2:SexM	-0.070	0.03	-2.13	0.033
Position.ord.L:as.factor(AgeGroup)2:SexM	-0.108	0.16	-0.66	0.508
Position.ord.Q:as.factor(AgeGroup)2:SexM	-0.060	0.12	-0.50	0.615
Position.ord.C:as.factor(AgeGroup)2:SexM	0.013	0.07	0.18	0.855
Position.ord^4:as.factor(AgeGroup)2:SexM	-0.035	0.05	-0.68	0.499
Voicingvoiceless:Position.ord.L:normdurms	0.103	0.03	3.18	0.001
Voicingvoiceless:Position.ord.Q:normdurms	-0.171	0.03	-5.27	< 1e-04
Voicingvoiceless:Position.ord.C:normdurms	0.147	0.03	4.55	< 1e-04
Voicingvoiceless:Position.ord^4:normdurms	-0.052	0.03	-1.61	0.108
Voicingvoiceless:Position.ord.L:as.factor(AgeGroup)2:SexM	0.333	0.07	4.54	< 1e-04
Voicingvoiceless:Position.ord.Q:as.factor(AgeGroup)2:SexM	0.028	0.07	0.38	0.701
Voicingvoiceless:Position.ord.C:as.factor(AgeGroup)2:SexM	-0.065	0.07	-0.88	0.377
Voicingvoiceless:Position.ord^4:as.factor(AgeGroup)2:SexM	0.107	0.07	1.46	0.145

F2

```
F2.lmerB <- lmer(normF2 ~ Voicing*Position.ord*normdurms +
Voicing*Position.ord*as.factor(AgeGroup)*Sex + PrecedingPhone + (1 + Position.ord | Name)
+ (1|Word), data=VANaI)
```

Table 82. Full F2 model of /aɪT/ vs. /aɪD/ in Vancouver

	Estimate	Std..Error	t.value	p
(Intercept)	-0.562	0.07	-7.79	< 1e-04
Voicingvoiceless	0.774	0.04	21.63	< 1e-04
Position.ord.L	0.820	0.09	9.21	< 1e-04
Position.ord.Q	0.112	0.05	2.07	0.039
Position.ord.C	-0.205	0.04	-5.86	< 1e-04
Position.ord^4	-0.039	0.03	-1.26	0.208
normdurms	0.000	0.01	-0.05	0.963
as.factor(AgeGroup)2	-0.169	0.09	-1.97	0.049
SexM	-0.163	0.09	-1.91	0.056

Table 82. Full F2 model of /aɪT/ vs. /aɪD/ in Vancouver (continued)

PrecedingPhoned	0.240	0.08	3.07	0.002
PrecedingPhoneʤ	0.081	0.10	0.85	0.397
PrecedingPhoneeeɪ	0.152	0.06	2.35	0.019
PrecedingPhoneg	0.247	0.10	2.46	0.014
PrecedingPhoneh	0.259	0.06	4.48	< 1e-04
PrecedingPhonek	0.183	0.07	2.78	0.005
PrecedingPhonel	0.161	0.10	1.60	0.109
PrecedingPhonen	0.320	0.07	4.83	< 1e-04
PrecedingPhonep	0.026	0.05	0.52	0.606
PrecedingPhoner	0.054	0.06	0.95	0.340
PrecedingPhones	0.204	0.06	3.36	0.001
PrecedingPhonet	0.121	0.05	2.51	0.012
PrecedingPhonew	-0.198	0.10	-1.94	0.052
Voicingvoiceless:Position.ord.L	0.150	0.05	3.04	0.002
Voicingvoiceless:Position.ord.Q	-0.186	0.05	-3.78	0.000
Voicingvoiceless:Position.ord.C	0.013	0.05	0.27	0.788
Voicingvoiceless:Position.ord^4	0.043	0.05	0.87	0.383
Voicingvoiceless:normdurms	-0.053	0.02	-2.49	0.013
Position.ord.L:normdurms	0.180	0.02	11.57	< 1e-04
Position.ord.Q:normdurms	0.078	0.02	5.01	< 1e-04
Position.ord.C:normdurms	0.013	0.02	0.83	0.408
Position.ord^4:normdurms	-0.003	0.02	-0.21	0.830
Voicingvoiceless:as.factor(AgeGroup)2	-0.056	0.03	-2.15	0.031
Position.ord.L:as.factor(AgeGroup)2	-0.133	0.13	-1.06	0.288
Position.ord.Q:as.factor(AgeGroup)2	-0.105	0.07	-1.41	0.159
Position.ord.C:as.factor(AgeGroup)2	0.023	0.05	0.49	0.624
Position.ord^4:as.factor(AgeGroup)2	0.054	0.04	1.34	0.182
Voicingvoiceless:SexM	-0.050	0.03	-1.94	0.053
Position.ord.L:SexM	-0.159	0.13	-1.27	0.202
Position.ord.Q:SexM	-0.052	0.07	-0.70	0.485
Position.ord.C:SexM	0.067	0.05	1.43	0.152
Position.ord^4:SexM	0.015	0.04	0.36	0.720
as.factor(AgeGroup)2:SexM	0.168	0.12	1.35	0.178
Voicingvoiceless:Position.ord.L:normdurms	0.093	0.04	2.51	0.012
Voicingvoiceless:Position.ord.Q:normdurms	-0.068	0.04	-1.84	0.066
Voicingvoiceless:Position.ord.C:normdurms	0.007	0.04	0.18	0.853
Voicingvoiceless:Position.ord^4:normdurms	0.020	0.04	0.53	0.594
Voicingvoiceless:Position.ord.L:as.factor(AgeGroup)2	-0.023	0.06	-0.40	0.687
Voicingvoiceless:Position.ord.Q:as.factor(AgeGroup)2	0.036	0.06	0.62	0.534
Voicingvoiceless:Position.ord.C:as.factor(AgeGroup)2	-0.014	0.06	-0.25	0.804
Voicingvoiceless:Position.ord^4:as.factor(AgeGroup)2	-0.008	0.06	-0.13	0.894
Voicingvoiceless:Position.ord.L:SexM	0.375	0.06	6.46	< 1e-04

Table 82. Full F2 model of /aɪT/ vs. /aɪD/ in Vancouver (continued)

Voicingvoiceless:Position.ord.Q:SexM	0.133	0.06	2.30	0.022
Voicingvoiceless:Position.ord.C:SexM	-0.018	0.06	-0.32	0.750
Voicingvoiceless:Position.ord^4:SexM	0.034	0.06	0.59	0.558
Voicingvoiceless:as.factor(AgeGroup)2:SexM	-0.039	0.04	-1.04	0.299
Position.ord.L:as.factor(AgeGroup)2:SexM	-0.053	0.18	-0.29	0.770
Position.ord.Q:as.factor(AgeGroup)2:SexM	0.066	0.11	0.61	0.542
Position.ord.C:as.factor(AgeGroup)2:SexM	-0.058	0.07	-0.85	0.396
Position.ord^4:as.factor(AgeGroup)2:SexM	-0.025	0.06	-0.43	0.670
Voicingvoiceless:Position.ord.L:as.factor(AgeGroup)2:SexM	-0.207	0.08	-2.47	0.013
Voicingvoiceless:Position.ord.Q:as.factor(AgeGroup)2:SexM	0.008	0.08	0.09	0.927
Voicingvoiceless:Position.ord.C:as.factor(AgeGroup)2:SexM	0.054	0.08	0.65	0.515
Voicingvoiceless:Position.ord^4:as.factor(AgeGroup)2:SexM	-0.049	0.08	-0.58	0.561

Comparing Seattle and Vancouver

F1

```
F1.lmerA <- lmer(normF1 ~ City*Voicing*normdurms*Position.ord +
City*Voicing*as.factor(AgeGroup)*Sex + (1 + Position.ord | Name) + (1|Word), data=BOTHaI)
```

Table 83. Full F1 model of /aɪ/ comparing Seattle and Vancouver

	Estimate	Std..Error	t.value	p
(Intercept)	0.355	0.05	7.60	< 1e-04
CityVAN	0.184	0.05	3.55	0.000
Voicingvoiceless	-0.547	0.05	-11.47	< 1e-04
normdurms	0.018	0.01	2.65	0.008
Position.ord.L	-1.205	0.04	-31.28	< 1e-04
Position.ord.Q	-0.334	0.03	-11.07	< 1e-04
Position.ord.C	0.139	0.02	9.03	< 1e-04
Position.ord^4	0.031	0.01	2.35	0.019
as.factor(AgeGroup)2	0.025	0.05	0.52	0.605
SexM	0.082	0.05	1.71	0.087
CityVAN:Voicingvoiceless	-0.397	0.03	-15.63	< 1e-04
CityVAN:normdurms	-0.089	0.01	-11.15	< 1e-04
Voicingvoiceless:normdurms	-0.040	0.01	-2.96	0.003
CityVAN:Position.ord.L	0.282	0.06	5.08	< 1e-04
CityVAN:Position.ord.Q	-0.129	0.04	-2.96	0.003
CityVAN:Position.ord.C	-0.077	0.02	-3.38	0.001
CityVAN:Position.ord^4	0.017	0.02	0.87	0.386
Voicingvoiceless:Position.ord.L	-0.481	0.02	-20.16	< 1e-04

Table 83. Full F1 model of /aɪ/ comparing Seattle and Vancouver

Voicingvoiceless:Position.ord.Q	0.332	0.02	13.95	< 1e-04
Voicingvoiceless:Position.ord.C	0.145	0.02	6.09	< 1e-04
Voicingvoiceless:Position.ord^4	-0.058	0.02	-2.43	0.015
normdurms:Position.ord.L	-0.102	0.01	-8.70	< 1e-04
normdurms:Position.ord.Q	-0.132	0.01	-11.27	< 1e-04
normdurms:Position.ord.C	0.021	0.01	1.78	0.075
normdurms:Position.ord^4	0.016	0.01	1.41	0.160
CityVAN:as.factor(AgeGroup)2	-0.066	0.07	-0.98	0.327
Voicingvoiceless:as.factor(AgeGroup)2	-0.104	0.02	-5.00	< 1e-04
CityVAN:SexM	0.025	0.07	0.37	0.710
Voicingvoiceless:SexM	-0.070	0.02	-3.19	0.001
as.factor(AgeGroup)2:SexM	0.005	0.07	0.07	0.945
CityVAN:Voicingvoiceless:normdurms	0.096	0.02	5.06	< 1e-04
CityVAN:Voicingvoiceless:Position.ord.L	-0.142	0.04	-3.83	0.000
CityVAN:Voicingvoiceless:Position.ord.Q	-0.074	0.04	-2.00	0.045
CityVAN:Voicingvoiceless:Position.ord.C	0.082	0.04	2.22	0.026
CityVAN:Voicingvoiceless:Position.ord^4	-0.005	0.04	-0.13	0.894
CityVAN:normdurms:Position.ord.L	0.019	0.02	1.06	0.289
CityVAN:normdurms:Position.ord.Q	0.046	0.02	2.63	0.008
CityVAN:normdurms:Position.ord.C	0.007	0.02	0.42	0.675
CityVAN:normdurms:Position.ord^4	-0.007	0.02	-0.38	0.706
Voicingvoiceless:normdurms:Position.ord.L	0.001	0.03	0.02	0.982
Voicingvoiceless:normdurms:Position.ord.Q	0.018	0.03	0.68	0.495
Voicingvoiceless:normdurms:Position.ord.C	0.126	0.03	4.72	< 1e-04
Voicingvoiceless:normdurms:Position.ord^4	-0.063	0.03	-2.37	0.018
CityVAN:Voicingvoiceless:as.factor(AgeGroup)2	0.246	0.03	8.09	< 1e-04
CityVAN:Voicingvoiceless:SexM	0.184	0.03	5.90	< 1e-04
CityVAN:as.factor(AgeGroup)2:SexM	0.077	0.10	0.79	0.430
Voicingvoiceless:as.factor(AgeGroup)2:SexM	0.150	0.03	4.92	< 1e-04
CityVAN:Voicingvoiceless:normdurms:Position.ord.L	0.101	0.04	2.42	0.015
CityVAN:Voicingvoiceless:normdurms:Position.ord.Q	-0.190	0.04	-4.58	< 1e-04
CityVAN:Voicingvoiceless:normdurms:Position.ord.C	0.016	0.04	0.38	0.701
CityVAN:Voicingvoiceless:normdurms:Position.ord^4	0.014	0.04	0.34	0.736
CityVAN:Voicingvoiceless:as.factor(AgeGroup)2:SexM	-0.254	0.04	-5.75	< 1e-04

F2

F2.lmerG <- lmer(normF2 ~ City*Voicing*Position.ord*normdurms + Voicing*Sex + Voicing*City*as.factor(AgeGroup) + PrecedingPhone + (1 + Position.ord | Name) + (1|Word), data=BOTHaI)

Table 84. Full F2 model of /aɪ/ comparing Seattle and Vancouver

	Estimate	Std..Error	t.value	p
(Intercept)	-0.425	0.06	-7.31	< 1e-04
CityVAN	-0.126	0.05	-2.35	0.019
Voicingvoiceless	0.587	0.03	17.23	< 1e-04
Position.ord.L	0.756	0.05	16.12	< 1e-04
Position.ord.Q	-0.050	0.02	-2.03	0.042
Position.ord.C	-0.175	0.02	-9.60	< 1e-04
Position.ord^4	0.000	0.02	0.01	0.994
normdurms	-0.019	0.01	-2.33	0.020
SexM	-0.077	0.04	-2.17	0.030
as.factor(AgeGroup)2	-0.021	0.05	-0.42	0.677
PrecedingPhoned	0.197	0.08	2.36	0.018
PrecedingPhoneʤ	0.080	0.10	0.78	0.435
PrecedingPhoneeeɪ	0.064	0.07	0.98	0.329
PrecedingPhoneg	0.262	0.11	2.44	0.015
PrecedingPhoneh	0.179	0.06	3.05	0.002
PrecedingPhonek	0.068	0.07	0.97	0.332
PrecedingPhonel	0.062	0.11	0.58	0.561
PrecedingPhonen	0.277	0.07	3.94	< 1e-04
PrecedingPhonep	-0.001	0.05	-0.01	0.991
PrecedingPhoner	0.018	0.06	0.30	0.768
PrecedingPhones	0.096	0.06	1.50	0.134
PrecedingPhonet	0.048	0.05	0.95	0.343
PrecedingPhonew	-0.216	0.11	-1.99	0.047
CityVAN:Voicingvoiceless	0.178	0.02	7.11	< 1e-04
CityVAN:Position.ord.L	-0.086	0.07	-1.28	0.201
CityVAN:Position.ord.Q	0.100	0.04	2.77	0.006
CityVAN:Position.ord.C	0.001	0.03	0.02	0.982
CityVAN:Position.ord^4	-0.011	0.02	-0.45	0.655
Voicingvoiceless:Position.ord.L	0.169	0.03	5.71	< 1e-04
Voicingvoiceless:Position.ord.Q	-0.167	0.03	-5.65	< 1e-04
Voicingvoiceless:Position.ord.C	0.012	0.03	0.42	0.676
Voicingvoiceless:Position.ord^4	0.038	0.03	1.29	0.199
CityVAN:normdurms	0.010	0.01	0.96	0.337
Voicingvoiceless:normdurms	0.007	0.02	0.44	0.663

Table 84 Full F2 model of /aɪ/ comparing Seattle and Vancouver (continued)

Position.ord.L:normdurms	0.171	0.01	11.82	< 1e-04
Position.ord.Q:normdurms	0.122	0.01	8.41	< 1e-04
Position.ord.C:normdurms	-0.021	0.01	-1.43	0.154
Position.ord^4:normdurms	-0.013	0.01	-0.93	0.355
Voicingvoiceless:SexM	-0.060	0.01	-4.41	< 1e-04
Voicingvoiceless:as.factor(AgeGroup)2	0.072	0.02	3.83	0.000
CityVAN:as.factor(AgeGroup)2	-0.052	0.07	-0.73	0.465
CityVAN:Voicingvoiceless:Position.ord.L	0.109	0.05	2.35	0.019
CityVAN:Voicingvoiceless:Position.ord.Q	0.065	0.05	1.40	0.161
CityVAN:Voicingvoiceless:Position.ord.C	-0.003	0.05	-0.07	0.945
CityVAN:Voicingvoiceless:Position.ord^4	0.008	0.05	0.18	0.859
CityVAN:Voicingvoiceless:normdurms	-0.062	0.02	-2.61	0.009
CityVAN:Position.ord.L:normdurms	0.009	0.02	0.39	0.698
CityVAN:Position.ord.Q:normdurms	-0.044	0.02	-2.02	0.043
CityVAN:Position.ord.C:normdurms	0.034	0.02	1.53	0.126
CityVAN:Position.ord^4:normdurms	0.010	0.02	0.46	0.646
Voicingvoiceless:Position.ord.L:normdurms	0.006	0.03	0.17	0.862
Voicingvoiceless:Position.ord.Q:normdurms	-0.170	0.03	-5.10	< 1e-04
Voicingvoiceless:Position.ord.C:normdurms	0.003	0.03	0.10	0.920
Voicingvoiceless:Position.ord^4:normdurms	0.034	0.03	1.03	0.301
CityVAN:Voicingvoiceless:as.factor(AgeGroup)2	-0.146	0.03	-5.36	< 1e-04
CityVAN:Voicingvoiceless:Position.ord.L:normdurms	0.090	0.05	1.74	0.082
CityVAN:Voicingvoiceless:Position.ord.Q:normdurms	0.103	0.05	2.00	0.045
CityVAN:Voicingvoiceless:Position.ord.C:normdurms	0.003	0.05	0.06	0.948
CityVAN:Voicingvoiceless:Position.ord^4:normdurms	-0.013	0.05	-0.26	0.792