SCANDINAVIAN INTERFERENCE ON THE /s ~ z/ VOICING CONTRAST IN AMERICAN ENGLISH

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ABSTRACT

ANNE BAKKEN: Scandinavian Interference on the /s ~ z/ Voicing Contrast in American English
(Under the direction of Jennifer Smith)

This thesis examines phonological substrate interference as a result of language shift. It has been observed that Scandinavian-American communities in the Upper Midwest, where Norwegian, Swedish, and Danish speakers shifted to English in the 19^{th} and 20^{th} centuries, devoice /z/. This phenomenon is thought to be due to the lack of a voicing contrast in sibilants in Scandinavian languages. Acoustic analysis was performed comparing the production of /s/ and /z/ in a highly Scandinavian region, the Red River Valley of North Dakota and Minnesota, and a region with very little Scandinavian presence, the Piedmont of North Carolina. Red River Valley residents with and without Scandinavian background were likewise compared. It was found in this study that the speakers with a greater degree of Scandinavian background produced less glottal pulsing in /z/ and more in /s/ than other speakers. The latter result had not been previously recorded. I therefore propose that the substrate effect is not devoicing of /z/, but greater neutralization of the voicing contrast.

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Chapter 1

INTRODUCTION

This thesis seeks to evaluate evidence of a substrate effect from Scandinavian languages in a dialect of American English. Acoustic data is analyzed to investigate whether a distinction can be demonstrated between the production of the /s ~ z/ voicing contrast in Scandinavian-American and non-Scandinavian communities.

Several impressionistic studies (Simley 1930, Moen 1988, Allen 1973, Haugen 1938) have reported that speakers from the Upper Midwest are more likely to produce devoiced /z/ than is expected for General American English (GAE). This is particularly the case in those regions with a history of substantial immigration from Scandinavian countries, such as North Dakota (ND) and Minnesota (MN), and it has been treated as a substrate effect from Scandinavian languages in the articles mentioned above. These languages categorically lack a phonological voicing contrast in sibilants; /s/ and /ʃ/ exist in their phonemic inventories, but not /z/ or /ʒ/. As these sounds do not exist as phonemes in Scandinavian languages, this may be responsible for a departure in the speech of Scandinavian-Americans from the expected pronunciation of voiced sibilants in GAE. Phonological traits such as these are among the more stable linguistic features, and are therefore subject to imposition on a second language (Thomas 2010). Could this lack of contrast in Scandinavian languages have survived transfer not only to L2 English but also to the L1 English of the immigrants' descendants?

1.1 Present Study

The current research seeks to add acoustic data to these existing impressionistic studies, and to test the hypothesis of a Scandinavian substrate effect more rigorously by comparing results from speakers who are highly likely to have been exposed to Scandinavian influence with a comparable group who is less likely to have had this exposure. On a regional level, the relevant groups for comparison are speakers from the Red River Valley (RRV) of ND and MN and speakers from a control group from a different region of the United States without high levels of Scandinavian immigration, the Piedmont area of North Carolina (NC). Results will also be compared for two subgroups of the former region, those with limited and with strong ties to previous generations of speakers of Scandinavian languages, measured through ancestral background and self-identification as a Scandinavian-American.

The acoustic data to be presented in this paper includes the duration of the fricative and the stressed vowel, glottal pulsing in the fricative, and the behavior of F_0, F_1, and F_2 in the vowel. All of these measures were taken in near-minimal pairs containing /s/ and /z/.

This study finds variation regionally and among the subgroups in the RRV, most notably in glottal pulsing. Pulsing is present for less of the phonemically voiced fricative in the RRV speakers than in NC, and a similar pattern is found when results are compared for the RRV speakers with strong Scandinavian backgrounds (RRVSc) and those with no Scandinavian background (RRVNS). However, the greater difference is found in /s/, which is more highly voiced in the RRV and RRVSc groups than in their counterparts. These two factors together contribute to a large distinction between speaker groups in the production of the voicing contrast, and this distinction correlates to the degree of expected Scandinavian influence.

The current study also addresses unanswered questions about some of the general patterns found in acoustic measures of phonemic voicing in GAE. Primary among these (which will be discussed in more detail in §3.3) are the behavior of the first formant in high monophthongal vowels adjacent to [±voice] fricatives and the universality of a distinction in F_0 and F_1 dependent on the voicing contrast. It was found that F_0 and F_1 do not behave in the same way in all speakers. An adjacent voiced fricative was found to have a stronger tendency to raise F_1 in /i/ in RRVSc speakers and to lower it in RRVNS speakers. Voiced fricatives were more likely to lower the pitch, however, in RRV and RRVSc speakers than in the NC and RRVNS groups, where it was lowered to a lesser extent or sometimes raised.

1.2 Questions and Contributions

1.2.1 Can Substrate Effect Be Confirmed Acoustically?

The primary question addressed by this study is whether any regional difference is found between speakers of the RRV and the NC Piedmont. The previous projects referred to above and outlined in §3.1.1 compared their impressionistic results with the canonical pronunciation of the phonemes /s/ and /z/, not with speakers from a control group. Is it possible that the authors were describing a tendency toward devoicing that could have been observed in any other location and with speakers of any ancestry, had they looked? If it was indeed a localized phenomenon in these studies, which were conducted between two and eight decades ago, does it still persist, or have subsequent generations of native English speakers in the region approached the voicing patterns of GAE? Finally, if systematic regional variation can be shown, can a significant correlation be established between this variation and the Scandinavian immigrant languages of the Upper Midwest, or is it a case of speculation becoming conventional wisdom without a factual basis?

1.2.2 Question of Ethnicity in Substrate Effects

While the major comparison to be discussed in §5 is between RRV and NC speakers, the fact that we are investigating a potential substrate effect raises the question of whether the effect is stronger in groups of speakers who are more closely connected to the substrate language. For this reason, the demographic data collected from participants includes ancestral background. By this I obviously do not mean to suggest that devoicing of /z/ is a genetic feature. Rather, I hope to capture the cumulative effect of generations of influence from parents to children and from the community to an individual. When a speaker acquires an L2, their child's speech may reflect the parent's L1, even if the child never spoke that language. In a community densely populated by other families with the same language background, the effect of the parents' speech may be compounded by peers and neighbors with similar accents. "[I]n relatively homogeneous immigrant communities where large numbers of adult speakers learned English as L2 during a single generation, this may provide enough impetus to plant features in a new generation. As we will discuss below, established features in a given community may later become ethnically unmarked regional features" (Salmons and Purnell 2010:460). In the current study, can a distinction be found between speakers on the basis of their proximity to immigrant Scandinavian speakers, or has the substrate effect, if it exists, been leveled across the region, as Salmons and Purnell suggest?

1.2.3 Study of Obstruents in American English

Another intention of this paper is to contribute a small part to the ongoing effort to complete the picture of the variation manifest in American English. While impressionistic studies of variation in obstruents have been done, acoustic analyses of regional differences in the United States have focused largely on vowels, a fact raised by Purnell, Salmons, and Tepeli (2005:137): “One should no longer assume that American English consonants do not show broad regional variation of the type found in vowels.” Thomas remarks that the aforementioned study, along with one by Docherty and Foulkes in 1999, “both demonstrate that acoustic analysis can reveal details of consonantal variation that are difficult or impossible to gauge using impressionistic analysis” (Thomas 2011:10).

Because the same stimuli and methodology will be used for each group of speakers, this study will be able to achieve a more accurate comparison between the test and control groups than if I had to rely on published accounts of results for GAE. At the same time, the open questions about pitch and F_1 behavior outlined in §1.1 mean that it would be impossible to know if RRV and RRVSc speakers differed from GAE in these ways.

1.3 Predictions

Given the reports in the literature, I predicted that there would be regional and intra-regional variation in the production of the /s ~ z/ voicing contrast in at least one measure of voicing. I expected that RRV speakers with a high degree of Scandinavian background would produce less distinction than those with few or no Scandinavian connections. The presence of the Scandinavian-Americans in this group would cause the RRV speakers to produce less of a contrast than NC speakers. I will refer to this as the Scandinavian Interference hypothesis.

There are competing hypotheses, including the null hypothesis, by which there would be no appreciable distinction in any measure of the voicing contrast as produced by any of the speaker groups. Finally, there is the Regional Variation hypothesis, which predicts variation between the voicing contrast in NC and RRV, but not among the RRV speakers. This hypothesis does not disprove substrate influence from Scandinavian languages, for such interference may have diffused to become a regional feature, as proposed in Salmons and Purnell (2010). However, it would not be possible to demonstrate a correlation in this case.

1.4 Structure of the Paper

Chapter 2 describes the historical context for this study, focusing on the heavy Scandinavian presence in the RRV. This stands in contrast to most of the United States, and certainly to the situation in the NC Piedmont, and allows for an effective test of the possible substrate effect from Scandinavian languages.

Chapter 3 reviews prior studies on the subject of /z/ devoicing in Scandinavian communities in the Upper Midwest, as well as information from descriptions of the acoustic manifestation of the voicing contrast in American English. I also discuss the primary model for this paper, an article by Purnell, Salmons, and Tepeli (2005).

In Chapter 4 I describe the methodology for the current project, including the test and control speaker groups, and the stimuli. In addition, details about the recording process and acoustic analysis are given.

Chapter 5 presents and discusses the acoustic results and statistical analyses. Data from the two major speaker groups are compared, as are results from the two subsets of the RRV test group. The outcomes of these analyses are also discussed in relation to the reported results from previous studies of American English voicing. Chapter 6 concludes the paper.

CHAPTER 2

HISTORICAL BACKGROUND

It is difficult to separate a study of regional variation from the history of the regions under scrutiny. This thesis considers the possible influence of settlement patterns on regional variation between North Carolina and the Upper Midwest, and so some understanding of the historical context in these regions is necessary. This chapter provides a summary of the history of European settlement to these two regions, with particular focus on demographic contrasts between them. These regions were chosen for comparison due to these distinctions and the likelihood of regional variation.

2.1 Norwegian Presence in the Midwest

The major focus of the background given in this paper will concern Norwegian-Americans due to that group's higher concentration in the Red River Valley of North Dakota and Minnesota (30.1% of North Dakotans claim Norwegian ancestry, compared to only 4.8% for Swedish and 1.2% for Danish) (U.S. Census Bureau n.d.). However, because the phonological facts stated above hold for all three languages, and because the languages are very closely related, any consideration of ethnicity in analyzing the results will classify Swedish, Danish, and Norwegian ancestry in the same way. In addition, general information given individually for North Dakota and Minnesota should be assumed to be analogous to the situation in the Red River Valley regions of both states for the purposes of this paper.

Norwegian communities in North Dakota (ND) are a good test case for protracted interference from a substrate language because of the high concentration of Norwegians in the area and the relative recency of their arrival. Since there have not been as significant secondary waves of migration to the state as to many places in the US (in fact, the current population hasn't yet reached the levels found before the Dust Bowl in the 1930's; see Table 1), one would also expect less dilution of the regional dialect. In addition, Norwegian-Americans are fairly concentrated in a few areas of the United States, so if there are substrate effects to be seen, we'd expect them to be concentrated (and thus more easily distinguishable) as well. While Norwegian ancestry is prevalent in ND, only 1.5% of the US population is of Norwegian descent. Compare this with German-Americans, which is the biggest group both in ND (46.9%) and the US (16.8%), and ranks no lower than the third largest ancestry group for each major region of the country (U.S. Census Bureau 2004).

Year	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000
Pop.	577,056	646,872	680,845	641,935	619,636	632,446	617,761	652,717	638,800	642,200

Table 1: North Dakota Population, 1910-2000 (Data from U.S. Census Bureau 1995, 2004)

The first Norwegian immigration to the United States was in 1825, with New York as the destination. Subsequent groups of immigrants settled progressively westward, first reaching what is now North and South Dakota in 1859 (Larson 1934:71-2). Wide-scale immigration to this area continued from the 1880's until 1915, with smaller migrations occurring in the 1920's and 1940's (Qualey 1931:278; Lovoll 2006:41, 227).

The border between ND and Minnesota is the Red River, and the Red River Valley (RRV) in both states is an area of relatively high concentration of Scandinavian settlement. It is from this region that the participants in this study will be selected. In the 1930's, Larson writes, at least one-third of the population of the RRV was of Norwegian descent (1934:72).

Using information from the 2000 census about the counties immediately adjacent to the Red River in North Dakota, I calculated that 36.5% of the current inhabitants of this region report Norwegian ancestry. In this respect, at least, the ethnic makeup of the residents of the RRV has not changed appreciably in 75 years. This population is well-entrenched in the region, and many of the settlers came directly from Norway, or after living for some time in places like Wisconsin, Iowa, or southern Minnesota (Hudson 1988:406-7, Haugen 1969:27). For example, in 1890, the year after statehood, 37.4% of the 10,217 people living in Traill County were born in Norway. Figure 1 (from the University of Virginia's Historical Census Browser 2004) illustrates this concentration. Traill County is the fourth county from the top along the eastern border, and Grand Forks County, where a portion of the ND recordings for this project took place, is directly to the north (these are the two darkest counties on this map).

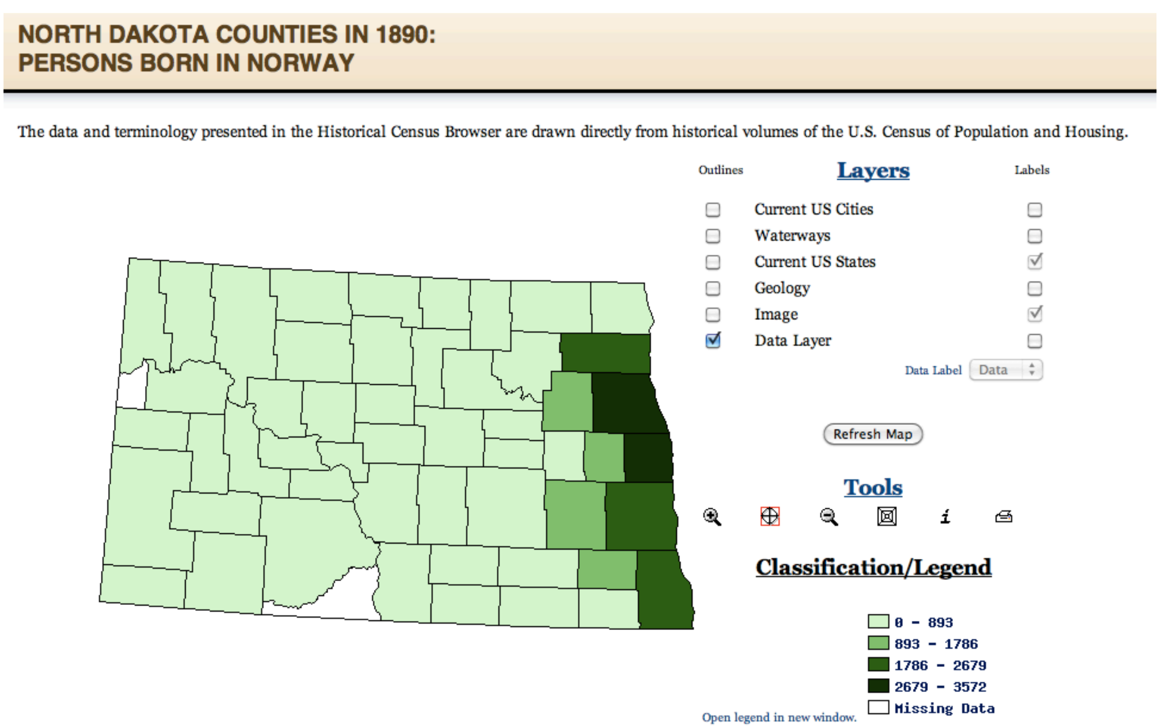

Figure 1: People Born in Norway, 1890 (Historical Census Browser 2004)

As can be seen from these statistics, Norwegians have formed a consistently large part of the population of this region since European immigration there began. In addition to large numbers of new arrivals, the Norwegian settlements in the Upper Midwest often had a cohesive sense of community, helping to maintain cultural traditions but verging at times toward insularity: “Old-timers still remember what they call 'lines' or boundaries between ethnic groups that should not be crossed: a country road or a stream might serve as a marker” (Lovoll 2006:61).

Part of the reason for this was the fact that settlements in America were often populated by immigrants from the same region or village in Norway, so that both bonds and prejudices that they’d carried with them had the chance to be reinforced in their new communities.

> The self-segregation of nationalities–as people of a similar past reunited in the rural middle west–is readily apparent, as Jon Gjerde points out; this tendency made cultural transfer possible. Gjerde explains, 'Family, friends, and countrymen crossed hundreds, even thousands of miles to return in a sense to webs of affiliation based on kinship and nationality in the rural settlements of the West....This pattern of movement had enormous significance not only for the individuals who migrated but also for the cultural development of the region.' (Lovoll 2006:60)

The transition from Norwegian to English varied by region, town, and individual, but some milestones are worth noting. The Norwegian Lutheran Church became part of the Evangelical Lutheran Church in 1946, while the official language had changed to English eighteen years earlier. The fraternal organization the Sons of Norway, meanwhile, switched to English officially in 1942 (Haugen 1969:275-277). Three widely read Norwegian newspapers existed into the 1930’s, but two of them folded by 1941 (279). However, there were still smaller newspapers. In North Dakota, the *Normanden* was published in Grand Forks until 1925, when it moved to Fargo and survived until 1954. In Minnesota, the

Minnesota Posten in Minneapolis was published until 1979 (Norwegian-American Historical Association 2011).

A detailed picture of the linguistic situation in Norwegian-American communities can be found in Einar Haugen's highly influential study of Norwegian in America, written in 1953 and republished in 1969. When it was written, Haugen was able to state that "[e]ven linguists have rarely exploited the possibilities of immigrant bilingualism for its bearing on problems of linguistic theory" (Haugen 1969:2). On the individual level, Haugen's informants included not only bilinguals but Norwegian monolinguals (45), but they felt themselves likely to be the last generation of native Norwegian speakers in America, and that World War I had been the end of widespread Norwegian fluency in the U.S (274).

2.2 Comparison with North Carolina

Since the current investigation focuses on a possible substrate effect from Scandinavian languages, it is desirable to compare the results from the Red River Valley with speech from an area that has little or no Scandinavian presence. The European settlement history and population of North Carolina contrasts sharply with that described above.

First Spain and then England attempted to establish settlements on the coast of present-day North Carolina, and it eventually became an English colony. Many settlers came from the British Isles and from Germany, and many North Carolinian families have been in the area since this time. The state also has large populations of African Americans, a presence in the region since the practice of slavery, and Native Americans, among them the Cherokee and Lumbee tribes (Powell 1989, Ready 2005). Another contrast with North Dakota is that there have been recent changes to the demographic composition of the state, with substantial migrations to the area of people from Latin America, Asia, and the northeastern United States (Ready 2005). Research Triangle Park, a scientific and industrial park near the cities of Raleigh, Durham, and Chapel Hill, became a strong presence in 1965 with the arrival of the National Environmental Health Sciences Center and IBM, drawing employees to the area from other parts of the country and world, and changing the demographics of the region. By the late 1960's, there were 5000 employees, and 10,000 by 1980 (Link and Scott 2003). In another important demographic change, the state's Hispanic population grew 129% between 1990 and 1999 (Johnson-Webb 2002). Since the speakers in this study are all near or over 50 years old, with families that have been NC residents for several generations, I can reasonably expect their production to be representative of conservative Piedmont speech and don't expect the data to significantly reflect these trends.

All ND speakers currently reside in either Grand Forks County, ND, or Polk County, MN. These counties have, respectively, 34.8% and 42.2% Norwegian, 4.7% and 10.2% Swedish, and 1.1% and 1.2% Danish populations, for a total of 40.6% and 53.6% Scandinavian background. In Durham County, NC, where most of the NC recordings took place, the same statistics are 0.5% Norwegian, 0.6% Swedish, and 0.2% Danish, for a total of 1.3% Scandinavian (U.S. Census Bureau n.d.). Because of this demographic contrast, and because I have been unable to find any research remarking either way on /z/ voicing in North Carolina, the Piedmont region will provide an effective comparison for the speakers from the Upper Midwest, and will serve as representative of General American English in this respect.

CHAPTER 3

CONSIDERATION OF EXISTING KNOWLEDGE: PERTINENT PHONETIC AND SOCIOLINGUISTIC STUDIES

The questions investigated in this thesis draw on prior research into both sociolinguistic and phonetic topics. These include descriptions of the acoustic realization of the phonemic voicing contrast in American English and the relationship between the settlement history of a region and the English spoken there today. In this chapter I present the primary sources of information and inspiration for the current study, beginning with those that first observed the phenomenon of /z/-devoicing in areas of heavy Scandinavian settlement and proceeding on to those applying acoustic methods to sociolinguistic studies. In my descriptions of these studies I will highlight the gaps that my research is designed to fill. I then introduce papers providing a theoretical sociolinguistic foundation, so that I can refer back to relevant points in the previous section. Finally, I discuss research describing characteristics of voicing in obstruents. The measurements included here were used to analyze the recordings collected for the current study.

3.1 Midwestern Voicing and Devoicing

The devoicing of /z/ in Upper Midwestern speech in general, and that of native Norwegian speakers and their descendants in particular, has been noted in many sources, ranging from brief descriptions to impressionistic studies and dating back at least 80 years.

3.1.1 Impressionistic Descriptions of Scandinavian-Influenced /z/

Studies devoted to recording Norwegian features in the English spoken in the Upper Midwest consistently report high rates of /z/-devoicing. This phenomenon was tied with devoiced /ʒ/ (another phoneme not found in Norwegian) for the most prominent Norwegian-influenced "speech defect" found by Anne Simley (1930) when she conducted an impressionistic study at a school in northwestern Minnesota, near where the recordings for the current study were made. Half of the 300 students there were of Norwegian parentage, and there were still communities where Norwegian was as prevalent as English. Of 115 Norwegian-American students studied, 95 devoiced /z/ when speaking English. Examples given include mostly word-final contexts, with one token (*zebras*) beginning and ending in /z/ and being devoiced both initially and finally. Word-medial examples (*pleasure* and *vision*) were given for /ʒ/. While the current study examines only /z/, I consider devoicing of /z/ and /ʒ/ to be closely related phenomena. Differentiation of the results, by position in the word or any other variables, is not given. Forty of the 115 were native English speakers, and six native Norwegian speakers were reported to have no trace of a Norwegian accent; we don't know how many of the 95 who devoiced /z/ had English as an L1, but it was at minimum 26 students, or 65% of the native English speakers.

Almost 60 years later, a similar study was conducted, including Norwegian-Americans of the first through the fifth generations living in Iowa, Minnesota, North Dakota, and Wisconsin, and ranging from native Norwegian speakers to monolingual English speakers (Moen 1988). Moen records that the devoicing of /z/ is the third most common "error", committed by 15 of 71 informants, and produced by 46% of those speakers who commit some sort of error. It occurs as late as the fourth generation. Unlike Simley, he excludes final /z/ from his consideration. If he had included this position, it is safe to assume that the results would have been higher, as it has been consistently noted as the most favorable position for devoicing (see Smith 1997 for discussion).

In addition to these studies, additional authors have noted devoiced /z/ in pieces focusing on other aspects of speech. Einar Haugen (1938:120) includes these remarks in an article primarily addressing other phonological adaptations in English loanwords into Norwegian:

> [T]hose features of Norwegian which still cling to many words of Group 2 [partially assimilated English loanwords] (e.g. unvoicing of z, Norwegian intonation) are precisely those features which characterize the American of the child raised in all-Norwegian communities. This is a continuation into English of the process sketched above: the phonological shift, which may be accomplished by an individual in one generation, but which a community can achieve only in several.

Haugen's article focused on a family near Blair, Wisconsin, in a strongly Norwegian area. Haugen clearly considers devoiced /z/ to be a salient marker of Norwegian-American speech, not only the L2 English of native Norwegian speakers, and one of the most pervasive effects of phonological interference in this community. The Midwestern speakers in the current study, ranging in age from the early 50's to 95, could easily be the children of the generation Haugen described. If his supposition was correct, we would expect their speech to maintain the tendency to devoice /z/ at a higher rate than other American English speakers.

Harold B. Allen (1973:138-9) notes briefly in his *Linguistic Atlas of the Upper Midwest* that among the 17 respondents whose parents were not native English speakers, there were nine of Scandinavian background. Some of these speakers devoiced final /z/, although the number of speakers and frequency of devoicing aren't specified, nor does he say whether he considered any speakers not of this group to exhibit the same behavior.

The current study builds on the descriptions recounted above, but adds acoustic data and compares speakers from multiple populations. The scope of this study differs greatly from Simley and Moen's contributions. While it incorporates non-Norwegian residents of the Red River Valley and of North Carolina, participation is limited to native English speakers rather than including native Norwegian speakers. At the same time, I narrow the focus to the question of /z/-devoicing, but expand the definition of voicing in accordance with the empirical research available in the phonetic literature. I also include more information about the phonetic context; /z/ is studied in various environments, including word-initially, medially, and finally, and the results are differentiated.

3.1.2 Instrumental Investigations

All studies cited above rely on impressionistic rather than acoustic information. I have found no acoustic study of the speech of Scandinavian communities in the midwestern United States that can confirm or refute the claims made above. However, in the past decade, there has been an increase in the output of sociophonetic studies of this kind focusing on regional and dialectal variation in American English. This recent research has informed the development of this thesis, which is intended to help complete the picture of substrate influence from Scandinavian languages on American English by means of acoustic analysis.

Instrumental data is preferable to impressionistic results in that it allows a far greater degree of accuracy. Acoustic measurements are reproducible, whereas impressionistic results could vary greatly from listener to listener. In addition, acoustic data are precise in their measurements and allow for gradations between voiced and unvoiced rather than requiring a discrete choice. For these reasons, it is desirable to incorporate acoustic data into the question at hand.

The current study is based to some extent on an acoustic study which was performed on final obstruent devoicing in Watertown, Wisconsin, as a possible substrate effect of German, which was once dominant in the area (Purnell, Salmons, and Tepeli 2005). It was found that the Wisconsin speakers produced final voiced obstruents differently than as described for other English varieties, but not, as in German, totally neutralized for voicing. Participants spoke with a rate of glottal pulsing even higher than has been described for SAE, and showed a strong voicing distinction in preceding vowel duration, but didn't exploit certain other cues to voicing such as lowered F_0 and F_1 to the same extent (these features will be discussed in §3.3). The authors cite this as evidence of regional variation, perhaps caused by hypercorrection due to the perceptual salience of glottal pulsing. This finding raises the point that an impressionistic report based on whether the consonant "sounds" voiced is likely insufficient to capture the full voicing profile of a speech community, and highlights the necessity for acoustic investigation.

In a second paper working with recordings made of speakers with birth dates dating to the 1860's and with younger speakers born as recently as 1986 in addition to the Watertown data from the previous study, Purnell, Salmons, Tepeli, and Mercer (2005) find significant changes in the manifestation of the voicing contrast throughout the years. The earlier generations distinguished voicing in obstruents almost exclusively by the amount of glottal pulsing in the constriction or closure, while the more recent generations are more likely to exhibit a trading relation between glottal pulsing and preceding vowel duration. This is especially true for the group born between 1920 and 1939 (constituting the bulk of the

Watertown speakers), which displays results similar in these measures to the control speakers. This seems to support the theory that the first native speakers of German (or other final obstruent devoicing languages like Polish or Dutch, which the authors note also established a presence in the region), upon learning English in Wisconsin, may have seized on glottal pulsing to express the contrast, possibly “display[ing] some degree of interlanguage (i.e., like neither GAE [General American English] nor German)” (315). This tendency has undergone recent change; the youngest group of speakers is the only group to produce less contrast between voiced and voiceless obstruents in the rate of glottal pulsing than the study’s General American English control speakers, and also the only test group whose voiced obstruents have less than 50% glottal pulsing.

The authors hypothesize that the pattern they found “extends across a broader regional and ethnic population” (Purnell, Salmons, Tepeli, and Mercer 2005:313), and none of the studies discussed to this point have searched for or found intra-regional differences, as this study is designed to do. The speakers from one region have been compared with speakers from other areas of the US or with the received GAE pronunciation. However, this means that an assumption is being made about the geographical range of the phenomena, which are at the same time presumed to be the result of factors that are not homogeneous for all speakers or all communities in the region.

There is, however, one study of /z/ devoicing that examines distinctions within the same city by comparing frequency of devoiced /z/ (again recorded impressionistically) for Jewish and Gentile residents of Grand Rapids, MI (Knack 1991). The two trends Knack found were that Jewish speakers and women devoiced more often than their Gentile and male counterparts, with all Jewish women (and no speakers from any of the other groups) devoicing more than 50% of their /z/ tokens. Only Jewish speakers devoiced /z/ in intervocalic or word-medial position, while all subjects did in word-final position. The gender-based differences run contrary to findings that men use more non-standard forms than women, such as described in Trudgill (1972). Knack's hypothesis is that women are "keepers of the faith" in the Jewish households, and /z/ devoicing is a linguistic marker of their Jewish identity, although this doesn't explain why the same distinction is found to a lesser extent among the Gentile men and women. Unfortunately, the gender distribution of the current study does not allow for further examination of this dynamic.

3.2. Sociolinguistic Theory

3.2.1 Establishing Substrate Influence

In her article on the methodology of establishing substrate influence, Thomason (2009) strives to avoid the term "substrate interference," as it can imply a socioeconomic as well as a historical substrate. The current paper does not follow her example in terminology, but takes her point in methodology.

Thomason prefers to use "shift-induced interference" to refer to interference as a result of imperfect learning of a language by a group of people, which is distinguished from other contact-induced change. In the former process, phonological and syntactic features are the primary areas affected, while in the latter case lexical borrowing is the dominant characteristic (all of these features may be affected by the other process as well, but in that case they are optional or later developments). Between two language groups in a language shift situation, both of these phenomena may occur simultaneously, with the shifting group's L1 influenced by borrowing and their L2 undergoing shift-induced interference.

The author identifies four criteria without which shift-induced interference cannot be proven. In order to apply this term, it is first necessary to be able to identify the contact circumstances in more than hypothetical terms. The current study satisfies this condition because the contact history of the region, from the point of first contact 150 years ago to the state of near-complete adoption of English that exists today, is well-documented. Secondly, there must be interference visible in more than one structural subsystem: "The reason is that structural interference is never completely isolated: if contact is intense enough to make structural diffusion possible, that diffusion will not be confined to a single interference feature" (Thomason 2009:322). Although an investigation into all of the features of Scandinavian-American English is beyond the scope of this paper, observed effects of Scandinavian interference exceed the devoicing of /z/ discussed herein. Klein 1998 provides a summary of some such traits, affecting, in addition to phonological features, morphosyntactic elements such as relative markers and verbal and nominal inflection, and the lexicon.

The third and fourth requisites relate to timing. The feature(s) in question must be shown to have existed in the language proposed to have caused the interference (Language A) prior to contact with the receiving language (Language B), and not to have existed in B until contact with A. To prove the first point, the timedepth of the attestation of the feature(s) in A or the widespread existence of it in A's family of languages may be used. In this case, given that A constitutes Norwegian, Swedish, and Danish, and that these languages continue to exist (with no voicing contrast in sibilants, and the other features noted in Klein 1998 still intact), we may consider the third consideration fulfilled. Considering English, while of course we may consult no acoustic data to confirm the /s ~ z/ voicing contrast in the speech of the 19th-century Anglophone settlers of the Upper Midwest, the phonemic inventories of English and the aforementioned Scandinavian languages provide the first evidence of the distinction between the languages; /z/ exists in the former, but not in the latter. Other morphosyntactic and lexical examples of Scandinavian interference as described in Klein 1998 may much easily be shown not to have existed prior to the period of contact. In all cases, the fact that these features of Scandinavian-American speech were the subject of commentary indicates that they deviated from the norm. The structure of the experiment, contrasting speakers by region and by proximity to Scandinavian speakers, is intended to delve further into this issue. If /z/ devoicing had already existed in 19th-century American English prior to widespread contact with Scandinavian languages but had gone unremarked, it would be expected to be present, possibly in multiple regions, but certainly in multiple populations within a region. The evidence that we have suggests that the fourth and final criterion for being able to present a case for shift-induced interference is satisfied in the case of devoiced /z/ in Scandinavian-American English.

3.2.2 Real- and Apparent-Time Change

In studying language change, two main strategies are used as a means of comparing speech from different time frames. Apparent-time change is a popular method, as speakers of different generations are studied concurrently as representative of the state of the language at the time they were learning it. Exploring change in real time, however, requires a great time investment as contemporary speakers in a community are compared with their counterparts of many years or decades earlier.

Simley's (1930) and Moen's (1988) studies, although they were conducted some time ago, present data from speakers that are not very far removed in age from many of those in the current study; see §4.1.2 for more information about the Red River Valley's speakers (the North Carolina speakers are not analogous to speakers in the older studies discussed above). Simley's speakers, who were schoolchildren eighty years ago, are of the same generation as the oldest participant (at 95 years old) in the current study. Moen recorded speakers with an average age of 60 in 1986, who would be on average 85 today.

Despite the generational overlap, however, we cannot necessarily consider the current study to include the same population as the previous research. We must approach any comparison of the results with caution, for reasons addressed in Bailey's (2002) discussion of the relative strengths and flaws of applying apparent-time and real-time methods to studies of sound change. While adults surveyed at different points in their lives have been found to have remarkable linguistic stability, teenagers' speech is generally still subject to change. For this reason alone, we could not draw any direct comparisons between Simley's findings and the results of this thesis; in addition, the schoolgirls who participated in her experiment included a majority of native Norwegian speakers, while the present study is restricted to native English speakers. Moen escapes the issues of adolescent participants and (for the most part) native language, but other problems remain. Among the pitfalls of real-time studies that Bailey cautions about are differences in sampling, demographics, elicitation, and data analysis, none of which have been controlled to match either previous study. Although the studies described in §3.1.1 provide background information and inspiration for this thesis, the methodological differences between the previous and current studies mean that any comparison between the results must remain purely speculative.

3.2.3 Hypercorrection

Hypercorrection occurs when a group of lower status (for instance, speakers learning the majority language of a place as their L2) exceed speakers of higher status in their use of standard or prestige features. Romaine (2003:102) writes of lower middle class speakers producing more prestige forms than speakers of a higher socio-economic status in more formal speech styles due to their linguistic insecurity; in trying to match higher-status speakers, they in fact "overshoot the mark". Because the data in this study was collected in sentence-reading tasks, a fairly formal speech style, hypercorrection is one possible result, which would manifest itself in the Red River Valley speakers regionally or the Scandinavian subgroup intra-regionally producing a higher voicing contrast in one or more measures of voicing than the North Carolina or non-Scandinavian Red River Valley subgroup. As mentioned in §3.1.2, Purnell, Salmons, and Tepeli (2005) argued in favor of hypercorrection as a cause of the heightened glottal pulsing in Watertown speakers' voiced obstruents compared to General American English participants.

3.2.4 Stereotypes and Popular Awareness of Dialects

Labov (1972) categorizes linguistic features showing sociolinguistic variation as belonging to one of three designations, indicators, markers, and stereotypes. The first vary by speaker group (whether defined by gender, age, ethnicity, or socioeconomic status), but do not show any effect from stylistic context. The production of indicators would not be altered whether the speaker was addressing an employer or a close friend. The second kind of variable, indicators, do undergo stylistic changes. Finally, stereotypes are the subject of explicit commentary.

Salmons and Purnell (2010) discuss linguistic stereotypes and popular perceptions in the context of language contact's role in the development of American English. Traditional accounts have been hesitant to attribute much influence to language contact, but this work explores cases where the source languages are well-documented and are widely considered by local speakers to influence their speech.

> Still, the widespread scholarly assumption of a lack of influence beyond the lexicon does not match some folk perceptions about American English in some parts of the country. In the Upper Midwest, as developed below, it is unremarkable for members of communities with strong ethnic/immigrant identities to assume that their personal speech reflects their heritage, even if they are monolingual English speakers. If asked about some distinctive-sounding pronunciation, such as "stopping" of interdental fricatives or final devoicing in a word like *beer*[s], speakers may matter-of-factly say "oh, that's just the Polish/German/Norwegian coming out in me" (Salmons and Purnell 2010:460).

This tendency appeared in the North Dakota and Minnesota speakers as well. One participant, upon entering the room and with no knowledge of the purpose of the experiment other than that it concerned the speech of the Red River Valley, joked about putting on a Norwegian accent for the recordings (there was no indication that this was more than a joke, however; I explained that I wanted natural speech and the speaker did not noticeably change production between conversation with me and the recordings).

Someone asked to mimic a Minnesota accent would likely get their cues from the movie *Fargo* by Ethan and Joel Cohen. This accent is popularly associated with the Scandinavian immigration to the area. In an online search for popular conceptions about the dialect, the most commonly described features were the "long o" and phrases such as "ja, sure, you betcha" or "uff da". Following these were comments about the "sing-song inflection", and occasional remarks about pronouncing "well" as [vɛl]. All of these features are thought to derive from Scandinavian languages, an impression which is often noted in user comments. In several websites, I found only one note about devoiced /z/ (from Filipino Bambino): "The people who have an old school European accent. Not an English accent or anything like that. It's more like this, 'Ohh, Dae-vuht, how'ss werk going thesse dayss?' (David, how's work going these days?) Notice the accent on the esses?"

It seems that the first four aspects of the Minnesota dialect mentioned above would most closely fall under the category of "stereotype" in Labov's stylistic continuum, as they are socially stratified and are the subject of "overt social consciousness" (Labov 1972:248), while devoiced /z/, which has been addressed by linguists but much less so by the general public, is a less salient feature. The criterion distinguishing the other two categories (indicators and markers) is the question of style-shifting, which has not yet been addressed in this case.

However, as explored in Purnell, Salmons, and Tepeli (2005), final /z/-devoicing is stereotypical of regional speech in other areas of the Midwest, where it has been proposed as an effect of final obstruent-devoicing languages like German and Polish. The *Saturday Night Live* sketches from the 1980's about the Chicago Bears superfans are perhaps the best example of this, with its catchphrase of "Da Bear[s]" throwing in interdental stopping as a bonus linguistic stereotype.

Interestingly, one feature named above, substituting [v] for /w/, seems to be very rare in actual speech, which is allowed by Labov's description: "There may or may not be a fixed relation between such stereotypes and actual usage" (Labov 1972:248). This trait, along with [j] instead of /dʒ/, would most certainly appear in an enthusiastically told Ole and Lena joke.

However, the actual occurrence of these accent features in daily speech is quite low (Simley 1930, Moen 1988). These substitutions are perceptually very salient, much more so than the difference between [s] and [z], and would likely not last long past the first generation of English learners.

3.3 Voiced Fricatives in American English

The studies from Wisconsin described above illustrate the inability of a single acoustic cue to accurately reflect the voicing contrast. For this reason, the present paper follows many previous studies (Purnell, Salmons, and Tepeli 2005, Smith et al. 2009, and Jacewicz et al. 2009 among them) in considering the effect of the phonological voicing contrast on multiple acoustic measures that have been observed as possible correlates to phonemic voicing. These will be discussed in the following paragraphs and summarized in Table 2 at the end of this section.

Among the possible correlates to voicing, some have been found to be stronger indications than others. While the role of glottal pulsing in phonological voicing (along with the use of the term “voicing” itself) may be disputed, it is generally included as at least part of the definition of phonetic voicing (for discussion, see Purnell, Salmons, and Tepeli 2005:138-9). In one test of the salience of glottal pulsing in identification of the phonemic voicing value, Pirello et al. (1997) attempted to devise a rubric which would categorize syllable-initial fricatives produced by four subjects as voiced or voiceless purely on the basis of glottal pulsing. To be classified as voiced, 30 ms of contiguous voicing needed to be present either at the onset or offset of frication. Their method successfully matched 93% of their tokens with their phonemic voicing assignment. Phonemically voiceless fricatives fared much better in this experiment; 99.9% were correctly categorized, compared with 86% of voiced fricatives, which is still significantly higher than chance. This suggests that their requirement is sufficient but not always necessary to identify voicing.

Duration of the segments involved is another commonly described factor in the voicing contrast. Vowels preceding voiced obstruents are generally significantly longer than those preceding voiceless sounds (see, for example, Stevens et al. 1992, Fischer and Ohde 1990). Conversely, shorter fricative durations have been found to pattern with voiced phonemes, but this may not be as strong an indicator of voicing.

A perceptual study by Flege and Hillenbrand (1986) is one example of this inequality. The authors reported asymmetrical findings depending on participants' native language when they altered the durations of a final fricative and of the preceding vowel in English words. Native English, French, Swedish, and Finnish speakers listened to the resulting sounds, and while lengthening the vowel resulted in a higher number of voiced fricative identifications for speakers of all four languages, shortening the fricative did the same (though to a lesser extent) only for the English and French participants. The judgments of the Swedish and Finnish speakers showed no significant effect from the manipulation of the fricative duration.

Data in Smith et al. (2009) are similarly indicative of an imbalance between the significance of preceding vowel and fricative durations. Native German speakers were found to produce total neutralization of the fricative duration contrast between phonologically voiceless and voiced stops in final position when speaking German, but to incompletely neutralize the contrast in the preceding vowel, lengthening it by an average of 9% before /b d g/ compared to before /p t k/.

The fundamental frequency and the formants are reported to be generally lower adjacent to voiced than to voiceless fricatives (Stevens et al. 1992, Kingston and Diehl 1994). However, these findings, especially in regards to F_1, mostly concern low and mid vowels. Perceptually, lowered F_1 has also been found to be a cue to voicing in /i/, but the effect was much less robust than for /æ/, while /I/ behaved similarly to /æ/ (Fischer and Ohde 1990). It has been proposed that hyperarticulation may occur adjacent to voiceless sounds, as F_1 has been found to be depressed in low vowels adjacent to voiced consonants, while diphthongs with high offglides have been shown to follow the opposite pattern (Moreton 2004). F_2 was shown to pattern in a similar way, with the following consonant causing the formant to be closer to the periphery of the vowel space (higher for front vowels, lower for back vowels) if it was phonologically voiceless.

Of further interest, Thomas (2000) finds regional differences in the behavior of F_1 and F_2 in the diphthong /ai/ preceding the voiceless and voiced stops /t/ and /d/. Non-Hispanic Caucasian speakers in Ohio exploited the voicing contrast to a greater extent than speakers in a Mexican-American community in Laredo, Texas. Thomas proposes that this may be the result of interference from Spanish in the variety of English spoken by Mexican-American bilinguals and English monolinguals. If this is the case this outcome, showing a regional distinction that correlates with ethnicity and is caused by substrate interference, is very similar to the predictions of the Scandinavian Interference hypothesis in the current study.

This study will include vowels from various areas of the vowel space: low /æ/, high front lax /I/, and the high tense vowels /i/ and /u/. While the reported results for vowels like /æ/ are fairly consistent, it isn't clear what to predict for the remaining three vowels. With this study I hope to shed some light on the behavior of these non-low vowels in proximity to voicing. If hyperarticulation of the high vowels does occur, rather than the scenario predicted by Stevens et al. and Kingston and Diehl, we would expect F_1 to be higher adjacent to voiced fricatives, as the already low F_1 would be brought even lower if it were hyperarticulated by voiceless consonants.

The main focus of this paper will be to compare the distinction between production of /s/ and /z/ in our different speaker groups, whether the formants pattern according to the low frequency or hyperarticulation hypotheses. However, attention will be paid to the question of F_1 and F_2's behavior in the high vowels, as another way to conceive of the different possibilities is whether the high monophthongal vowels will pattern with previous results for low monophthongs or with the high offglides of diphthongs.

It is unclear to what extent the various measures that correlate with voicing are dependent on one another. For example, it has been suggested that the presence of glottal pulsing may be necessary to show the greater transitions in F_0 and F_1 in [+voice] consonants (Stevens et al. 1992, Kingston et al. 2008), but Kingston and Diehl (1994) had earlier claimed that the contrast in F_0 was solely reliant on phonological voicing, completely independent of glottal pulsing. In contrast, Purnell, Salmons, and Tepeli's (2005) findings that the Watertown speakers did not exploit either F_0 or F_1, while the phonemic contrast manifested itself clearly in their rates of glottal pulsing, argues against the assertion that F_0 is intrinsic to either phonological or phonetic voicing. Trading relationships between multiple measures, such as between glottal pulsing and preceding vowel duration, have also been observed, as described in Purnell, Salmons, Tepeli, and Mercer (2005). In these cases one cue at a time may bear the bulk of the perceptual burden, but that cue may vary from token to token. The variety of measurements taken in the current study allows further insight into the interactions between voicing correlates.

Table 2 summarizes the voicing correlation measures that will be examined in this study and the observed effects of the phonemic voicing distinction (the accounts ascribed to the low frequency and hyperarticulation hypotheses are both included for F_1, but F_2 wasn't addressed by the low frequency hypothesis).

MEASURE		OBSERVED FOR [+VOICE]	OBSERVED FOR [-VOICE]
Glottal pulsing % of constriction		Higher	Lower
Vowel duration		Longer	Shorter
Fricative duration		Shorter	Longer
F_0		Lower	Higher
F_1	Low Frequency	Lower	Higher
	Hyperarticulation	Lower for low vowels, higher for high vowels	Higher for low vowels, lower for low vowels
F_2	Low Frequency	--	--
	Hyperarticulation	Higher for front vowels, lower for back vowels	Lower for front vowels, higher for back vowels

Table 2: Measures of Voicing Correlation

CHAPTER 4

METHODOLOGY

4.1 North Dakota Participants

4.1.1 Recruitment

An attempt was made in North Dakota to recruit two distinct groups that would be highly likely and unlikely, respectively, to include Scandinavian-Americans. To this end, recruitment of the former group originally took the form of flyers placed in the Sons of Norway lodge (a Norwegian-American organization; although non-Norwegians are not excluded, the organization does have a high concentration of Scandinavian members). Recruitment was also done in Lutheran churches and by personal appeal. Traditionally, Scandinavian immigrants belonged to the Lutheran church, which was (and is) the official state church of Norway. According to Odd Lovoll (2006:107),

> a strong ethnoreligious identity...kept Norwegians within the Lutheran fold; in fact, one may claim a nearly symbiotic relationship between Lutheran and Norwegian ethnicity. Conversion to other faiths placed barriers between Norwegians. Protestant antipathy toward Roman Catholicism made conversions to the Catholic Church in the nineteenth century, and even much later, almost unheard of among Norwegian immigrants.

Accordingly, it seemed logical given this history that there would be a higher-than-average chance of finding non-Scandinavian participants in Catholic congregations, and that these groups would be somewhat distinct. Anecdotal support for this tactic was provided by family members in the targeted age group, who recalled not knowing many Catholic children growing up because they attended public schools, while most Catholic children attended parochial school. To further illuminate this dynamic, ND study participants were requested to answer whether or not they knew many people from different ethnic backgrounds growing up.

4.1.2 Speakers

Speakers 1-19 were natives of North Dakota and Minnesota. Speaker 16 was excluded from analysis on the basis of being a native speaker of German, having learned English upon entering school. These participants ranged in age from the early 50's to 95 and included three men and 15 women, and more details are given in Table 3. This includes where their families came from and when they arrived in the Red River Valley, as well as whether the speaker identifies strongly with their ancestry (or, as is sometimes the case, with the culture of their neighbors). The notation "EL1" refers to the number of generations in the speaker's family to have been native English speakers (for example, 1 means that the speaker is of the first generation to have English as their first language). A dash (-) indicates that the question was not answered or the information was unknown.

SPKR	SEX	AGE	FAMILY BACKGROUND	ARRIVED IN RRV	IDENTIFY AS	EL1
7	F	80-85	German, Polish, Irish, English	1910	German, Polish	1
13	F	90-95	English	1900	-	3+
17	F	60-65	Czech	Grandparents	Czech	1
18	F	60-65	Scottish, Dutch, German	-	Scottish	-
3	M	50-55	Norwegian, German, Czech French Canadian	1880-1910	-	2
4	F	75-80	German, English, Scottish, Irish, Welsh	Grandparents	Norwegian	1
6	F	80-85	Norwegian, Pennsylvania German	Grandparents	German, Norwegian	1
8	F	55-60	German, Scottish, Irish, English, Norwegian	-	-	2
9	F	55-60	German, Norwegian	Grandparents	-	1
14	F	70-75	Scottish, Danish	1920	Scottish, Danish (somewhat)	2
19	M	70-75	Norwegian, Czech	Grandparents	-	1
1	F	80-85	Danish, Dutch, English	1890	Norwegian	1
2	F	55-60	Norwegian, German, Dutch	1870	Norwegian somewhat	2
5	F	70-75	Swedish, Norwegian	1913	Swedish, Norwegian	1
10	F	60-65	Norwegian	mid-1800's	Norwegian	2
11	M	70-75	Norwegian	1885-1928	Norwegian	1
12	F	70-75	Swedish, Norwegian	late 1800's	Swedish, Norwegian	2
15	F	60-70	Swedish	1896	Swedish, Norwegian	2

Table 3: Characteristics of Speakers 1-19

In an effort to quantify the information gathered from participants about their family background, I assigned 1 point if the speaker reported up to 50% Scandinavian ancestry, 2 points if they reported over 50%, and an extra point if they stated that they identify strongly with this background. This rubric yielded four speakers with scores of 0 (7, 13, 17, and 18, with no shading in Table 3) and five speakers with scores of 3 (5, 10, 11, 12, and 15, with the heaviest shading) out of 18 subjects. The majority of the remaining speakers had scores of 1, which meant either that they reported between 0 and 50% Scandinavian ancestry (non-inclusive) or that they themselves had no Scandinavian family background but grew up around the culture and identified with it. This rubric is not finely tuned enough to categorize all of the RRV speakers, so those with 1 (light shading) or 2 points (intermediate shading) are not separated into groups for the purpose of data analysis, although they are indicated in Table 3. However, I am confident that it does distinguish those with the most (3 points) and the least (0 points) Scandinavian background. The RRV results will be compared as a whole with results from North Carolina, but these two groups of 0 and 3 points will also be compared with each other in §5; those with 0 points comprise the RRVNS (non-Scandinavian) group, and those with 3 points are assigned the label RRVSc (Scandinavian).

4.2 North Carolina Participants

4.2.1 Speakers

Because no significant Scandinavian influence was anticipated in North Carolina, all participants from North Carolina were considered to form one group for the purpose of this study. Some demographic information (e.g., age, family and language background) was still collected.

Subjects who were native to the Piedmont region and in the same age range as the ND speakers were recruited by the means of flyers posted in public libraries, personal requests, and word of mouth. A total of six participants were recorded and five of them, between the ages of 45-55, were analyzed. Subject 20 was excluded, having moved to the Piedmont as an adult from out of state. More information on Subjects 21-25 is included in Table 4.

SPKR	SEX	AGE	FAMILY BACKGROUND	ARRIVED IN PIEDMONT	IDENTIFY AS	EL1
21	F	45-50	-	-	-	3+
22	M	48-53	African American, Native American	Father born here, mother moved from Western NC	African-American	3+
23	F	50	Scotch-Irish and German	Around 1800	-	3+
24	M	50-55	Scottish	Late 1800's	-	3+
25	F	45-50	Scottish, English, Irish, Cherokee	Many generations ago	-	3+

Table 4: Characteristics of Speakers 21-25

This information confirms expectations from the demographic data presented in §2. In our NC speaker group there is clearly no one who claims Scandinavian ancestry. It is also true that these speakers' families have for the most part lived in the region longer than in the more recently settled RRV and have been Anglophone for many generations (even factoring in the difference in the age ranges of the two groups). From this information it is clear that if a substrate effect is present in the speech of the RRV, it would contrast strongly with that of the NC Piedmont.

4.3 Materials

4.3.1 Stimuli

Informants were given a series of three tasks, decreasing in naïveté. Results from the first task are not reported for reasons explained below, but it did serve the purpose of allowing participants to acclimate to speaking into the microphone and being recorded. The first was to narrate or describe a set of six photographs expected to lead to certain target words. This task was designed in an attempt to capture speech that is somewhat unself-conscious and naturalistic, or at least unaware of the target segments, while maintaining some control and inter-speaker consistency of the sounds spoken. All photographs were obtained through open-source online collections. The target words included both /s/ and /z/ in initial, medial, and final positions: *ceiling*, *zebra*, *whistle*, *lizard*, *lace*, and *maze*. Added to the linguistic restrictions on these terms was the concern that the items should be fairly recognizable, and that they be prominent enough in the photograph to warrant mention, but not the singular focus, lest they draw too much attention to the target sounds. However, many speakers did not arrive at every desired term, and some issues of vocabulary arose. For example, the train whistle was sometimes called a "flute" and the lizard a "gecko". Because of this wide variability in the completeness of the data sets available for the respective participants, this task was excluded from analysis.

The second and third tasks both involved the same 12 pairs of words containing /s/ and /z/ in word-initial, word-medial (intervocalic or, in a couple of instances, intersonorant), and word-final positions; see Table 5. In this chapter and throughout, the terms S-word and Z-word will be used to differentiate these tokens by the phonemic value of the fricative. Minimal pairs were not possible in many cases, but the stimuli have been matched for stress (always on the first syllable), length (two syllables when the fricative is in word-medial position, one syllable elsewhere), and quality of the stressed vowel (/i u ɪ æ/).

VOWEL	INITIAL	MEDIAL	FINAL
/i/	see / zee	recent / reason	lease / please
/u/	sue / zoo	lucid / floozy	loose / lose
/ɪ/	sip / zip	gristle / drizzle	hiss / his
/æ/	sap / zap	fasten / hazard	gas / jazz

Table 5: Target Stimuli

In selecting the stimuli, priority was given to monomorphemic words to avoid placing /s ~ z/ at a morpheme boundary. José (2010:51) found in Indiana that the morphological status of the fricative affects the voicing results. Possessive and plural /z/ favored devoicing, while the third-person singular present /z/ morpheme was devoiced to a lesser extent. Non-morphemic /z/ was the most resistant to devoicing.

Where possible, approximants have been avoided in proximity to the stressed vowel, as segmentation between these sounds can prove difficult, but in all cases where I had to resort to these segments, they appear in both the S- and Z-Word members of the pair, allowing for better consistency of comparison. In addition, an attempt has been made to avoid other fricatives in the word and to match the voicing of the other consonants in each word pair, but given the constraints, this goal wasn't always met.

Efforts were made to avoid conditions that would increase the probability of devoicing for reasons other than those investigated in the study. Because positions at the edges of domains higher in the prosodic hierarchy favor devoicing more (Smith 1997), the frame sentence for Task 2 was chosen to encourage primary stress on the target word without placing it at the edge of the utterance or allowing list-reading intonation: *Please say "______" again*. Each of the 24 words under investigation, plus an equal number of distractor words, were inserted in the frame, and the 48 resulting sentences randomized in two different orders. Speakers were asked to read two repetitions of each sentence to allow calculation of the mean in most cases and to help assure that at least one repetition would be usable. The distractor words were chosen to match the target words in stressed vowel quality, stress placement, and number of syllables; see Table 6.

VOWEL	1 SYLLABLE	2 SYLLABLE
/i/	key, bee, leak, deep	peeking, meter
/u/	do, grew food, roof	looping, cupid
/ɪ/	dip, skip, mist, pick	tickle, little
/æ/	cap, bad, flap, bag	masking, after

Table 6: Distractor Stimuli

Task 3 was designed to draw the most focus to the purpose of the experiment, as it pairs the minimal or near-minimal pairs side-by-side. Each pair of words (excluding the distractors) were inserted into each slot of the sentence, *I said "______", not "_______".* For example, the stimuli included both *I said "sip", not "zip"*, and *I said "zip", not "sip"*, for a total of 24 sentences, which were again presented in two different randomized orders.

There were some stimuli that caused unforeseen problems for more than one speaker, or more than one repetition for a certain speaker. For example, both *lose* and *his* were occasionally pronounced as their corresponding S-word counterparts, and the pairing of *gristle* and *drizzle* led some people to focus on the initial stop contrast and pronounce *gristle* with a voiced fricative. In addition, *recent* was pronounced as *resent* in most repetitions by one speaker, and another included the [t] in *fasten*. It was somewhat problematic to determine how to treat those tokens that sounded like the other member of the word pair, as the distinction between these words is such a large part of the research question. However, it was judged preferable to exclude data that might be accurate than to include false data. Accordingly, any tokens that sounded like errors (whether they sounded like the other member of the pair or like another word entirely) were excluded. In many cases the mistake was clear (for example, one repetition of *his* sounded both very different from other repetitions for that speaker and similar to their production of *hiss*). Tokens from speakers from all groups and subgroups were rejected, and the same few pairs mentioned above elicited repeated mispronunciations in all populations. For this reason, if a few of the excluded tokens were not actually errors, I do not believe that it will greatly skew the data.

4.3.2 Other Materials

After completing the recordings, participants were asked to complete a questionnaire providing information about their language and family background (see Appendix). This information was used to ensure that only native English speakers and natives of the region studied were included. As mentioned in §4.1-4.2, two speakers were disqualified based on these criteria. The information was also intended to allow for further differentiation of the data by factors such as age, generation in America, gender, and ethnic group identification, although most of these considerations proved beyond the scope of this project.

4.4 Recording Procedure

Recordings were made on a MacBook running OS X version 10.6.7 using Praat version 5.2.14 at 16 bits with a sampling rate of 44,100 Hz. A Gigaware headset microphone with a USB connection was used. The sessions took place mainly in study rooms provided by local libraries, and also occasionally in the homes of the participants or of the author. It was not possible to avoid all background noise such as automatic fluorescent lights or the computer itself, but in most cases low-frequency noise was not sufficient to interfere with analysis. In all recordings made in a certain location, a high-frequency hum was present; this caused some issues and will be discussed in §4.5.

Prior to beginning the experiments, participants were asked to read and sign the consent forms, and encouraged to ask for clarification if needed. I also gave them an additional sheet describing the process in more detail and noting my contact information in case questions arose later. Once the recording session was done, they were given the choice of a small bag of Chex mix or of chocolate. No compensation was provided.

4.5 Acoustic Analysis

4.5.1 Segmentation

Analysis was performed on the same computer as was used for the recordings, using the same version of Praat. Boundaries for the relevant segments were set manually. These were the fricative (/s/ or /z/) and the stressed vowel in the word (following the fricative in fricative-initial words, and preceding it in fricative-medial and -final words). Vowel criteria included the appearance and disappearance of the second and third formants, which often coincided with the edge of frication. However, there were rare instances where the formants dropped out significantly before any frication. These periods without either formant structure in F_2 and F_3 or frication were classified with the fricative, following the vowel criteria outlined above. In some cases the opposite occurred, with these formants continuing into or even through the period of noticeable frication. These intervals were also judged to be part of the fricative due to the fricative noise. When adjacent to a pause, the fricative boundary was placed at the appearance of frication or of glottal vibration, in the event of pre-voicing. In Task 3, where initial fricatives followed not vowels but the consonants /d/ and /t/ (e.g. *I said "sip", not "zip"*), voicing in the stop closure was treated in one of three ways. If it clearly began after the start of the closure, it was included as part of the fricative as voicing preceding the frication, whereas if it tapered off before the end of the closure, it was counted as part of the stop. However, if the voicing seemed to continue throughout the closure, as happened with all four possible combinations (/t/ and /s/, /t/ and /z/, /d/ and /s/, and /d/ and /z/), there was no clear way to tell if it was voicing in the preceding stop or voicing preceding the frication in the following fricative. In these cases the boundary was placed at the midpoint of the closure.

4.5.2 Measurement

As discussed previously, many possible correlates to voicing were measured: stressed vowel and fricative duration, glottal pulsing in the consonant, pitch in the vowel, and F_1 and F_2. All of these measures were obtained from Praat using the software's scripting capabilities. Duration was recorded based on the segment boundaries, as described above. The other measurements left more room for error, as they didn't rely on manual inspection, but an automated analysis did provide consistent standards. Pitch and formant settings were adjusted as specified below to ensure a balance of accuracy and automation, and anomalous results were flagged for manual confirmation, as discussed in §5.

Glottal pulsing was measured as a percentage of the duration of the fricative. Each fricative was cut into a separate sound file and put through a low-pass filter at 500 Hz. The resulting file was sent to a Point Process with a pitch range of 50 to 350 Hz, which is a record of the file's pulses, and which was read into a VUV TextGrid with a maximum period of 0.025 and a mean period of 0.01. This step marks intervals of the sound file as voiced (V) or unvoiced (U) based on the presence and frequency of the pulses. The total duration of all voiced intervals within each fricative was then calculated and this sum divided by the duration of the fricative.

F_0, F_1, and F_2 measurements were taken in the stressed vowel at 20, 50, and 80% of its duration, although the 50% values are not included in the analysis. Only one of these measurements was used for each vowel, however: the point closest to the fricative. This was the 20% value in fricative-initial words and the 80% value elsewhere. The edge-adjacent values of corresponding S-words and Z-words were compared.

Pitch readings were taken with a pitch range of 75-400 Hz and a voicing threshold of 0.25. Otherwise the default Praat settings were used, although a 0.01 silence threshold was necessary for certain speakers to avoid error readings. Formant settings were default except for the time step (0.025) and the maximum formant. The latter setting deviated from the standard suggested values of 5000 Hz for males and 5500 Hz for females. In some, but not all, cases this was because the hum mentioned in §4.4, at about 4100 Hz, was mistaken for a formant. This setting was adjusted on an individual basis upon visual inspection of the spectrogram, but the maximum number of formants was always set at 5, as varying this setting was not found to be as beneficial. An example of the maximum formant adjustment is shown below in spectrograms for *zoo* in Task 2's frame sentence, "Say zoo again." Figure 2 shows the formant trackers findings with a maximum of 5000 Hertz for Speaker 3 (a male speaker). Figure 3 demonstrates that in this case a maximum formant value of 4500 Hertz produces formant tracker results for the lower formants that more closely match a visual inspection of the spectrogram.

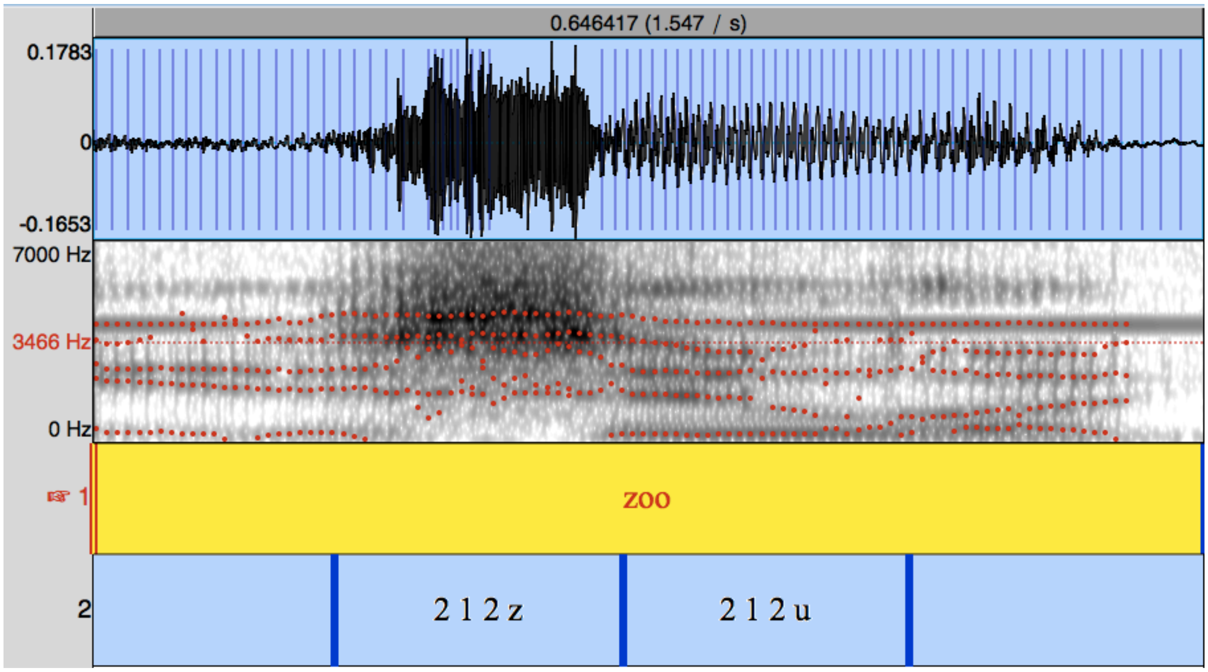

Figure 2: Speaker 3, Task 2 *zoo*, Maximum Formant 5000 Hz

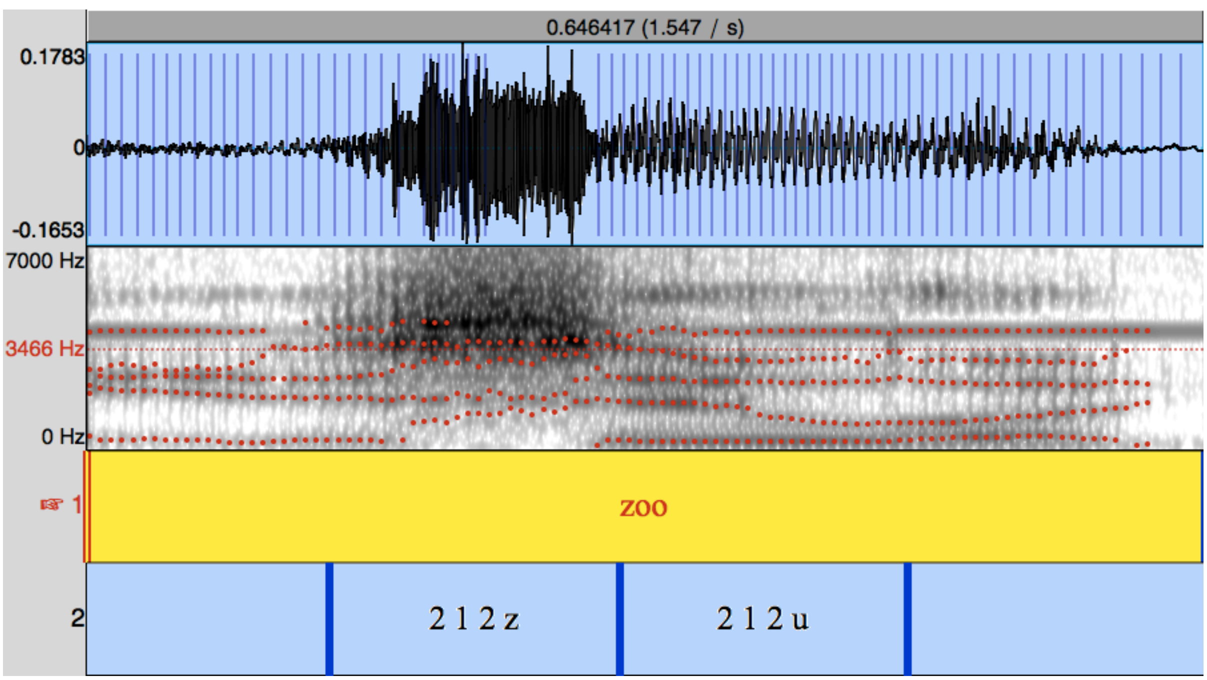

Figure 3: Speaker 3, Task 2 *zoo*, Maximum Formant 4500 Hz

The maximum formant value was often a matter of balance between two potential errors; when it was too high, F_1 was often ignored, while when it was too low, Praat detected spurious formants. The former error was deemed preferable, as it was easier to filter out F_1 values that were greater than expected because they were actually F_2. See §5 for more details.

Chapter 5

RESULTS

In this chapter I present the results of my study and discuss how they relate to previously published findings. The greatest regional difference is found in glottal pulsing, where /z/ is voiced approximately equally in both regions, but the high amount of voicing in the Red River Valley speakers' /s/ contributes to a lesser voicing contrast in that region.

5.1 Calculation of Results

The mean of each speaker's two repetitions were calculated for each token. Some utterances were excluded because of mispronunciation or omission, and in these cases the mean value is equal to the remaining repetition. In rare cases, both repetitions for a speaker were excluded, which is reflected in the "null" cells in all results tables (this happened in three of 360 tokens in North Carolina and six of 1368 tokens in the Red River Valley). Results are given as the raw means and as comparisons showing the effect of the phonemic voicing contrast for each speaker. In all cases, comparisons were made between the values for the word containing the phonologically voiceless fricative (S-word) and the similar word whose fricative is phonologically voiced (Z-word) when the tokens are matched by speaker and environment. For example, values for *sip* were always compared to values for *zip*. In task 3, identical place in the sentence was an additional criterion. In those sentences with the frame *I said __1__, not __2__*, the *sip* in the (1) blank was only compared with the *zip* in the (1) blank, and likewise for the (2) place.

Most comparisons are expressed as a ratio of the S-word value over the Z-word value. This method was chosen to normalize variation in the inter-speaker values (Thomas 2000, Moreton 2004). However, because in previous studies vowels have been found to be longer when the fricative is voiceless (the opposite of the pattern for fricative duration), this comparison is expressed as the Z-word values divided by the S-word value. This is so that the value predicted by the existing literature on the voicing contrast in English fricatives will be greater than 1 in both cases, allowing for easier comparison.

In contrast, glottal pulsing results for each fricative are already expressed in ratio format, so it isn't necessary to normalize them as it is the other measures. These comparisons are calculated as differences, with the S-word value subtracted from the Z-word value. The expectation is that these values will be greater than zero, with a higher percentage of glottal pulsing in the Z-words.

Pitch and formant values are compared at a point close to the fricative (the 20% point in fricative-initial words, 80% in fricative-medial and -final tokens). These values are calculated as a ratio, with the S-word value in Hertz divided by the Z-word value.

The fundamental frequency ratios adjacent to the fricative are expected to be greater than 1, as voiced consonants have generally been observed to lower F_0. However, as discussed in §3.2, we don't have an exact model of the expected results for the first and second formants. Studies of mid and low vowels have shown that in American English the pitch and F_1 are generally lower and transitions greater adjacent to voiced fricatives. However, this may be due to hyperarticulation adjacent to voiceless sounds as Moreton

(2004) found the opposite result in the first formant of diphthongs with high offglides, and found F_2 to be similarly subject to hyperarticulation. The chart below shows the results predicted by the hyperarticulation (unshaded cells) and low frequency (shaded cells) hypotheses, given their competing predictions about the formant patterns near voiced and voiceless consonants. Table 7 assumes canonical formant values; /u/ was significantly fronted in most NC speakers' production, for example, often to the extent that we might expect hyperarticulation of F_2 to act in the opposite direction. Similarly, although /I/ is described as a high lax or near-high vowel, production of F_1 in /I/ was often around 500 Hertz, which would be expected for mid /ə/.

VOWEL	F1 S/Z	F1 S/Z	F2 S/Z	F2 S/Z
/i/	<1	>1	>1	-
/u/	<1	>1	<1	-
/I/	<1	>1	<1	-
/æ/	>1	>1	>1	-

Table 7: Predicted Outcomes Assuming Canonical Formant Values. Unshaded cells show Hyperarticulation predictions and shaded cells Low Frequency predictions.

While formant and pitch settings were adjusted to try to provide the best fit (see §4.5.2), there were some outlying results. Formant values that fell outside the expected range for each vowel were flagged for manual confirmation or correction. The anticipated maxima in Hertz were determined by inspection of several speakers' sound files and are shown in Table 8.

FORMANT/VOWEL	i	u	I	æ
1	500	500	700	1100
2	3100	2100	2700	2700

Table 8: Expected Maxima for F_1 and F_2

Some results that exceeded the expected maximum value for the vowel were found to be legitimate (especially those that were less than 100 Hertz greater than shown above), but others were in fact the F_2 value, where F_1 was not found by the software at the settings used.

In these cases, the maximum formant value was adjusted until the formant tracker matched the formants visible in the spectrogram, and measurements were then taken (this method is advocated by Thomas 2010:43). This was done to achieve higher accuracy than simply placing the cursor over the visible formants, as a seemingly small change in the placement can result in a large numerical difference.

In all comparisons, the Red River Valley (RRV) speakers are considered as a whole in comparison with North Carolina (NC) speakers and as subgroups, but the RRV results contain participants who are not part of either subgroup. The subgroups, as assigned in §4.1.2, are RRV speakers with a strong Scandinavian background (RRVSc) and those with no Scandinavian background (RRVNS). In the rubric devised to quantify the degree of Scandinavian connection, these speakers had scores of 3 and 0 points, respectively, while those with 1 and 2 points were assigned to neither subgroup. At each level of comparison, one group will be termed the "test group" (RRV speakers regionally, and RRVSc speakers intra-regionally), and their results will be considered against the "control group" (NC or RRVNS speakers).

5.2 Statistical Analysis

The difference in the values recorded in each specific context for each pair of speaker groups (RRV and NC at the regional level, RRVSc and RRVNS intra-regionally) was calculated using a simple contrast of means (chi-square distribution with one degree of freedom). For example, the results of all speakers in the RRV group for the duration of /i/ in following a voiceless initial fricative (*see*) were compared with those of the NC group.

Adjustments were made to the standard error to account for multiple observations within subjects. An alpha level of 0.05 was used to determine significance.

5.3 Findings

Results for each measure of voicing will be presented first as an aggregate comprising all analyzed data for Task 2 ("Please say ___ again") and both phrase positions in Task 3 ("I said ___, not ___"). Then, within each section, the data for Task 2 and each position of Task 3 will be reported separately. Larger trends will be summarized first, and any style-specific patterns will be discussed. Task 2, which was the reading task with an equal number of distractor and target words, was not intended to draw focus to the /s ~ z/ voicing contrast, while Task 3 was designed to highlight it explicitly. If the data for each task is not a great departure from the overall trends, these results will be presented with minimal comment.

5.3.1 Glottal Pulsing

5.3.1.1 Aggregate Results

As expected, a greater distinction was found between glottal pulsing results in S-words and Z-words for NC speakers than for RRV speakers, and the RRVSc speakers produced the least distinction. However, this is not due to the extent to which /z/ is devoiced in the test groups. Rather, the distinction owes more to the high amount of voicing in /s/ in RRV and particularly RRVSc speakers. These results are shown in the following tables as the average of the values for each speaker in the designated group, categorized by position of the fricative in the word. Here and throughout, unshaded cells represent the instances where the difference between the test and control groups at that particular level (as NC was always compared with RRV, and RRVNS with RRVSc) was found to be significant, as defined by $p < 0.05$. Table 9 shows the percentage of glottal pulsing to fricative duration for /s/, Table 10 the same for /z/, and Table 11 shows the difference between these values (/z/ - /s/). The same information is represented graphically in Figure 4, Figure 5, and Figure 6, respectively.

	INITIAL	MEDIAL	FINAL
NC	7.91	8.58	11.71
RRV	18.30	17.91	18.42
RRVNS	15.07	14.74	14.21
RRVSc	31.60	24.40	30.24

Table 9: Glottal Pulsing for /s/ (%). Unshaded cells represent significant differences between test and control speakers.

	INITIAL	MEDIAL	FINAL
NC	82.48	49.97	24.09
RRV	72.83	46.39	35.01
RRVNS	81.58	58.81	31.81
RRVSc	73.83	43.28	44.88

Table 10: Glottal Pulsing for /z/ (%). Unshaded cells represent significant differences between test and control speakers.

	INITIAL	MEDIAL	FINAL
NC	74.57	40.94	12.63
RRV	54.66	28.30	16.59
RRVNS	66.51	44.07	17.60
RRVSc	42.73	18.61	14.65

Table 11: Difference of /z/ and /s/ Glottal Pulsing (%). Unshaded cells represent significant differences between test and control speakers.

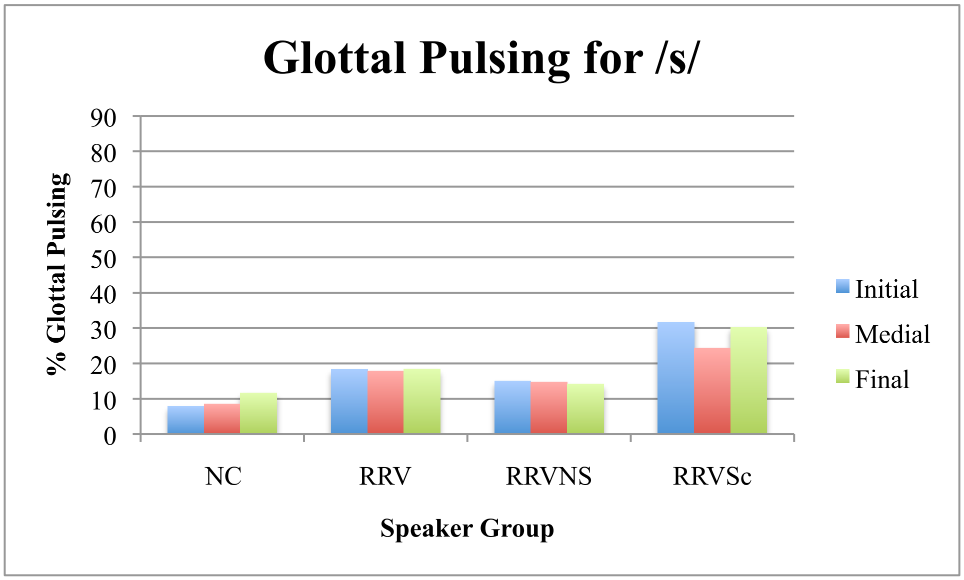

Figure 4: Glottal Pulsing for /s/ by Speaker Group (%)

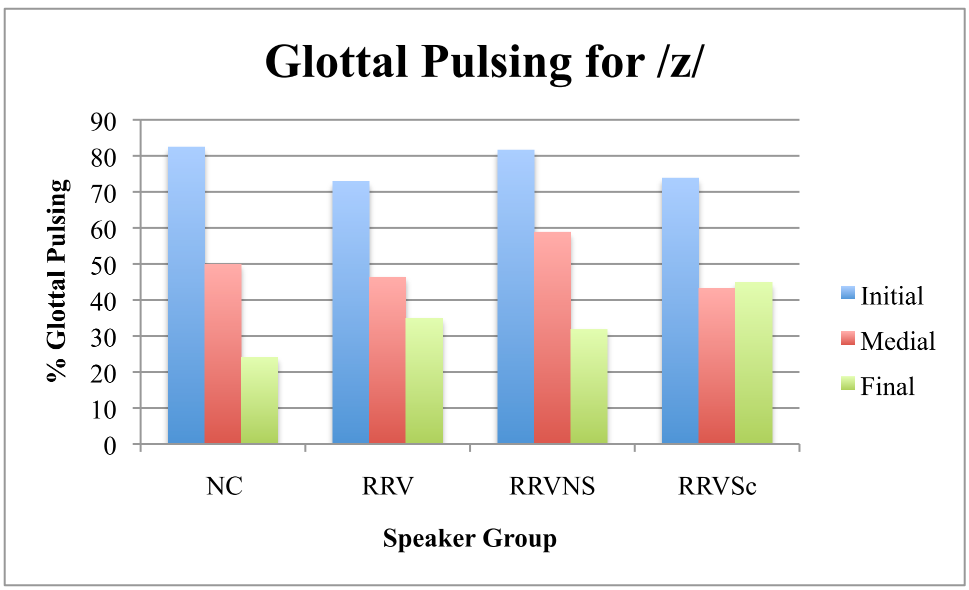

Figure 5: Glottal Pulsing for /z/ by Speaker Group (%)

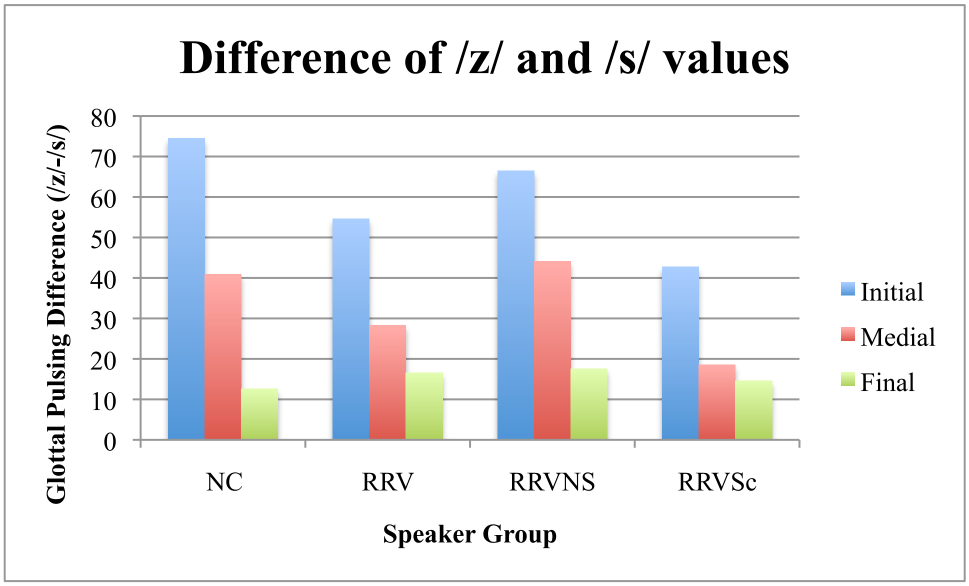

Figure 6: Difference of /z/ and /s/ values by Speaker Group

	Position	χ^2	p Value
S-words	Initial	4.77	0.029
	Medial	5.29	0.021
	Final	2.15	0.142
Z-words	Initial	3.50	0.062
	Medial	0.04	0.834
	Final	5.86	0.016
Differences	Initial	9.72	0.002
	Medial	1.70	0.192
	Final	0.77	0.380

Table 12: Significance for Glottal Pulsing in RRV vs. NC. $p < 0.05$ is held to be significant.

	Position	χ^2	p Value
S-words	Initial	1.38	0.239
	Medial	0.85	0.356
	Final	1.37	0.242
Z-words	Initial	2.84	0.092
	Medial	2.53	0.112
	Final	1.65	0.199
Differences	Initial	2.50	0.114
	Medial	5.13	0.024
	Final	0.10	0.755

Table 13: Significance for Glottal Pulsing in RRVSc vs. RRVNS. $p < 0.05$ is held to be significant.

The results that show significant difference between the test and control speakers are concentrated in the regional comparison groups, NC and RRV. The size of the speaker groups may play a role in this; RRV, with eighteen speakers, brings much more information to the comparison with NC (five speakers) than RRVSc or RRVNS can provide, with five and four speakers respectively.

Significant results in the glottal pulsing of /s/ occur in the regional comparison for initial and medial position, but not for final position. In these cases, RRV voiced /s/ more than NC, which would not have been predicted by the previous studies that found devoicing of /z/ to be the prime effect of substrate influence from Scandinavian languages. However, it does make sense if we conceive of the effect as a lack of voicing distinction in /s ~ z/, with both members of the pair showing a more moderate amount of glottal pulsing (higher than otherwise in /s/, lower in /z/). Even in this light, though, the /z/ glottal pulsing results in Table 10 are initially surprising. While most values here show lower glottal pulsing in the test groups, the only result that is significant is the final position comparison between NC and RRV, where RRV speakers produce *more* glottal pulsing. However, because this is final position, there is another contributing factor. Final obstruents have the tendency to become devoiced in American English (Smith 1997), and if we compare the medial and final results for NC and RRV speakers, this process acts more strongly upon NC speakers, reducing the glottal pulsing by half in this group, but only by 25% in RRV participants. In fact, if we widen our scope of comparison, RRVSc speakers voice final /s/ more than NC, and nearly as much as RRVNS, speakers do /z/. This drives home the point that Steriade (1997:22) makes, that it is necessary to know the range of values for voiced and voiceless obstruents for each population if one is to categorize a sound: "It is the comparison between the two that yields information about the categorization of any given token."

Correspondingly, the voicing distinction values in final position are quite low for all speakers in Table 11, and there is no significant difference between any groups. The regional groups show significant difference in initial position, which is where all groups produced the most voicing in every case. I had expected this to be true of medial position, which was in every case intersonorant and in most cases intervocalic, and this context is the most likely to encourage glottal pulsing throughout the constriction (Stevens et al. 1992). The voicing distinction in medial position is the only instance where we see significance in the difference between the RRV subgroups. RRVSc speakers voice /s/ and /z/ to a much more similar extent than RRVNS speakers. In fact, this value is almost as low as it is in final position for most groups.

The comparison between the RRV subgroups is explored in more detail in Figure 7, which shows the differences between /s/ and /z/ voicing values for the RRVSc (blue symbols) and RRVNS speakers (red symbols). The numbers in the key refer to the individual speaker identification numbers. The data are separated by position, with the first group of symbols representing the fricative in initial position, then medial, and then final. We can see that both speaker groups have some high results (meaning that the /z/ glottal pulsing ratio is much higher than for /s/) in initial position, the RRVSc group also has a large number of negative responses (denoting the opposite pattern, unpredicted by canonical descriptions of the voicing contrast). This is true in every position, while the RRVNS speakers only have one data point below 0 in initial and medial positions (and 2 points at 0 in medial position, indicating no difference between /s/ and /z/), and show a large number of negative results only in final position, where we've established a tendency for devoicing of /z/ in American English. However, this graph illustrates that most of the RRVSc data points that differ from those of the RRVNS speakers are from the same two subjects, Speakers 11 and 12. If these speakers were removed, the results would be much more similar for all speakers. However, Speakers 11 and 12 represent 40% of the RRVSc speakers, so their contribution is substantial and, as we saw in Table 11, significant in medial position.

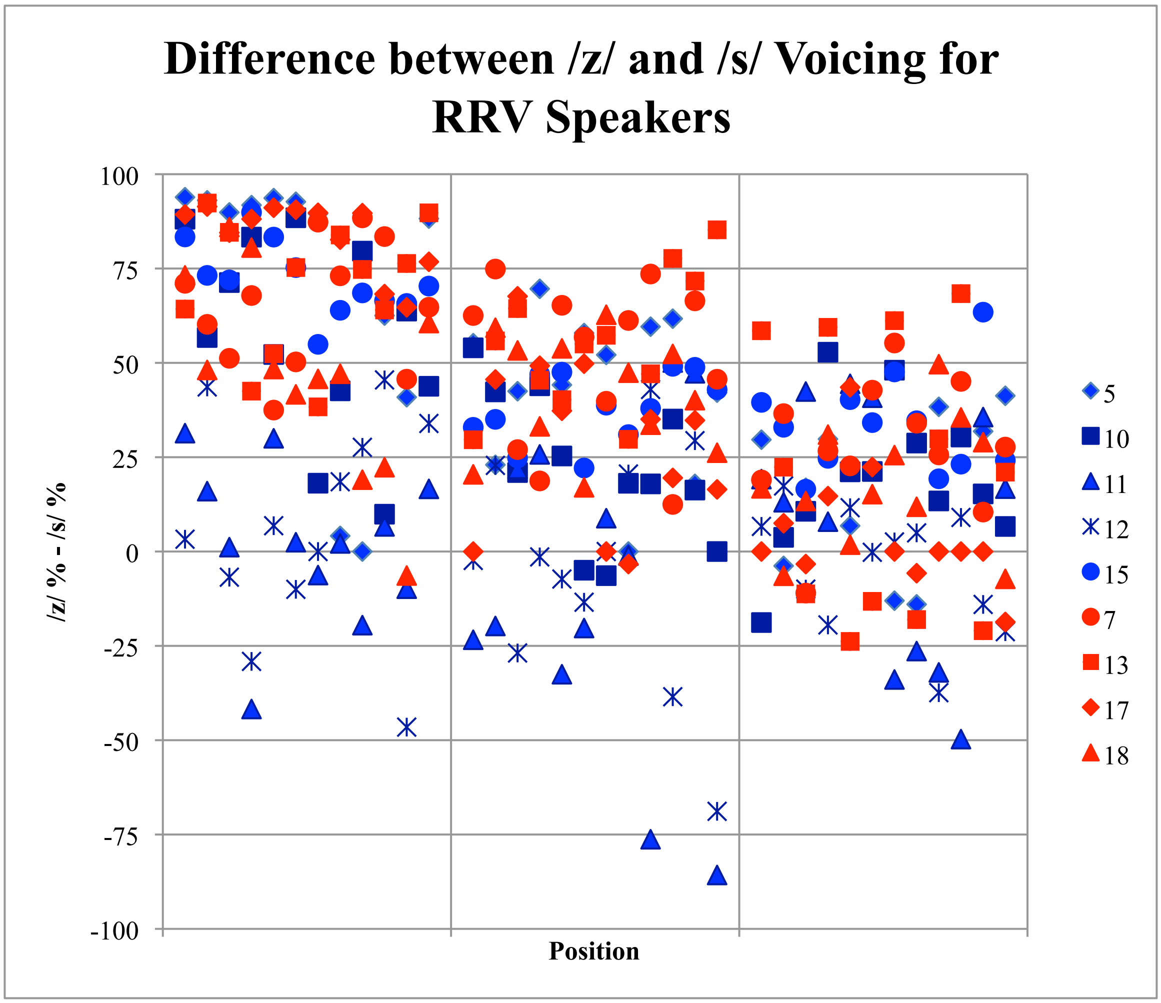

Figure 7: Voicing Difference by Speaker for RRVSc and RRVNS

Taken together this data suggests that, while RRV and RRVSc speakers in particular do not devoice /z/ to a significantly greater extent than NC or RRVNS speakers, the voicing profile is nonetheless quite different. In addition to the reduced prominence of the voicing contrast in the test groups, position for these speakers has a much less robust effect than is expected from the literature and found in the control population. It is possible that this lack of variance is due to the lack of a voicing contrast in Scandinavian sibilants. Unlike in German and other languages with final obstruent devoicing where the contrast between /s/ and /z/ exists but is neutralized in certain position, the /z/ phoneme does not exist in Scandinavian languages. It is conceivable that the distinction between these sounds in English would not be as salient or important to native Scandinavian speakers, and that the same would be true of their children, growing up as native English speakers but learning it in a community of speakers of Scandinavian languages.

5.3.1.2 Task 2

The values and the significance of the results in Task 2 do not deviate greatly from the aggregate results. The chief differences are that initial /s/ pulsing is not significantly different in the regional groups, and that the medial voicing distinction is significant different between NC and RRV rather than RRVNS and RRVSc, meaning that no RRV subgroup differences are significant in Task 2. Comparing the values, the largest variation from the aggregate results is that RRVNS speakers voice final /z/ much more in Task 2 than they do overall. It is curious that their pronunciation (and only their pronunciation) should be closer to the canonical glottal pulsing of /z/ in the task that brings less focus to the sounds of interest to the study.

	INITIAL	MEDIAL	FINAL
NC	9.43	7.02	13.67
RRV	19.49	18.27	19.39
RRVNS	15.78	17.99	14.66
RRVSc	29.67	21.50	29.42

Table 14: Glottal Pulsing for /s/, Task 2 (%). Unshaded cells represent significant differences between test and control speakers.

	INITIAL	MEDIAL	FINAL
NC	83.27	57.72	26.27
RRV	73.92	48.08	39.66
RRVNS	83.03	54.30	46.97
RRVSc	72.47	49.10	42.81

Table 15: Glottal Pulsing for /z/, Task 2 (%). Unshaded cells represent significant differences between test and control speakers.

	INITIAL	MEDIAL	FINAL
NC	73.84	50.70	12.17
RRV	54.86	29.82	20.27
RRVNS	67.26	36.32	32.31
RRVSc	44.29	27.60	13.40

Table 16: Difference of /z/ and /s/ Glottal Pulsing, Task 2 (%). Unshaded cells represent significant differences between test and control speakers.

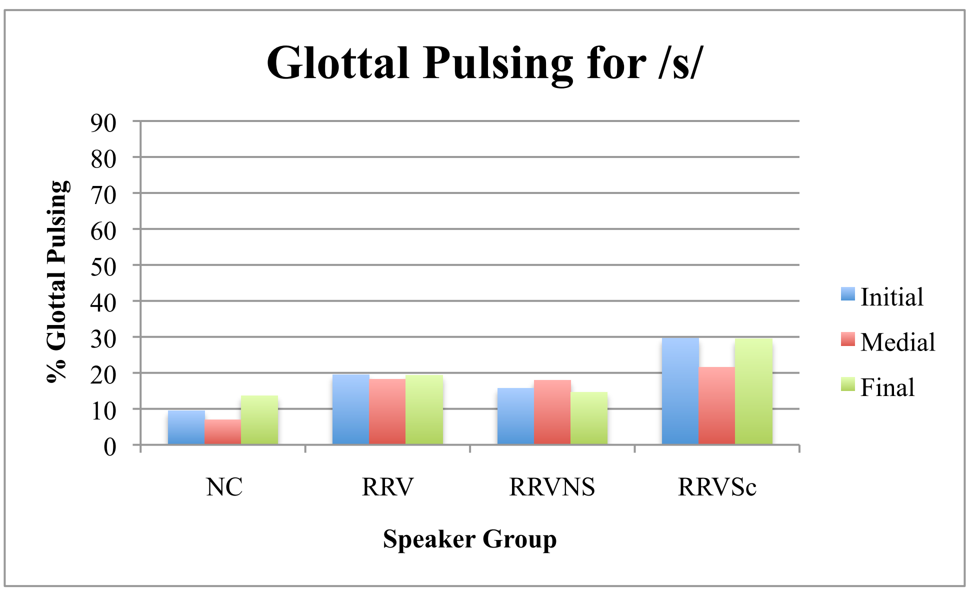

Figure 8: Glottal Pulsing for /s/ by Speaker Group, Task 2 (%)

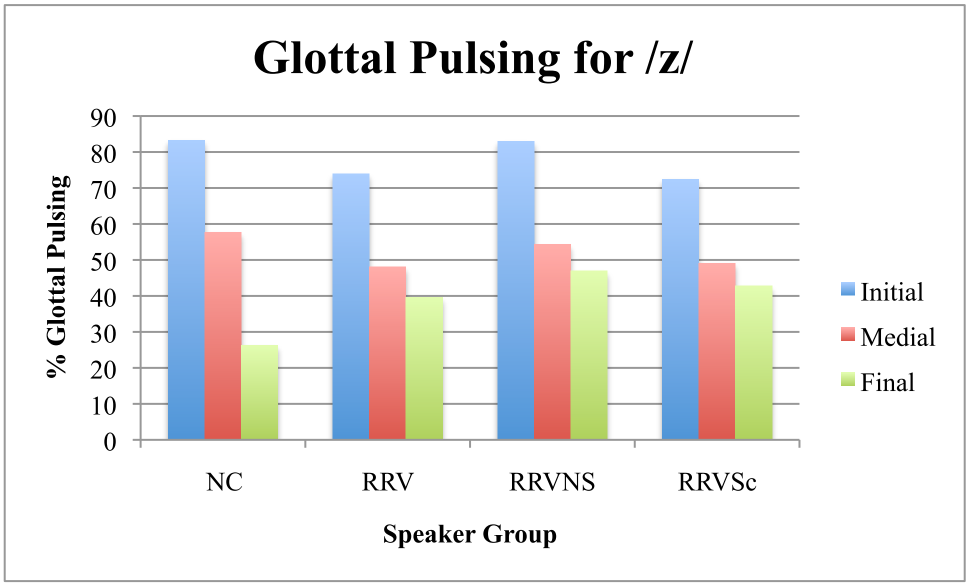

Figure 9: Glottal Pulsing for /z/ by Speaker Group, Task 2 (%)

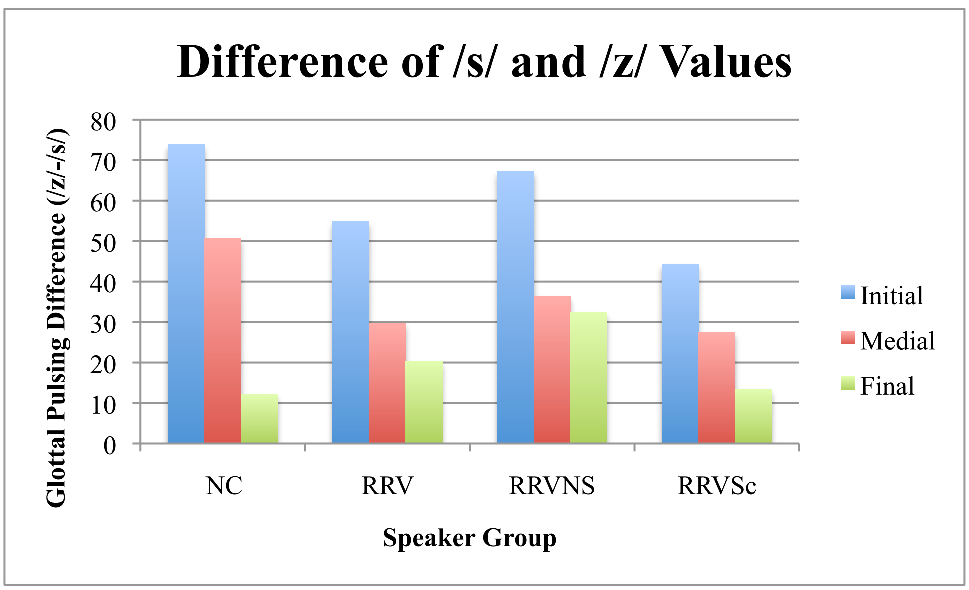

Figure 10: Difference of /z/ and /s/ Glottal Pulsing by Speaker Group, Task 2 (%)

	Position	χ^2	p Value
S-words	Initial	3.16	0.075
	Medial	7.66	0.006
	Final	1.00	0.318
Z-words	Initial	2.99	0.084
	Medial	0.84	0.358
	Final	5.68	0.017
Differences	Initial	6.58	0.010
	Medial	6.35	0.012

	Final	2.12	0.145

Table 17: Significance for Glottal Pulsing in RRV vs. NC, Task 2. $p < 0.05$ is held to be significant.

	Position	χ^2	p Value
S-words	Initial	0.73	0.392
	Medial	0.14	0.707
	Final	1.37	0.242
Z-words	Initial	2.59	0.108
	Medial	0.14	0.708
	Final	0.02	0.897
Differences	Initial	1.95	0.163
	Medial	0.49	0.486
	Final	1.54	0.214

Table 18: Significance for Glottal Pulsing in RRVSc vs. RRVNS, Task 2. $p < 0.05$ is held to be significant.

5.3.1.3 Task 3, Position 1

Task 3, position 1, does not vary greatly from the results already discussed except in one particular. While no significance is found in the glottal pulsing of final /z/, the RRV subgroups do show a significant difference medially. The RRVSc value is very close to the aggregate result, but in RRVNS speakers the pulsing is somewhat higher. This may or may not be due to the heightened focus on the voicing distinction in this task; speakers from RRV (which of course includes RRVNS) and NC speakers exhibit the same pattern in this position to a lesser extent.

	INITIAL	MEDIAL	FINAL
NC	8.51	8.87	10.59
RRV	19.99	16.87	18.53
RRVNS	19.99	16.75	18.16
RRVSc	35.90	21.24	28.56

Table 19: Glottal Pulsing for /s/, Task 3, Position 1 (%). Unshaded cells represent significant differences between test and control speakers.

	INITIAL	MEDIAL	FINAL
NC	83.13	54.64	26.04
RRV	72.24	50.01	36.90
RRVNS	81.77	65.52	27.20
RRVSc	75.59	43.60	45.95

Table 20: Glottal Pulsing for /z/, Task 3, Position 1 (%). Unshaded cells represent significant differences between test and control speakers.

	INITIAL	MEDIAL	FINAL
NC	74.62	45.77	16.33
RRV	52.25	33.01	18.37
RRVNS	61.79	48.77	9.05
RRVSc	39.70	21.52	17.39

Table 21: Difference of /z/ and /s/ Glottal Pulsing, Task 3, Position 1 (%). Unshaded cells represent significant differences between test and control speakers.

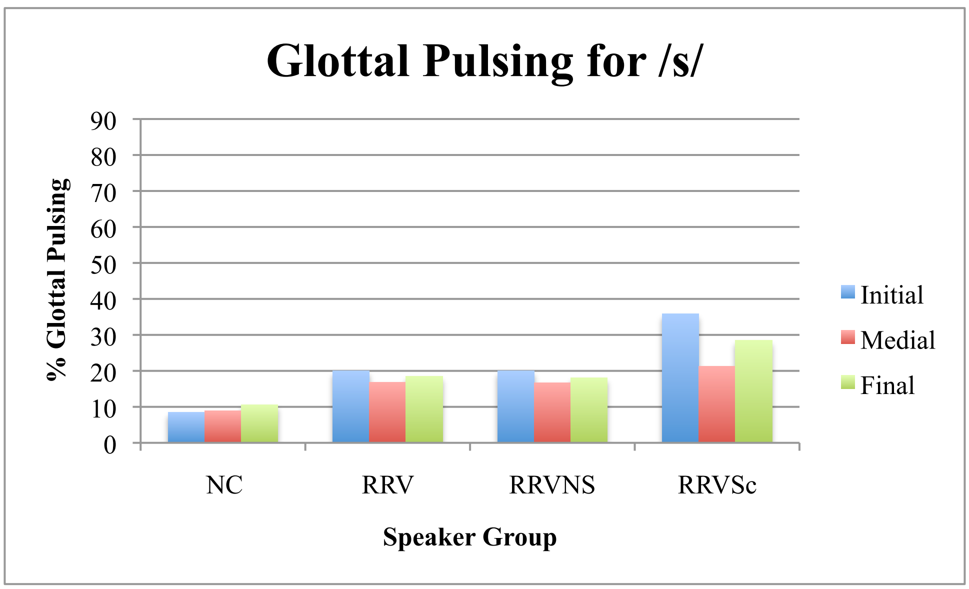

Figure 11: Glottal Pulsing for /s/ by Speaker Group, Task 3, Position 1 (%)

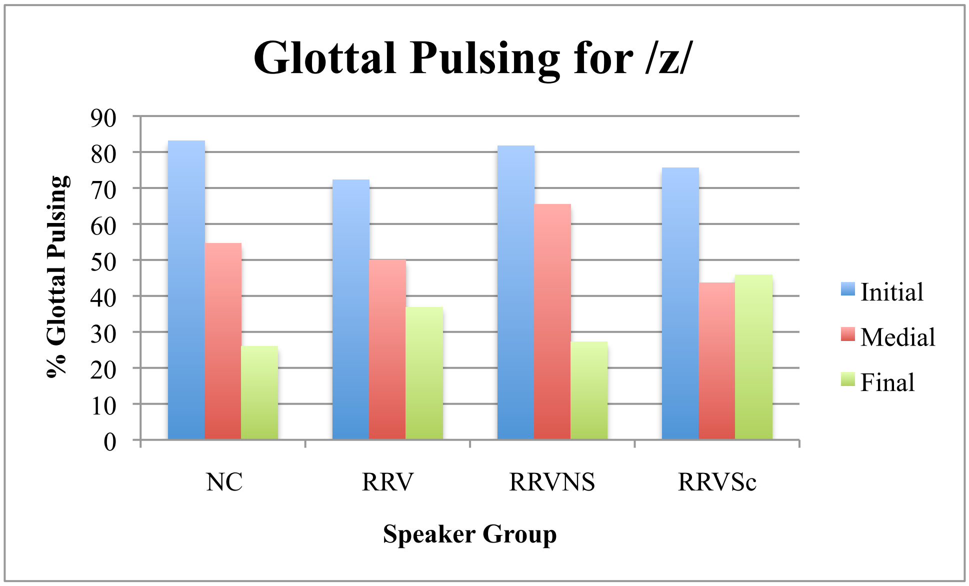

Figure 12: Glottal Pulsing for /z/ by Speaker Group, Task 3, Position 1 (%)

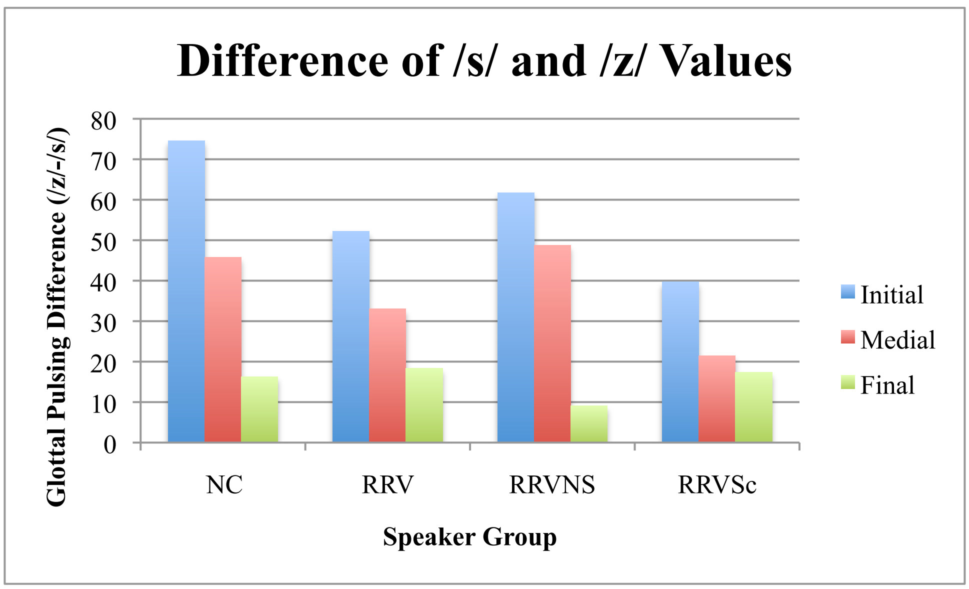

Figure 13: Difference of /z/ and /s/ Glottal Pulsing by Speaker Group, Task 3, Position 1 (%)

	Position	χ^2	p Value
S-words	Initial	7.40	0.007
	Medial	4.15	0.042
	Final	2.91	0.088
Z-words	Initial	3.24	0.072
	Medial	0.07	0.797
	Final	3.08	0.079

Differences	Initial	11.47	< 0.001
	Medial	1.01	0.315
	Final	0.03	0.858

Table 22: Significance for Glottal Pulsing in RRV vs. NC, Task 3, Position 1. $p < 0.05$ is held to be significant.

	Position	χ^2	p Value
S-words	Initial	1.56	0.211
	Medial	0.20	0.654
	Final	0.58	0.448
Z-words	Initial	0.95	0.329
	Medial	5.16	0.023
	Final	2.06	0.151
Differences	Initial	2.07	0.150
	Medial	7.59	0.006
	Final	0.88	0.348

Table 23: Significance for Glottal Pulsing in RRVSc vs. RRVNS, Task 3, Position 1. $p < 0.05$ is held to be significant.

5.3.1.4 Task 3, Position 2

Results for Task 3, position 2, are a bit more of a departure. No groups show a significant difference for /s/, unlike in the other tasks. In Table 25, the pattern of the regional test speakers producing significantly higher glottal pulsing in final /z/ continues, and is extended to the RRV subgroups. As word-final /z/ is also utterance-final in this phrase position, a greater tendency toward final devoicing is seen in these results for all groups except RRVSc, for whom the glottal pulsing for final, and also initial, /z/ remains very nearly the same for all tasks. The only position that shows much variance for this group is medial /z/ in Task 3, position 2, where the glottal pulsing drops well below the word-final value.

The results for difference in glottal pulsing in Table 26 are similar to the first position in Task 3 in significance and most values within the significant comparisons, but here RRVSc speakers produce much less distinction in medial position, almost none at all. On the whole, the contrast tends to be less in the second phrase position, possibly due to the higher emphasis usually placed on the word in the first position.

	INITIAL	MEDIAL	FINAL
NC	5.79	9.91	10.81
RRV	15.45	18.59	17.34
RRVNS	9.44	9.48	9.81
RRVSc	29.14	30.29	32.73

Table 24: Glottal Pulsing for /s/, Task 3, Position 2 (%). Unshaded cells represent significant differences between test and control speakers.

	INITIAL	MEDIAL	FINAL
NC	81.04	37.56	20.39
RRV	72.33	41.06	28.47
RRVNS	79.93	56.60	21.24
RRVSc	73.41	37.16	45.88

Table 25: Glottal Pulsing for /z/, Task 3, Position 2 (%). Unshaded cells represent significant differences between test and control speakers.

	INITIAL	MEDIAL	FINAL
NC	75.25	25.57	9.58
RRV	56.88	22.06	11.14
RRVNS	70.49	47.12	11.43
RRVSc	44.28	6.86	13.15

Table 26: Difference of /z/ and /s/ Glottal Pulsing, Task 3, Position 2 (%). Unshaded cells represent significant differences between test and control speakers.

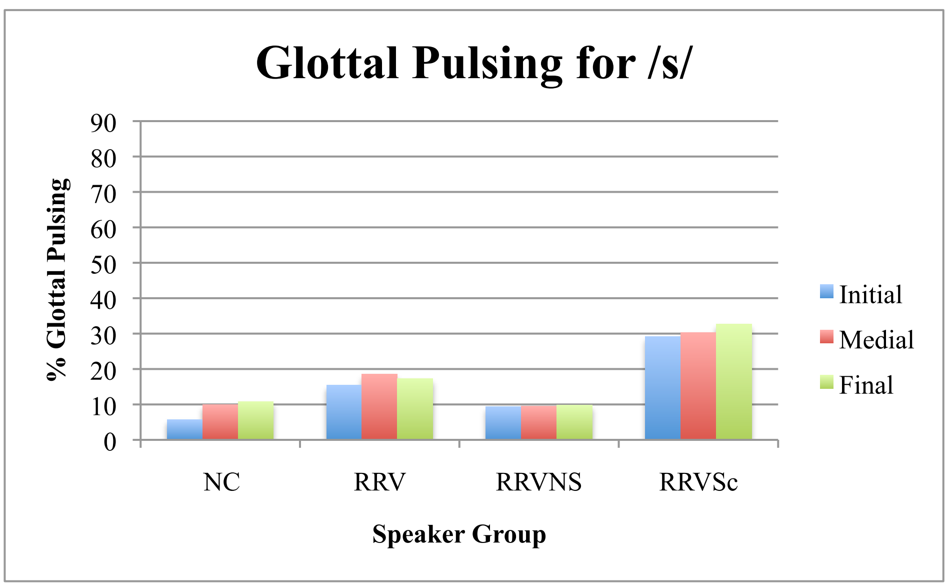

Figure 14: Glottal Pulsing for /s/ by Speaker Group, Task 3, Position 2 (%)

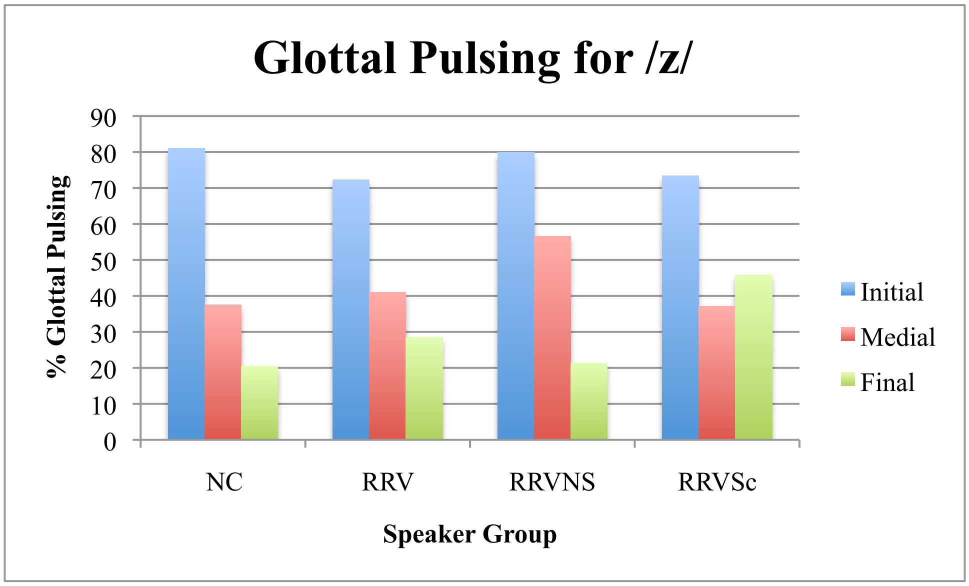

Figure 15: Glottal Pulsing for /z/ by Speaker Group, Task 3, Position 2 (%)

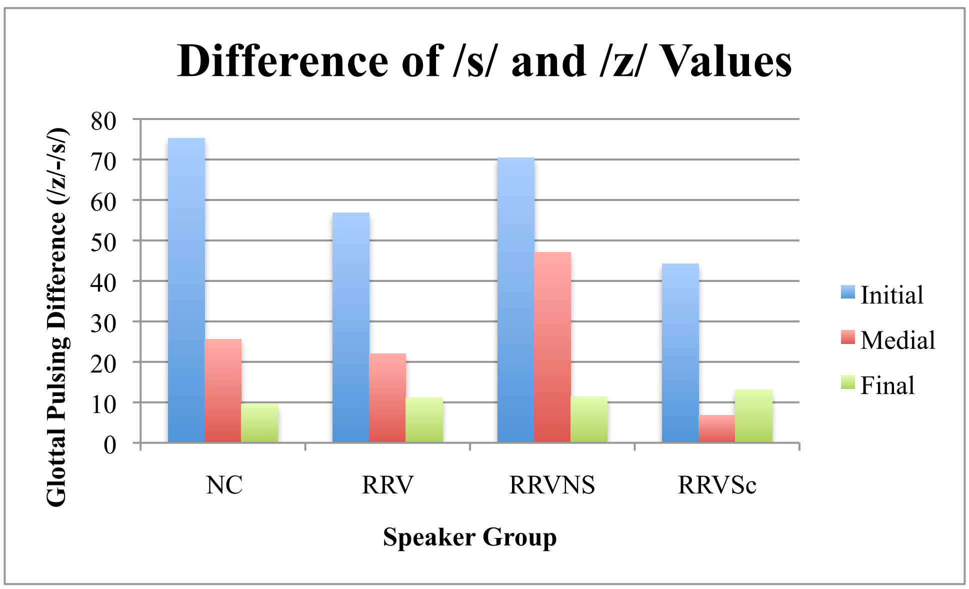

Figure 16: Difference of /z/ and /s/ Glottal Pulsing by Speaker Group, Task 3, Position 2 (%)

	Position	χ^2	p Value
S-words	Initial	2.85	0.091
	Medial	2.21	0.137
	Final	1.30	0.255
Z-words	Initial	1.78	0.182
	Medial	0.30	0.586
	Final	4.01	0.045
Differences	Initial	5.94	0.015

	Medial	0.05	0.831
	Final	0.10	0.752

Table 27: Significance for Glottal Pulsing in RRV vs. NC, Task 3, Position 2. $p < 0.05$ is held to be significant.

	Position	χ^2	p Value
S-words	Initial	1.53	0.216
	Medial	2.50	0.114
	Final	2.13	0.144
Z-words	Initial	1.76	0.184
	Medial	3.60	0.058
	Final	4.21	0.040
Differences	Initial	2.78	0.095
	Medial	6.67	0.010
	Final	0.04	0.838

Table 28: Significance for Glottal Pulsing in RRVSc vs. RRVNS, Task 3, Position 2. $p < 0.05$ is held to be significant.

5.3.2 Duration

While in the voicing values the magnitude of distinction was greatest for initial position, followed by medial and then final position, the exact opposite hierarchy holds for both vowel and fricative duration in almost every case. This may reflect a trading relation between the voicing and duration values; as voicing becomes less distinct, the duration contrast is emphasized to ensure comprehension. Few regional differences were found to be significant in the duration values related to the voicing contrast.

5.3.2.1 Vowel Duration

5.3.2.1.1 Aggregate Data

The overall results for vowel duration are strikingly similar in each region. The vowel duration averages by group and by position are shown below, with the duration for S-words in Table 29, for Z-words in Table 30, and the ratio of Z-word over S-word values in Table 31. Figure 17, Figure 18, and Figure 19 contain graphs of the same information.

The only significant difference is between NC and RRV speakers in the vowel preceding final /z/, where NC speakers produce longer vowels. This is not reflected in the ratio between vowel duration in S-words and Z-words.

	INITIAL	MEDIAL	FINAL
NC	0.230	0.115	0.193
RRV	0.216	0.118	0.186
RRVNS	0.234	0.123	0.202
RRVSc	0.212	0.112	0.169

Table 29: Vowel Duration in S-words (in seconds). Unshaded cells represent significant differences between test and control speakers.

	INITIAL	MEDIAL	FINAL
NC	0.244	0.137	0.323
RRV	0.236	0.140	0.280
RRVNS	0.250	0.143	0.292
RRVSc	0.231	0.134	0.269

Table 30: Vowel Duration in Z-words (in seconds). Unshaded cells represent significant differences between test and control speakers.

	INITIAL	MEDIAL	FINAL
NC	1.076	1.276	1.773
RRV	1.125	1.290	1.633
RRVNS	1.090	1.205	1.507
RRVSc	1.143	1.289	1.773

Table 31: Ratio of Z-word/S-word Values. Unshaded cells represent significant differences between test and control speakers.

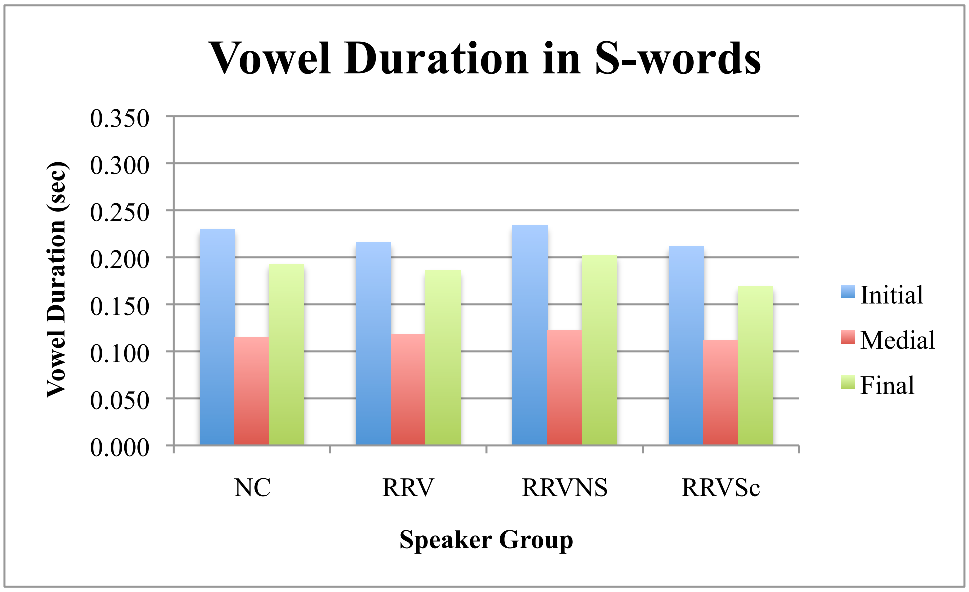

Figure 17: Vowel Duration in S-words

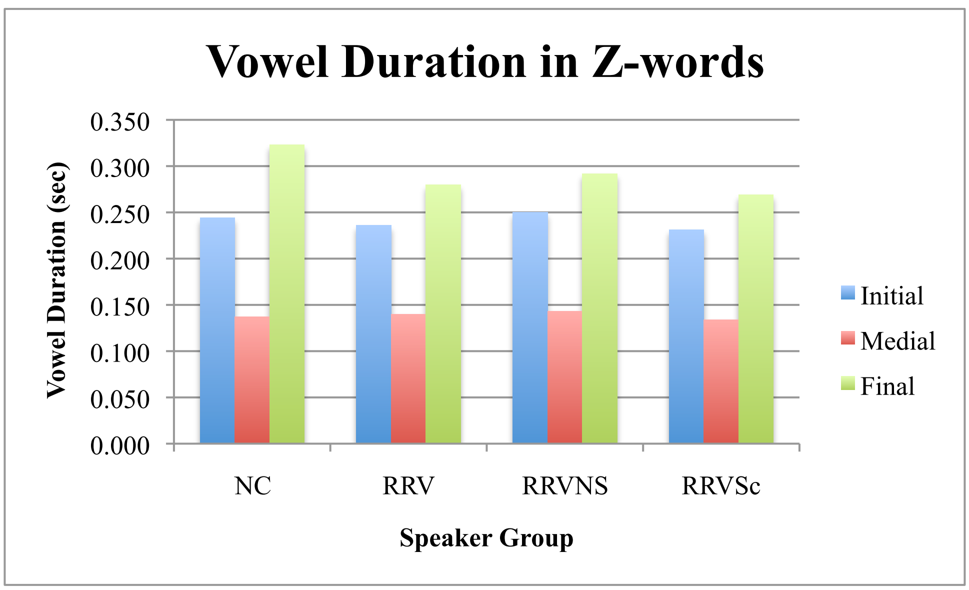

Figure 18: Vowel Duration in Z-words

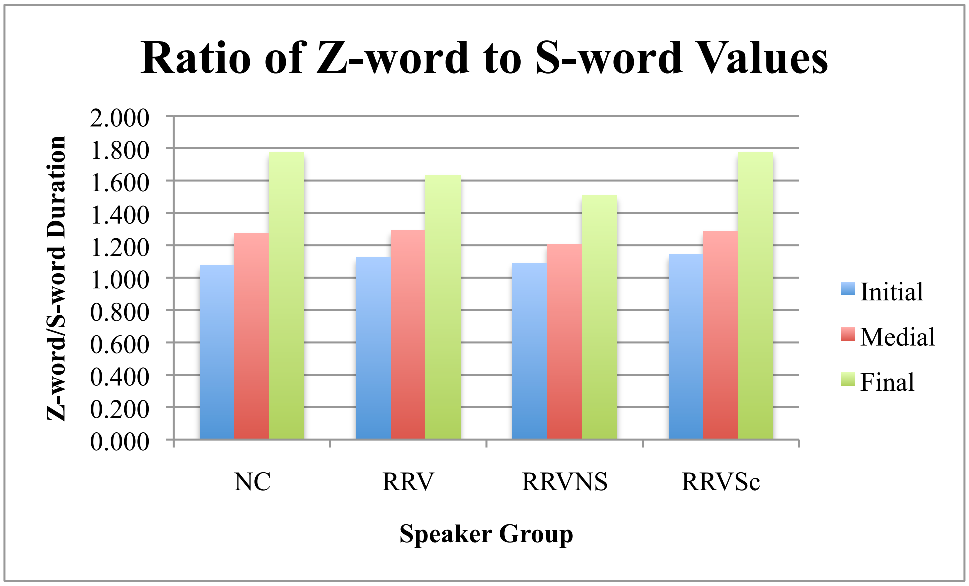

Figure 19: Ratio of Z-word to S-word Values

	Position	χ^2	p Value
S-words	Initial	0.37	0.541
	Medial	0.15	0.694
	Final	0.18	0.673
Z-words	Initial	0.11	0.743
	Medial	0.09	0.763
	Final	8.45	0.004
Ratios	Initial	2.96	0.085
	Medial	0.01	0.932
	Final	3.10	0.078

Table 32: Significance for Vowel Duration in RRV vs. NC. $p < 0.05$ is held to be significant.

	Position	χ^2	p Value
S-words	Initial	1.10	0.295
	Medial	1.30	0.254
	Final	3.72	0.054
Z-words	Initial	0.99	0.321
	Medial	0.71	0.398
	Final	1.07	0.302
Ratios	Initial	0.52	0.472
	Medial	1.74	0.187
	Final	1.57	0.210

Table 33: Significance for Vowel Duration in RRVSc vs. RRVNS. $p < 0.05$ is held to be significant.

On average, all speakers produce the shortest vowels preceding a medial fricative, and all speakers manifest the expected voicing contrast, with longer vowels when they are adjacent to /z/ than to /s/. This distinction is very small following an initial fricative, however; this is unsurprising as most accounts of a vowel duration contrast refer to a following consonant.

5.3.2.1.2 Task 2

More significance was found in Task 2 results than overall or in the other tasks, although this was the task with the least awareness drawn to the voicing contrast. In addition to the vowel being longer before final /z/ in NC than in RRV results, which we saw in the aggregate data, the ratio in this position was also significantly different, with greater distinction in NC. In the subgroups, the vowel before medial /s/ was longer for RRVNS speakers than for the RRVSc group.

	INITIAL	MEDIAL	FINAL
NC	0.202	0.107	0.169
RRV	0.189	0.122	0.167
RRVNS	0.203	0.129	0.183
RRVSc	0.185	0.114	0.153

Table 34: Vowel Duration in S-words, Task 2 (in seconds). Unshaded cells represent significant differences between test and control speakers.

	INITIAL	MEDIAL	FINAL
NC	0.220	0.132	0.300
RRV	0.207	0.143	0.245
RRVNS	0.217	0.144	0.248
RRVSc	0.203	0.133	0.228

Table 35: Vowel Duration in Z-words, Task 2 (in seconds). Unshaded cells represent significant differences between test and control speakers.

	INITIAL	MEDIAL	FINAL
NC	1.098	1.301	1.908
RRV	1.146	1.233	1.594
RRVNS	1.126	1.149	1.410
RRVSc	1.205	1.228	1.614

Table 36: Ratio of Z-word/S-word Vowel Duration, Task 2. Unshaded cells represent significant differences between test and control speakers.

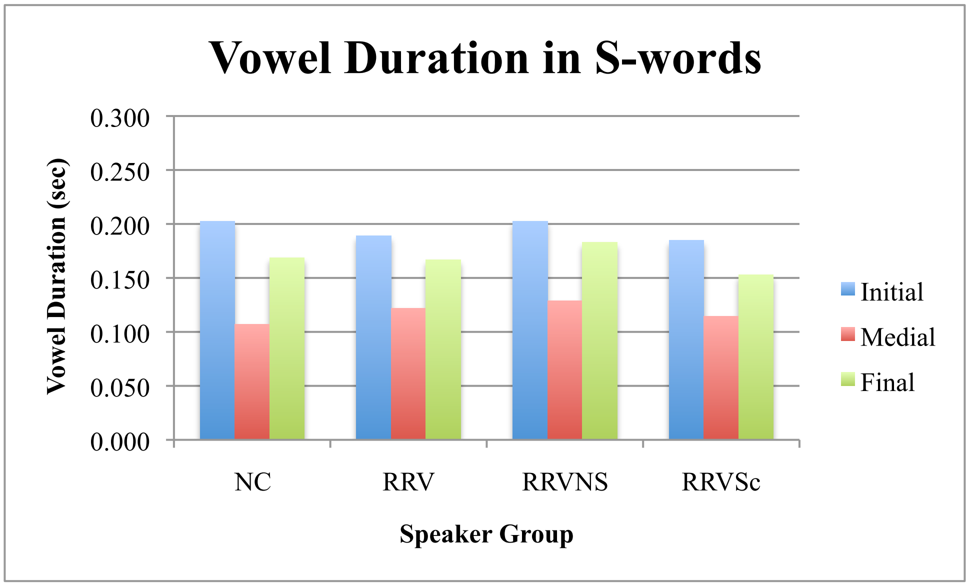

Figure 20: Vowel Duration in S-words, Task 2

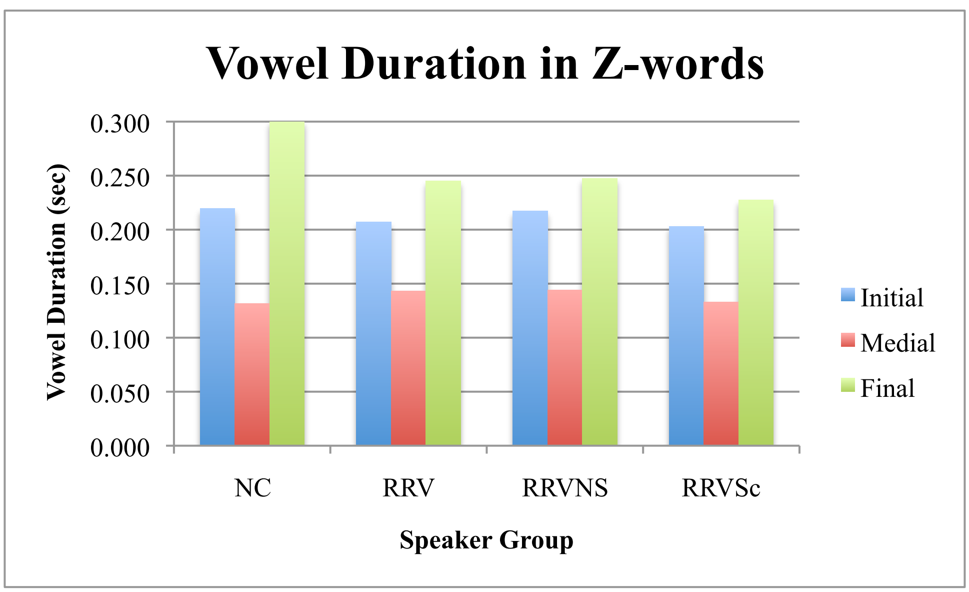

Figure 21: Vowel Duration in Z-words, Task 2

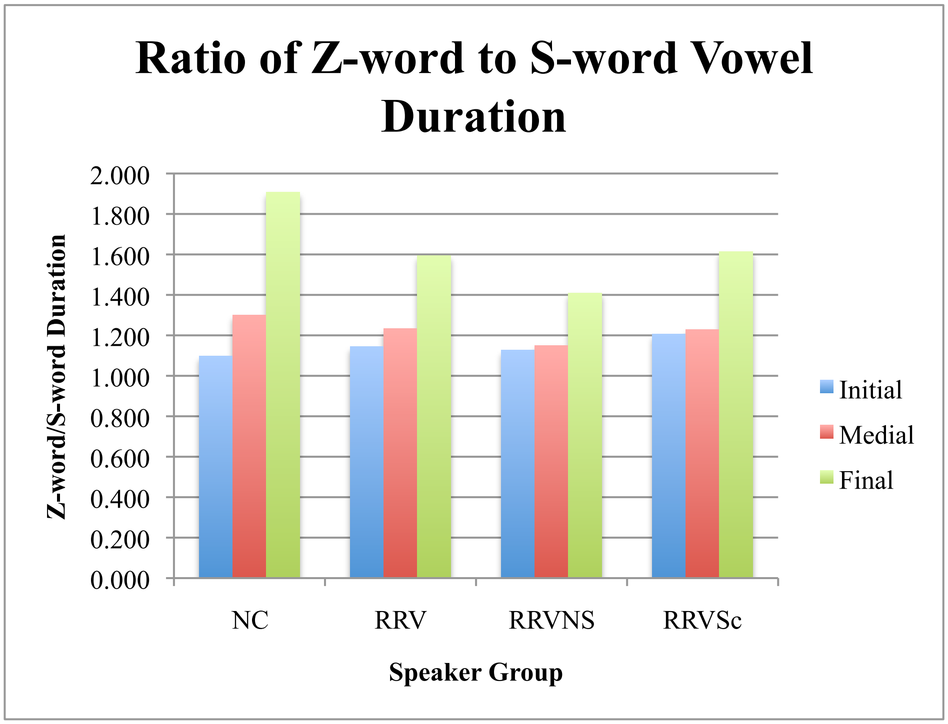

Figure 22: Ratios of S-word to Z-word Values, Task 2

	Position	χ^2	p Value
S-words	Initial	0.48	0.487
	Medial	4.35	0.037
	Final	0.02	0.900
Z-words	Initial	0.34	0.557
	Medial	1.11	0.293
	Final	14.99	< 0.001
Ratios	Initial	0.04	0.838
	Medial	1.66	0.197
	Final	5.74	0.017

Table 37: Significance for Vowel Duration in RRV vs. NC, Task 2. $p < 0.05$ is held to be significant.

	Position	χ^2	p Value
S-words	Initial	0.64	0.423
	Medial	1.25	0.264
	Final	2.00	0.157
Z-words	Initial	0.34	0.558
	Medial	0.83	0.363
	Final	0.45	0.503
Ratios	Initial	0.79	0.373
	Medial	0.47	0.492
	Final	1.76	0.185

Table 38: Significance for Vowel Duration in RRVSc vs. RRVNS, Task 2. $p < 0.05$ is held to be significant.

5.3.2.1.3 Task 3, Position 1

Little significance between groups was found in the first position of Task 3. The only exception is that RRVNS vowels are longer preceding final /s/ than in RRVSc speakers.

	INITIAL	MEDIAL	FINAL
NC	0.256	0.121	0.209
RRV	0.238	0.120	0.199
RRVNS	0.257	0.121	0.215
RRVSc	0.235	0.115	0.179

Table 39: Vowel Duration in S-words, Task 3, Position 1 (in seconds). Unshaded cells represent significant differences between test and control speakers.

	INITIAL	MEDIAL	FINAL
NC	0.268	0.140	0.339
RRV	0.256	0.143	0.306
RRVNS	0.272	0.149	0.322
RRVSc	0.251	0.138	0.294

Table 40: Vowel Duration in Z-words, Task 3, Position 1 (in seconds). Unshaded cells represent significant differences between test and control speakers.

	INITIAL	MEDIAL	FINAL
NC	1.060	1.259	1.692
RRV	1.104	1.275	1.642
RRVNS	1.064	1.270	1.584
RRVSc	1.086	1.337	1.810

Table 41: Ratio of Z-word/S-word Vowel Duration, Task 3, Position 1. Unshaded cells represent significant differences between test and control speakers.

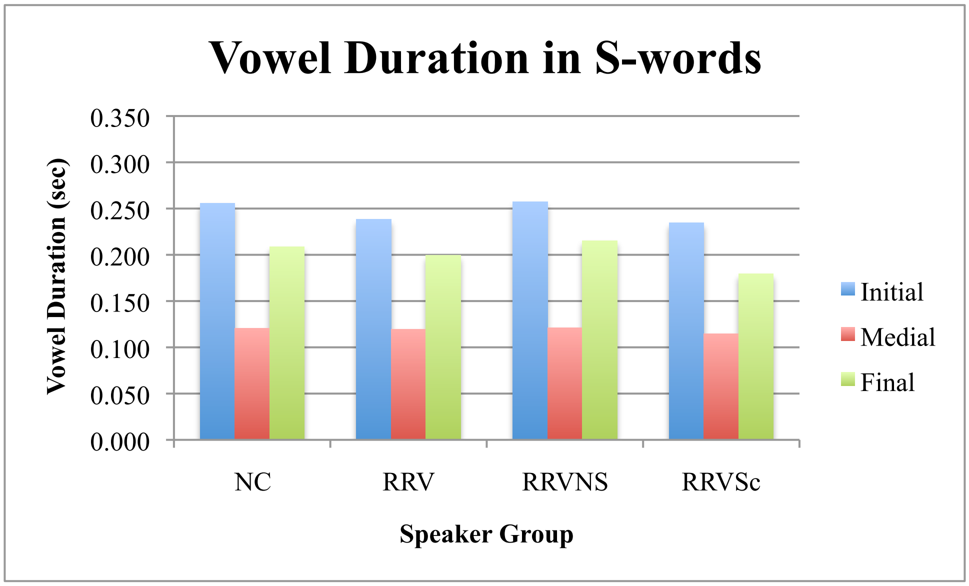

Figure 23: Vowel Duration in S-words, Task 3, Position 1

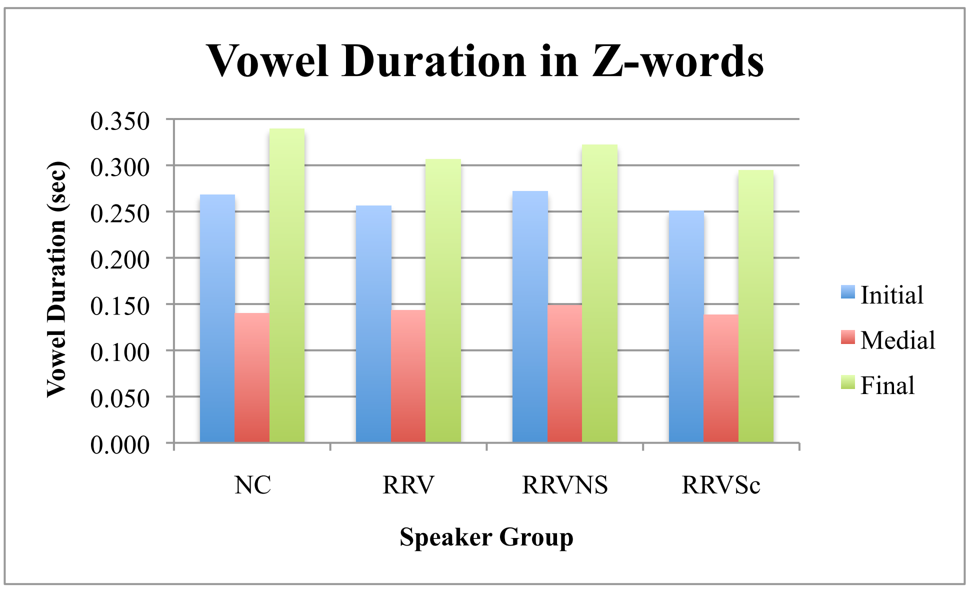

Figure 24: Vowel Duration in Z-words, Task 3, Position 1

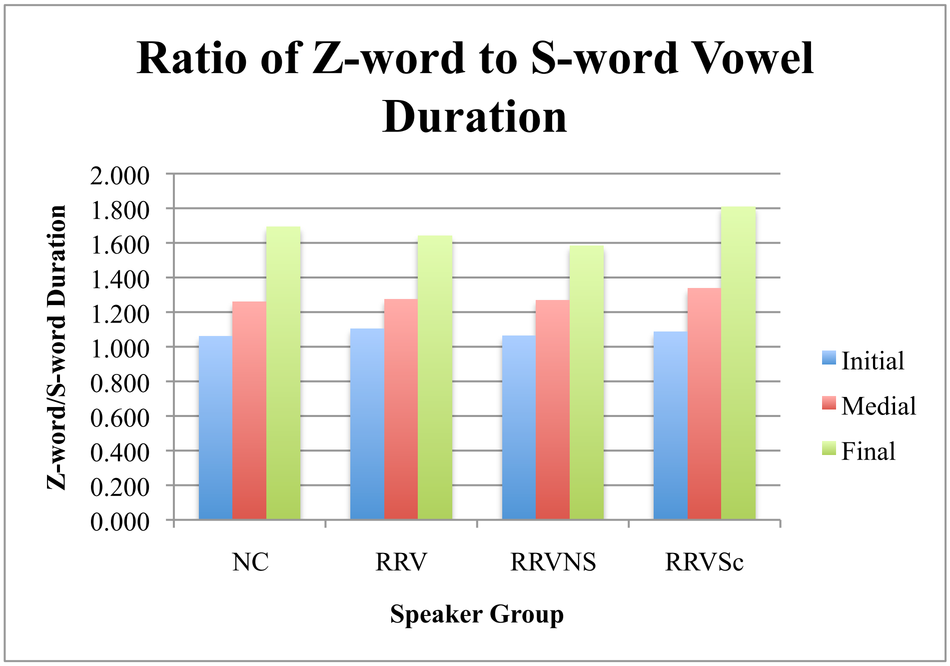

Figure 25: Ratio of Z-word to S-word Vowel Duration, Task 3, Position 1

	Position	χ^2	p Value
S-words	Initial	0.42	0.518
	Medial	0.04	0.842
	Final	0.36	0.550
Z-words	Initial	0.15	0.699
	Medial	0.14	0.712
	Final	1.86	0.173
Ratios	Initial	0.53	0.468
	Medial	0.86	0.354
	Final	0.60	0.437

Table 42: Significance for Vowel Duration in RRV vs. NC, Task 3, Position 1. $p < 0.05$ is held to be significant.

	Position	χ^2	p Value
S-words	Initial	0.89	0.347
	Medial	0.35	0.552
	Final	4.45	0.035
Z-words	Initial	0.75	0.386
	Medial	0.85	0.356
	Final	1.27	0.259
Ratios	Initial	0.08	0.780
	Medial	0.09	0.769
	Final	0.98	0.323

Table 43: Significance for Vowel Duration in RRVSc vs. RRVNS, Task 3, Position 1. $p < 0.05$ is held to be significant.

5.3.2.1.4 Task 3, Position 2

In this phrase position, no vowel duration values were found to be significantly different between test and control speakers. Yet, surprisingly, a distinction was found in the ratio of Z-word to S-word values for vowels before medial fricatives in the RRV subgroups, with a greater distinction in the Scandinavian-Americans.

	INITIAL	MEDIAL	FINAL
NC	0.233	0.118	0.200
RRV	0.221	0.113	0.193
RRVNS	0.241	0.120	0.208
RRVSc	0.216	0.106	0.176

Table 44: Vowel Duration in S-words, Task 3, Position 2 (in seconds). Unshaded cells represent significant differences between test and control speakers.

	INITIAL	MEDIAL	FINAL
NC	0.245	0.140	0.328
RRV	0.243	0.135	0.289
RRVNS	0.261	0.136	0.307
RRVSc	0.240	0.130	0.284

Table 45: Vowel Duration in S-words, Task 3, Position 2 (in seconds). Unshaded cells represent significant differences between test and control speakers.

	INITIAL	MEDIAL	FINAL
NC	1.071	1.265	1.726
RRV	1.127	1.363	1.663
RRVNS	1.080	1.195	1.527
RRVSc	1.140	1.305	1.895

Table 46: Ratio of Z-word/S-word Values, Task 3, Position 2. Unshaded cells represent significant differences between test and control speakers.

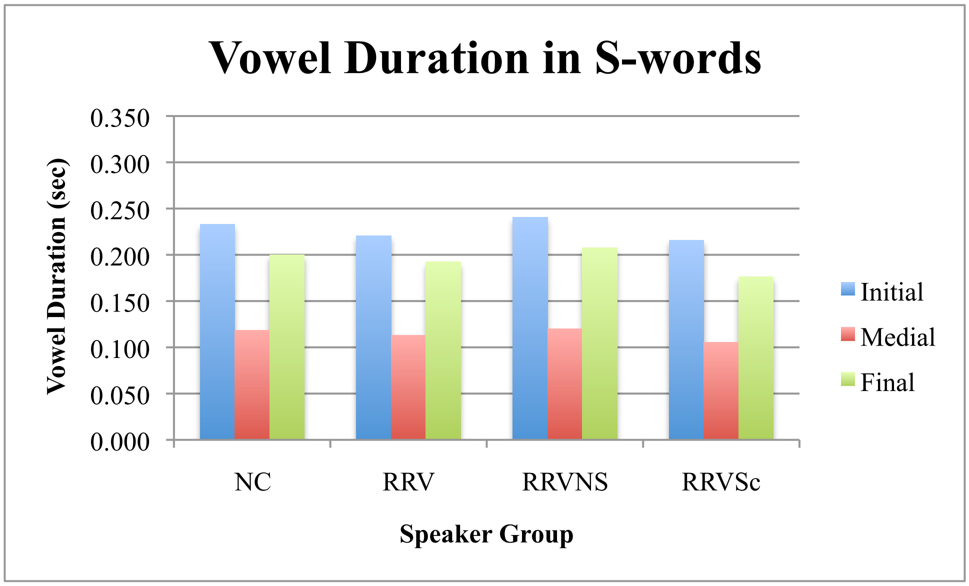

Figure 26: Vowel Duration in S-words, Task 3, Position 2

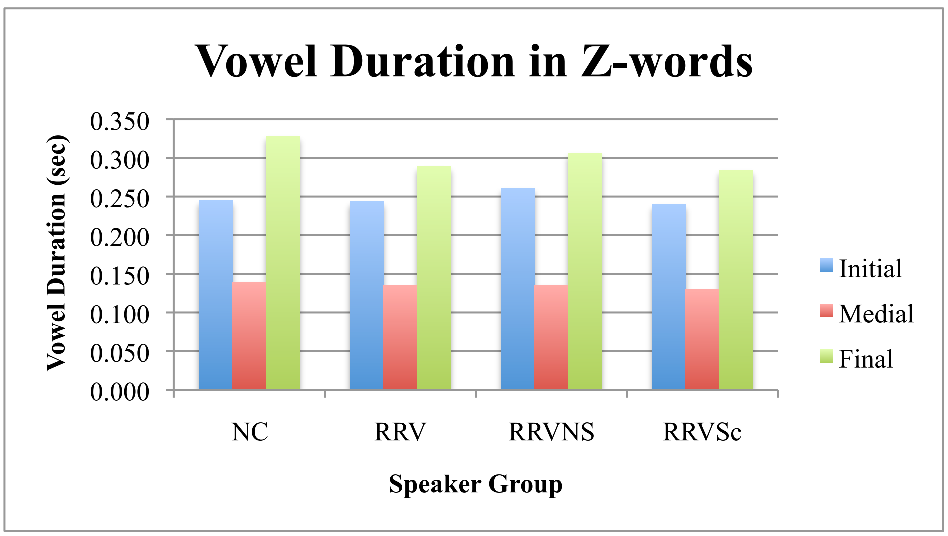

Figure 27: Vowel Duration in S-words, Task 3, Position 2

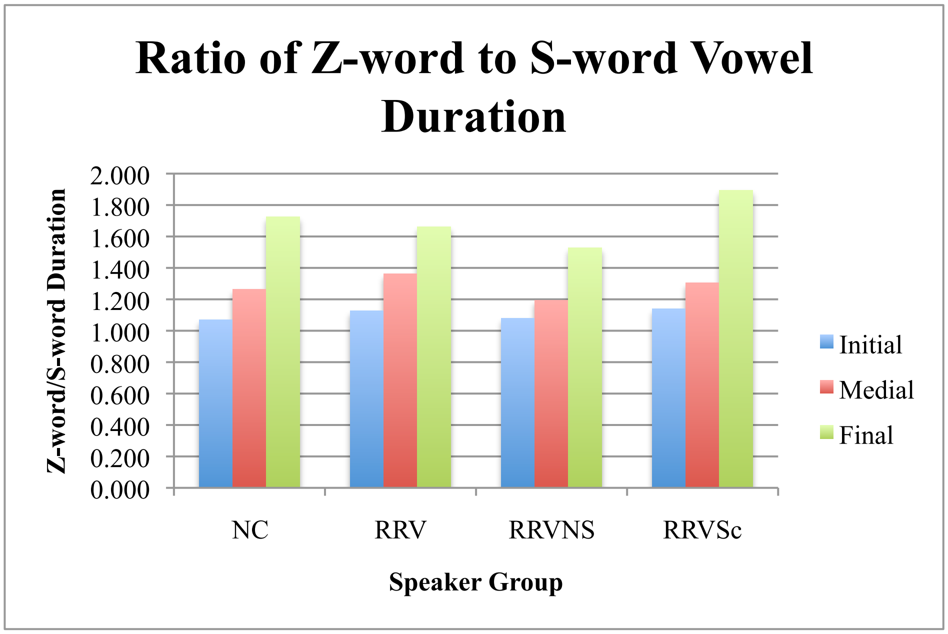

Figure 28: Ratio of Z-word to S-word Vowel Duration, Task 3, Position 2

	Position	χ^2	p Value
S-words	Initial	0.08	0.773
	Medial	0.66	0.417
	Final	0.13	0.721
Z-words	Initial	0.00	0.983
	Medial	0.36	0.550
	Final	1.86	0.172
Ratios	Initial	2.32	0.127
	Medial	0.06	0.801
	Final	2.31	0.128

Table 47: Significance for Vowel Duration in RRV vs. NC, Task 3, Position 2. $p < 0.05$ is held to be significant.

	Position	χ^2	p Value
S-words	Initial	1.01	0.314
	Medial	2.51	0.113
	Final	3.81	0.051
Z-words	Initial	0.90	0.344
	Medial	0.32	0.570
	Final	0.62	0.431
Ratios	Initial	0.31	0.577
	Medial	4.93	0.026
	Final	0.69	0.405

Table 48: Significance for Vowel Duration in RRVSc vs. RRVNS, Task 3, Position 2. $p < 0.05$ is held to be significant.

5.3.2.2 Fricative Duration

5.3.2.2.1 Aggregate Data

Fricative duration results are also quite similar for all speaker groups, with only one significant difference between groups. This is in the ratio for medial fricatives between NC and RRV speakers, as seen in the pair of unshaded cells in Table 51. In this position, which is where both /s/ and /z/ are shortest by far for all speakers, NC speakers showed more of a voicing distinction than RRV speakers.

As shown in Table 49 (/s/ duration) and Table 50 (/z/ duration), results for the fricative duration show the expected pattern; /s/ is longer than /z/ when matched for position and speaker, although as with the vowels this trend is weakest in initial position (see the ratio between the values in Table 51). This corroborates Pirello et al.'s (1997) findings that the fricative duration contrast is not present initially, and once again corresponds to a much greater distinction in glottal pulsing in this position.

	INITIAL	MEDIAL	FINAL
NC	0.242	0.157	0.255
RRV	0.234	0.151	0.254
RRVNS	0.229	0.150	0.240
RRVSc	0.253	0.152	0.269

Table 49: Duration of /s/ (in seconds). Unshaded cells represent significant differences between test and control speakers.

	INITIAL	MEDIAL	FINAL
NC	0.205	0.105	0.174
RRV	0.205	0.111	0.184
RRVNS	0.211	0.114	0.173
RRVSc	0.213	0.110	0.196

Table 50: Duration of /z/ (in seconds). Unshaded cells represent significant differences between test and control speakers.

	INITIAL	MEDIAL	FINAL
NC	1.212	1.503	1.605
RRV	1.197	1.391	1.430
RRVNS	1.107	1.349	1.420
RRVSc	1.216	1.423	1.399

Table 51: Ratio of /s/ to /z/ Duration. Unshaded cells represent significant differences between test and control speakers.

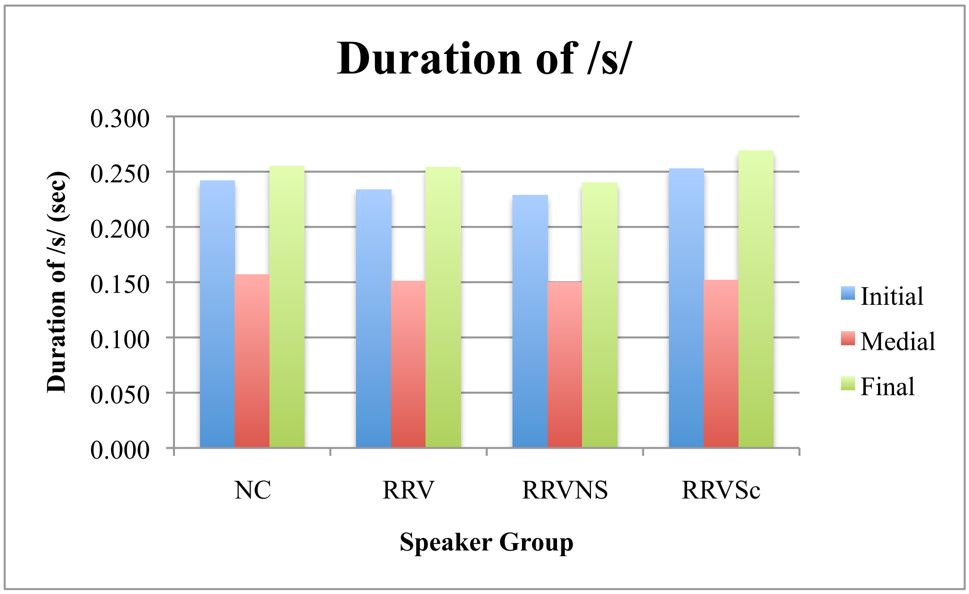

Figure 29: Duration of /s/ by Speaker Group

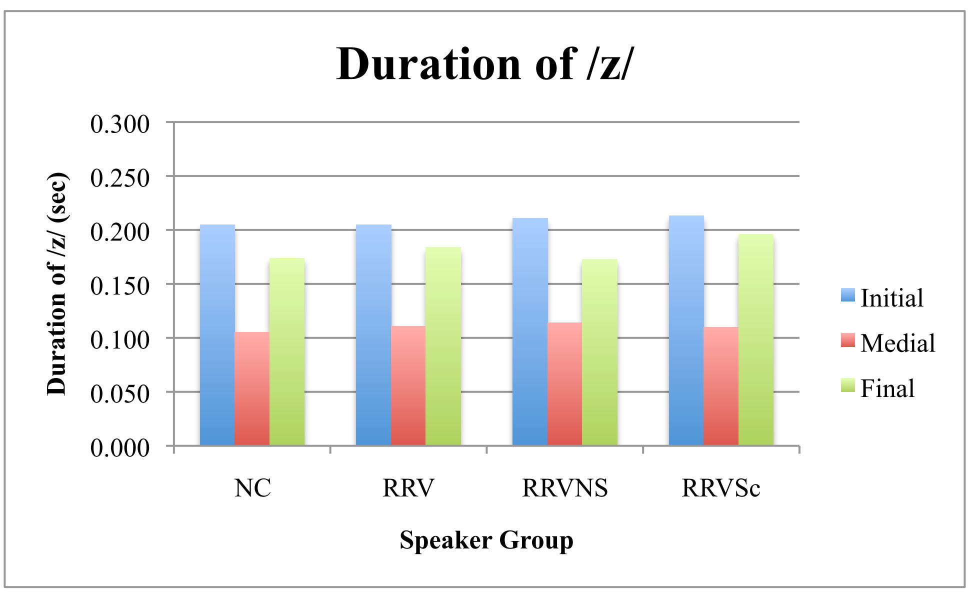

Figure 30: Duration of /z/ by Speaker Group

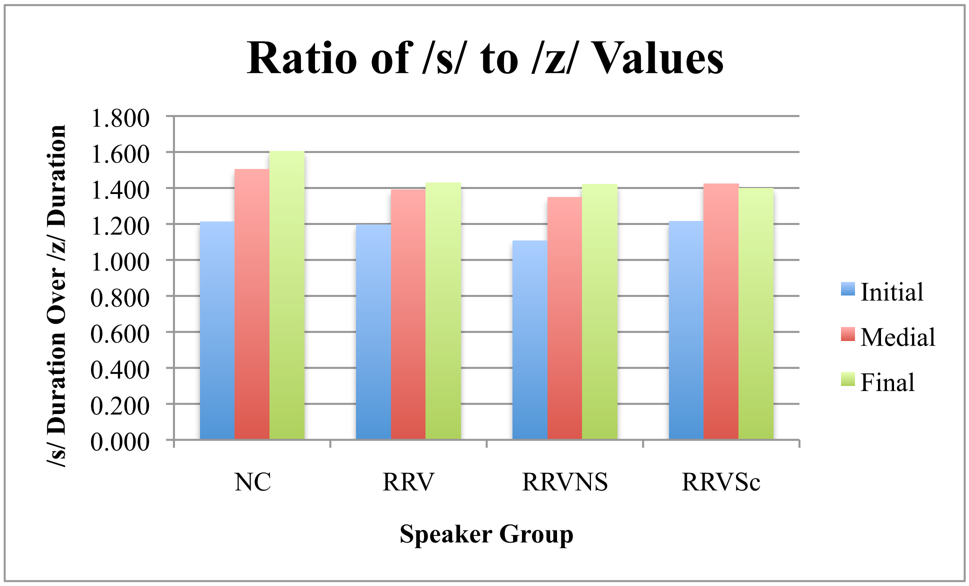

Figure 31: Ratio of /s/ to /z/ Duration Values

	Position	χ^2	p Value
S-words	Initial	0.11	0.746
	Medial	0.51	0.476
	Final	0.01	0.910
Z-words	Initial	0.02	0.894
	Medial	0.89	0.346
	Final	0.15	0.694
Ratios	Initial	0.82	0.364
	Medial	7.04	0.008
	Final	0.38	0.535

Table 52: Significance for Fricative Duration in RRV vs. NC. $p < 0.05$ is held to be significant.

	Position	χ^2	p Value
S-words	Initial	1.30	0.255
	Medial	0.13	0.721
	Final	2.72	0.099
Z-words	Initial	0.01	0.919
	Medial	0.15	0.703
	Final	2.33	0.127
Ratios	Initial	1.01	0.316
	Medial	0.43	0.513
	Final	0.04	0.835

Table 53: Significance for Fricative Duration in RRVSc vs. RRVNS. $p < 0.05$ is held to be significant.

While the fricatives share the vowels' tendency to manifest the greatest contrast in final position, the distinction between S-word and Z-word results in fricatives is quite similar in medial and final position, whereas in vowels the medial distinction is closer to the initial position results (and to 1) than to the final results. In addition, the distinction in final position, where glottal pulsing provides the least distinguishing information, is greater for vowels than for fricatives for all speakers. This supports the observations by Flege and Hillenbrand (1986) and Smith et al. (2009) that vowel duration has priority over fricative duration in production and perception.

5.3.2.2.2 Task 2

Task 2's results conform very closely to the overall results, both in general patterns and in significance; again, the ratio for medial fricative duration is the only case where significance was found.

	INITIAL	MEDIAL	FINAL
NC	0.243	0.161	0.257
RRV	0.226	0.151	0.230
RRVNS	0.227	0.152	0.204
RRVSc	0.228	0.150	0.235

Table 54: Duration of /s/, Task 2 (in seconds). Unshaded cells represent significant differences between test and control speakers.

	INITIAL	MEDIAL	FINAL
NC	0.200	0.107	0.169
RRV	0.193	0.114	0.164
RRVNS	0.193	0.114	0.149
RRVSc	0.198	0.112	0.172

Table 55: Duration of /z/, Task 2 (in seconds). Unshaded cells represent significant differences between test and control speakers.

	INITIAL	MEDIAL	FINAL
NC	1.244	1.524	1.677
RRV	1.209	1.364	1.444
RRVNS	1.198	1.364	1.396
RRVSc	1.174	1.385	1.415

Table 56: Ratio of /s/ to /z/ Duration, Task 2. Unshaded cells represent significant differences between test and control speakers.

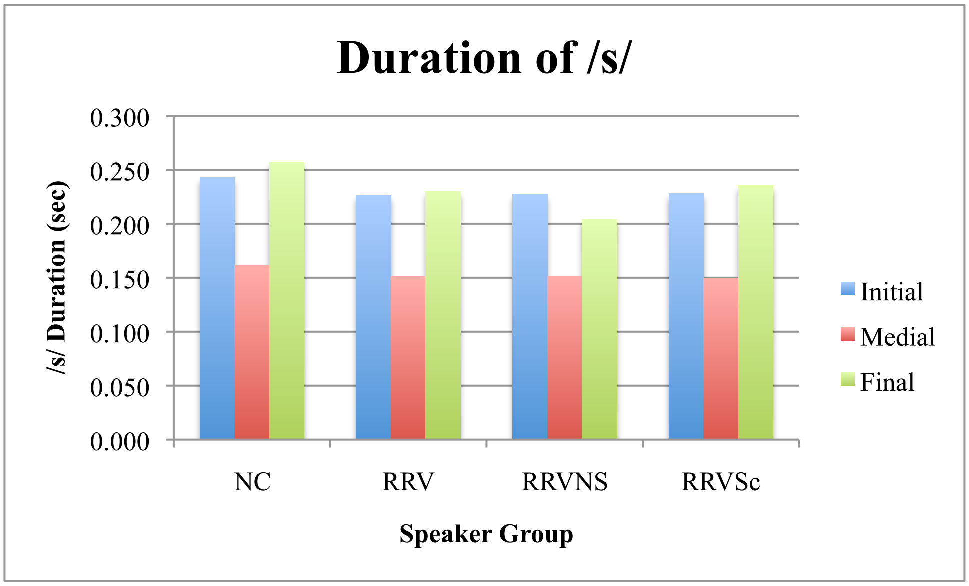

Figure 32: Duration of /s/ by Speaker Group, Task 2

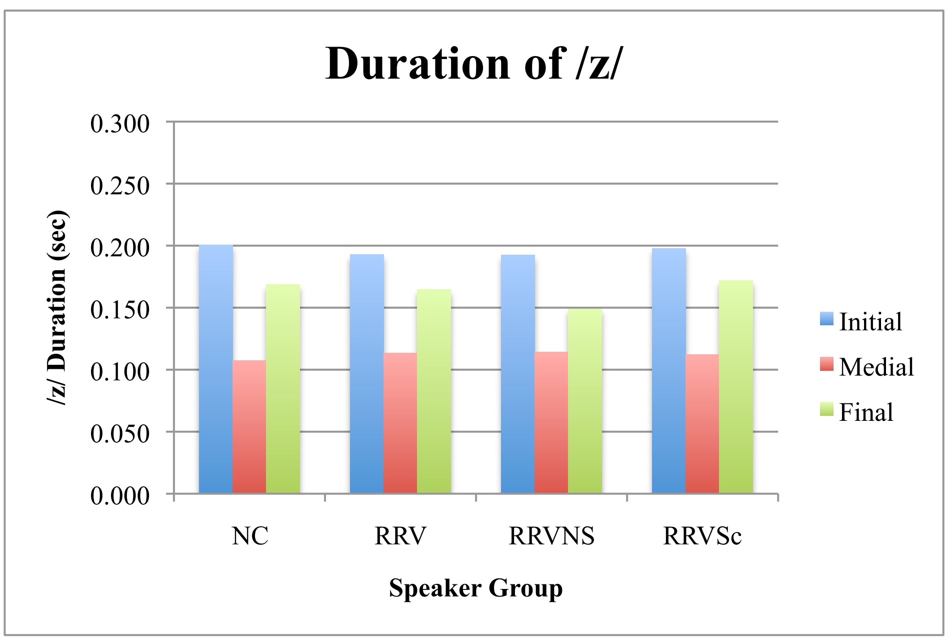

Figure 33: Duration of /z/ by Speaker Group, Task 2

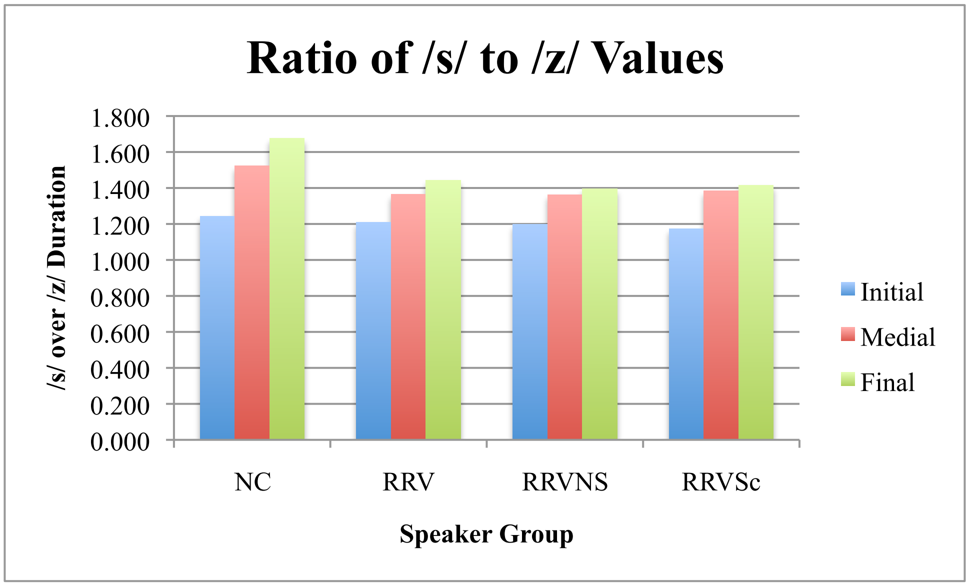

Figure 34: Ratio of /s/ to /z/ Duration Values, Task 2

	Position	χ^2	p Value
S-words	Initial	1.08	0.299
	Medial	2.01	0.157
	Final	2.03	0.154
Z-words	Initial	0.15	0.701
	Medial	0.89	0.345
	Final	0.11	0.738
Ratios	Initial	0.27	0.601
	Medial	6.72	0.010
	Final	0.61	0.436

Table 57: Significance for Fricative Duration in RRV vs. NC, Task 2. $p < 0.05$ is held to be significant.

	Position	χ^2	p Value
S-words	Initial	0.00	0.980
	Medial	0.10	0.748
	Final	1.91	0.167
Z-words	Initial	0.14	0.712
	Medial	0.06	0.814
	Final	2.45	0.118
Ratios	Initial	0.07	0.796
	Medial	0.01	0.942
	Final	0.32	0.570

Table 58: Significance for Fricative Duration in RRVSc vs. RRVNS, Task 2. $p < 0.05$ is held to be significant.

5.3.2.2.3 Task 3, Position 1

In the first position of Task 3, the results are much the same as above. The general patterns still hold, but there is one more significant result to note in addition to the regional medial fricative ratio that we saw in the previous sections, with a greater voicing contrast in the control speakers. The initial RRVSc ratio in Table 61 is higher than RRVNS, showing greater distinction in the test speakers instead.

	INITIAL	MEDIAL	FINAL
NC	0.255	0.157	0.236
RRV	0.248	0.152	0.256
RRVNS	0.250	0.152	0.245
RRVSc	0.270	0.154	0.277

Table 59: Duration of /s/, Task 3, Position 1 (in seconds). Unshaded cells represent significant differences between test and control speakers.

	INITIAL	MEDIAL	FINAL
NC	0.219	0.104	0.155
RRV	0.218	0.109	0.180
RRVNS	0.239	0.112	0.171
RRVSc	0.222	0.109	0.201

Table 60: Duration of /z/, Task 3, Position 1 (in seconds). Unshaded cells represent significant differences between test and control speakers.

	INITIAL	MEDIAL	FINAL
NC	1.174	1.530	1.628
RRV	1.199	1.421	1.479
RRVNS	1.056	1.391	1.451
RRVSc	1.267	1.460	1.403

Table 61: Ratio of /s/ to /z/ Duration, Task 3, Position 1. Unshaded cells represent significant differences between test and control speakers.

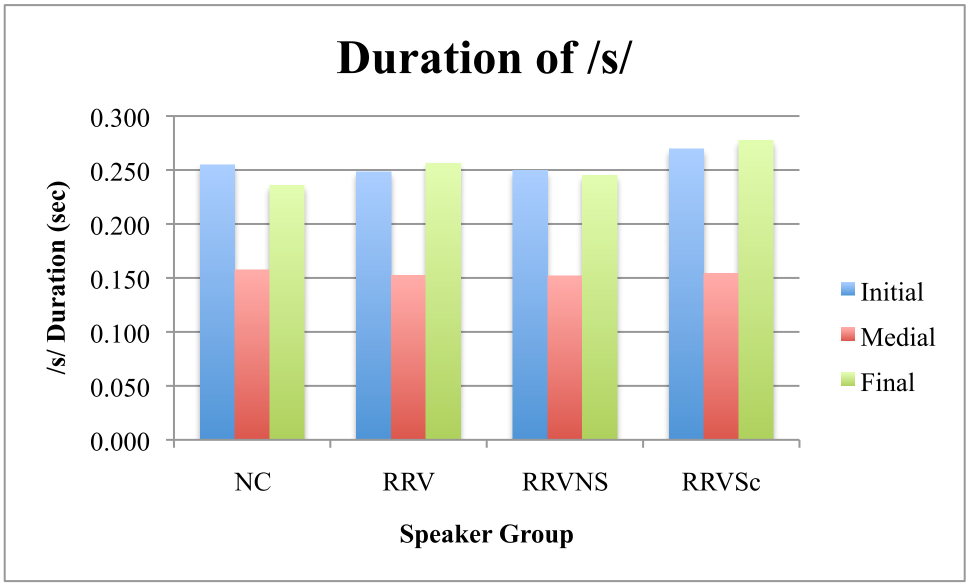

Figure 35: Duration of /s/ by Speaker Group, Task 3, Position 1

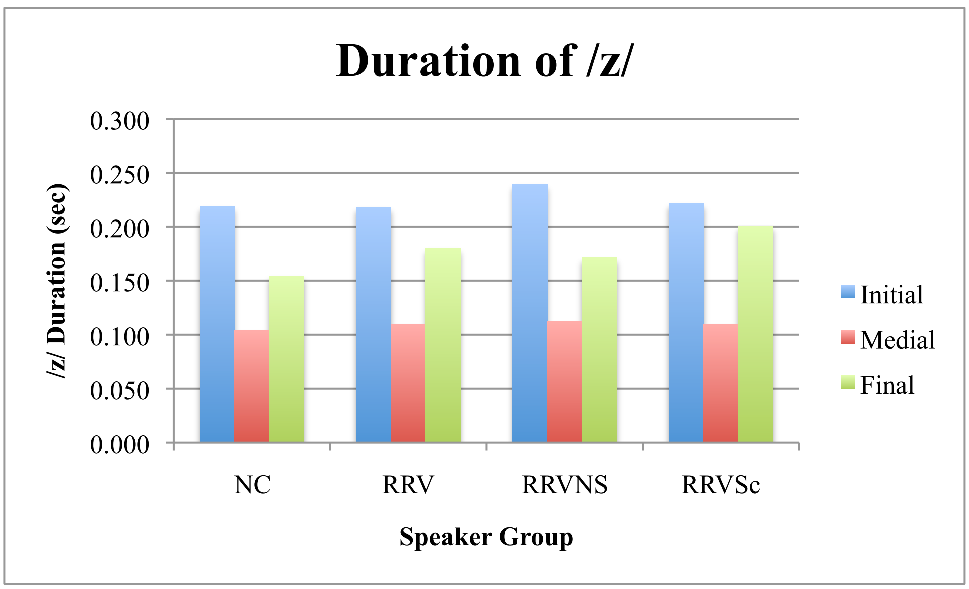

Figure 36: Duration of /z/ by Speaker Group, Task 3, Position 1

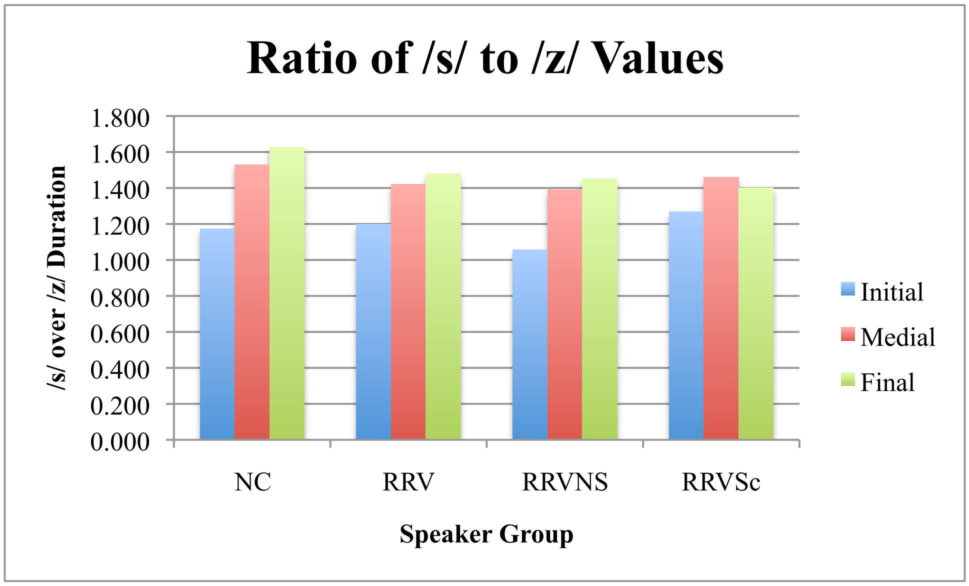

Figure 37: Ratio of /s/ to /z/ Duration Values, Task 3, Position 1

	Position	χ^2	p Value
S-words	Initial	0.03	0.872
	Medial	0.25	0.619
	Final	0.93	0.335
Z-words	Initial	0.04	0.841
	Medial	0.57	0.451
	Final	1.00	0.317
Ratios	Initial	0.49	0.486
	Medial	5.97	0.015
	Final	0.51	0.474

Table 62: Significance for Fricative Duration in RRV vs. NC, Task 3, Position 1. $p < 0.05$ is held to be significant.

	Position	χ^2	p Value
S-words	Initial	1.49	0.222
	Medial	0.07	0.792
	Final	1.30	0.255
Z-words	Initial	0.83	0.363
	Medial	0.04	0.836
	Final	1.97	0.160
Ratios	Initial	4.75	0.029
	Medial	0.31	0.579
	Final	0.68	0.411

Table 63: Significance for Fricative Duration in RRVSc vs. RRVNS, Task 3, Position 1. $p < 0.05$ is held to be significant.

5.3.2.2.4 Task 3, Position 2

While the patterns that were discussed in §5.3.2.2.1 hold on the whole for the second position of Task 3, it does differ in having no significant distinction between speaker groups, in either fricative duration or in the ratios between values for /s/ and /z/.

	INITIAL	MEDIAL	FINAL
NC	0.228	0.152	0.273
RRV	0.228	0.152	0.275
RRVNS	0.211	0.146	0.271
RRVSc	0.259	0.152	0.293

Table 64: Duration of /s/, Task 3, Position 2 (in seconds). Unshaded cells represent significant differences between test and control speakers.

	INITIAL	MEDIAL	FINAL
NC	0.195	0.105	0.197
RRV	0.204	0.110	0.206
RRVNS	0.202	0.116	0.199
RRVSc	0.219	0.109	0.217

Table 65: Duration of /z/, Task 3, Position 2 (in seconds). Unshaded cells represent significant differences between test and control speakers.

	INITIAL	MEDIAL	FINAL
NC	1.218	1.453	1.515
RRV	1.185	1.388	1.368
RRVNS	1.066	1.291	1.414
RRVSc	1.205	1.424	1.378

Table 66: Ratio of /s/ to /z/ Duration, Task 3, Position 2. Unshaded cells represent significant differences between test and control speakers.

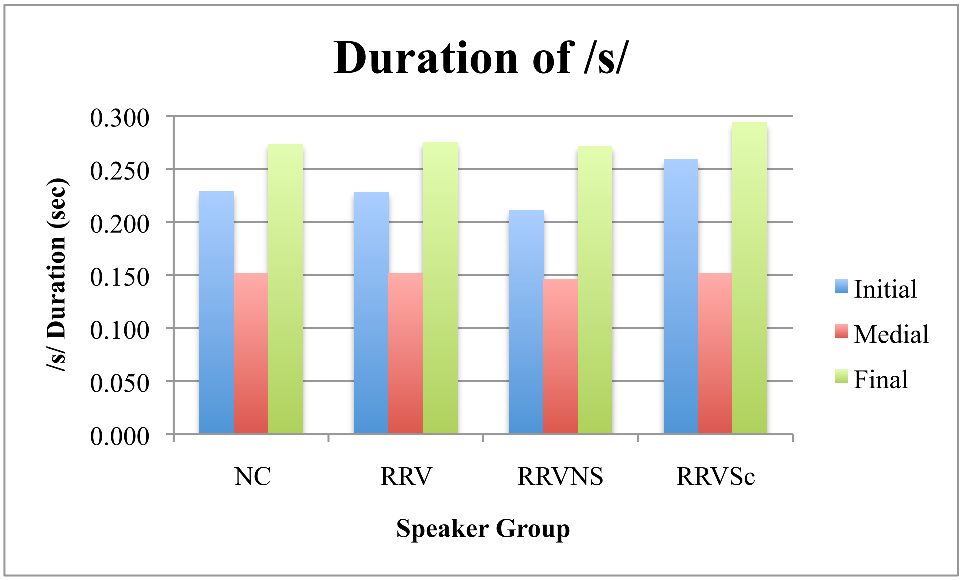

Figure 38: Duration of /s/ by Speaker Group, Task 3, Position 2

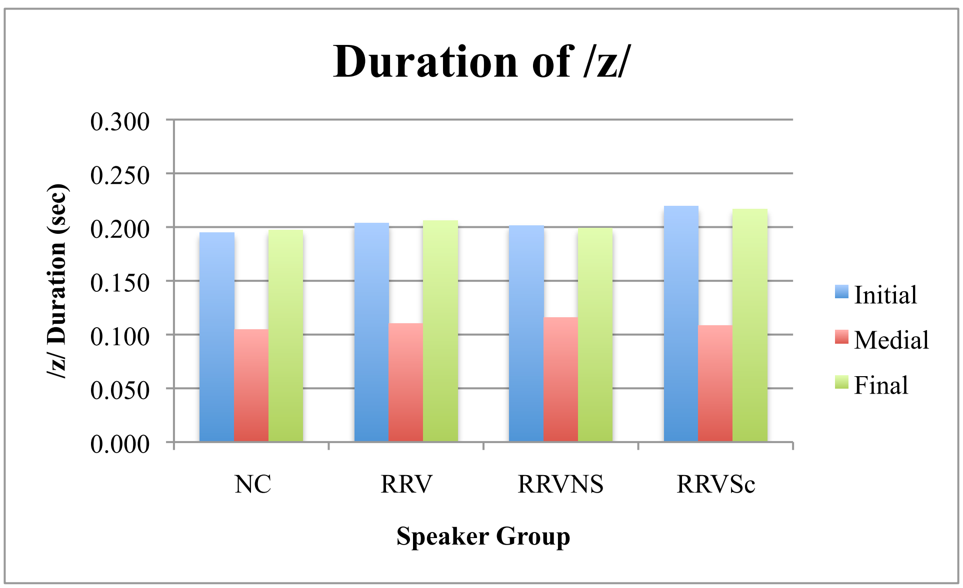

Figure 39: Duration of /z/ by Speaker Group, Task 3, Position 2

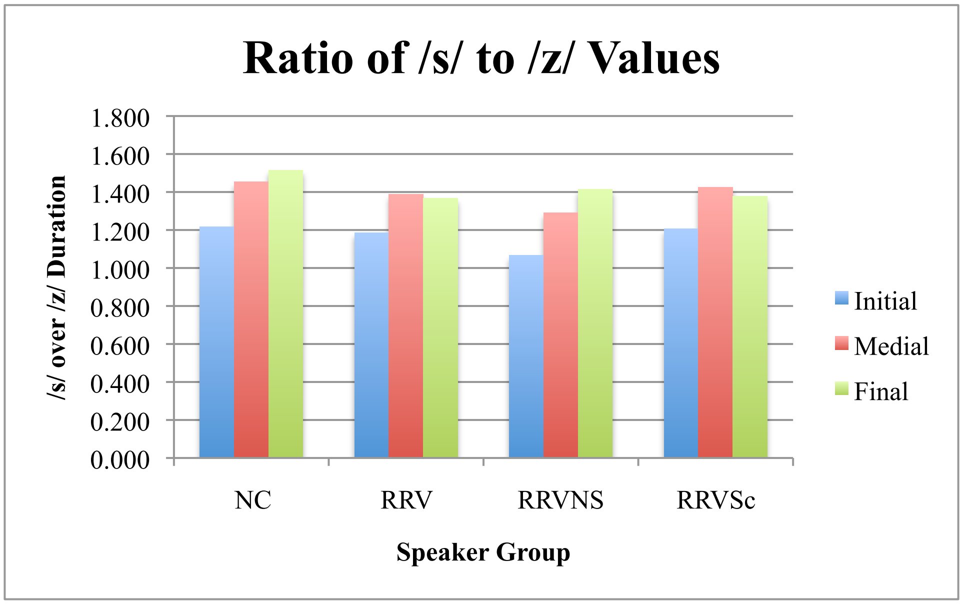

Figure 40: Ratio of /s/ to /z/ Duration Values, Task 3, Position 2

	Position	χ^2	p Value
S-words	Initial	0.00	0.992
	Medial	0.06	0.804
	Final	0.05	0.823
Z-words	Initial	0.17	0.678
	Medial	1.30	0.254
	Final	0.11	0.740
Ratios	Initial	0.69	0.405
	Medial	3.80	0.051
	Final	0.08	0.773

Table 67: Significance for Fricative Duration in RRV vs. NC, Task 3, Position 2. $p < 0.05$ is held to be significant.

	Position	χ^2	p Value
S-words	Initial	2.05	0.152
	Medial	0.79	0.374
	Final	1.68	0.194
Z-words	Initial	0.60	0.440
	Medial	0.48	0.489
	Final	0.45	0.503
Ratios	Initial	0.83	0.362
	Medial	2.21	0.137
	Final	0.01	0.925

Table 68: Significance for Fricative Duration in RRVSc vs. RRVNS, Task 3, Position 2. $p < 0.05$ is held to be significant.

5.3.3 Formants

Formant data is presented in vowel plots showing corresponding test and control group results (NC and RRV, RRVNC and RRVSc) together in the same plot. The ratios between formant values in S-words and Z-words are then given in table format. Some regional and intra-regional variation was found both in the placement of vowels in the vowel space and in the effect of the voicing contrast on F_1 and F_2.

The vowel whose placement varies the most between speaker groups is /u/, and this is true in both F_1 and F_2. The difference in height is visible both regionally and intra-regionally, although not in the same direction; in NC /u/ is always higher than in RRV, but within the subgroups the test group's /u/ is higher. The difference in the second formant is very much a regional pattern, with NC /u/ being much fronter than RRV /u/. This is only significant in the RRV subgroups in one instance in all of the task results, presented in the following sections. /i/ varies in the same way as /u/, with regional control but intra-regional test groups always producing higher vowels. The front/back difference in /i/ is exclusively regional variation, but here it is fronter in the RRV speakers, contributing to the overall tendency of the high tense vowels to be more widely spaced in RRV than in NC. /æ/, however, shows substantial variance in F_2 at both levels of speaker group comparison (always fronter in test groups), but little change at all in F_1. /I/ varies the least of all vowels, and then only in F_1, regionally and intra-regionally.

In general, there are more significant differences in formant values between speaker groups at 80% of the pre-fricative vowel than at 20% of the post-fricative vowel. This holds true overall and in all tasks but the first position of Task 3, where there are an equal number of significant formant differences between the RRV subgroups.

Significant differences between groups in the ratio results are not similarly weighted in favor of either point in the vowel. This means that, while the height and backness of the vowels are more distinct between speaker groups at the 80% point, the voicing contrast does not cause appreciably stronger differences between the groups depending on the placement of the fricative.

One question that was raised earlier in the paper relates to the Low Frequency and Hyperarticulation hypotheses. For the purposes of this paper, this discussion will focus on the direction of those voicing contrast ratios that show a distinction between speaker groups. Refer to Table 7 for the results predicted by each hypothesis, assuming canonical formant values.

Considering all overall and task-specific results, presented in the following sections, we see some trends emerge. In F_1, distinction is found in the subgroups' /i/ in Table 81 and Table 97, and in both cases the test group, RRVSc, produces a ratio less than one, conforming to the Hyperarticulation hypothesis (HH), while the control group's ratio is slightly above one. As a high vowel, /u/ would be expected to follow the same pattern, but it does not in all respects, as seen in Table 81, Table 93, and Table 97. Control speakers in every case do show ratios greater than one, as predicted by the Low Frequency hypothesis (LFH). However, the test speakers do not conform to the HH, as their values are at or slightly above one, showing very little effect of the voicing contrast. Whereas I would have expected /I/ to pattern with /i/ based on its canonical height, in fact it is usually quite lower and behaves like low /æ/, as found in Fischer and Ohde (1990). The distinction in F_1 is better captured, then, as tense and lax vowels as opposed to high and low. With this consideration, in these vowels, the HH and LFH make the same prediction for F_1, and this prediction is borne out, shown in the unshaded cells of Table 81, Table 85, Table 89, and Table 93. Both control and test speakers produce ratios greater than one, and in every case the control speakers' ratios are more distant from one, indicating that in F_1 in these lax vowels, as well as in /u/, the control groups exploit the voicing contrast to a greater extent. The opposite is true of /i/, however. We can also see that where the test speakers show the greater distinction, it is in favor of the HH, and where the control speakers do, it supports the LFH, indicating that the direction of F_1 as affected by the voicing contrast may in itself be systematically variable, as well as the degree of the effect. One possible cause of this variation is that the test speakers may not have fully acquired this aspect of the voicing contrast in GAE.

The LFH does not explicitly predict the behavior of F_2 as the HH does, and so fewer conclusions can be drawn. In addition, most vowels show few significant differences in the F_2 ratios. The only case where a strong pattern emerges is that of /u/ (Table 78, Table 82, Table 94, and Table 98). With one minor exception (where it is 1.01), all test speaker ratios are less than one, which is predicted by the HH as the low F_2 of the back vowel become lower adjacent to /z/. The control group ratios are greater than one in all cases but one, and again in the exception the ratio is barely less than one at 0.99. It is clear that the test groups' productions of /u/ follow the predictions of the HH, while the control groups' do not. Moreover, if we assume that the predictions of the LFH (lower formants adjacent to voiced consonants) apply to the second formant, the ratios of S-word over Z-word results would be greater than one, as found in the majority of the control group results. However, one other consideration in the regional results is that NC /u/, being much fronter than RRV /u/, may not behave the same way under hyperarticulation, since its effect depends on the formant value and therefore the position in the vowel space.

5.3.3.1 Aggregate Data

5.3.3.1.1 RRV and NC

Formant results were calculated for a point in the vowel near /s/ or /z/ (20% of the duration in words with an initial fricative, representing one-third of the tokens, and 80% where the fricative is medial or final, representing the remaining two-thirds). For all plots of /i I u æ/ in this and the following sections, test results are blue (RRV in the following plot) and control results red (NC below). The darker shade of each color shows the vowel adjacent to /s/ and the lighter tint represents the vowel when adjacent to /z/. Here and throughout, the black arrows indicate that the difference between the test and control group formant values for that vowel and context were found to be significant ($p < 0.05$) in F_1 (vertical arrow) or F_2 (horizontal arrow). For consistency, the arrows point from the position of the test group vowel to that of the control group. Then, to show the numerical values of the patterns observed in the vowel plots, means of the S-word/Z-word ratios are given for F_1 and F_2 in RRV and NC and for the RRV subgroups for the 20% and 80% points of each vowel (for the corresponding post- and pre-fricative contexts). Cells that are unshaded represent those cases where a significant difference ($p < 0.05$) was found between the test and control groups.

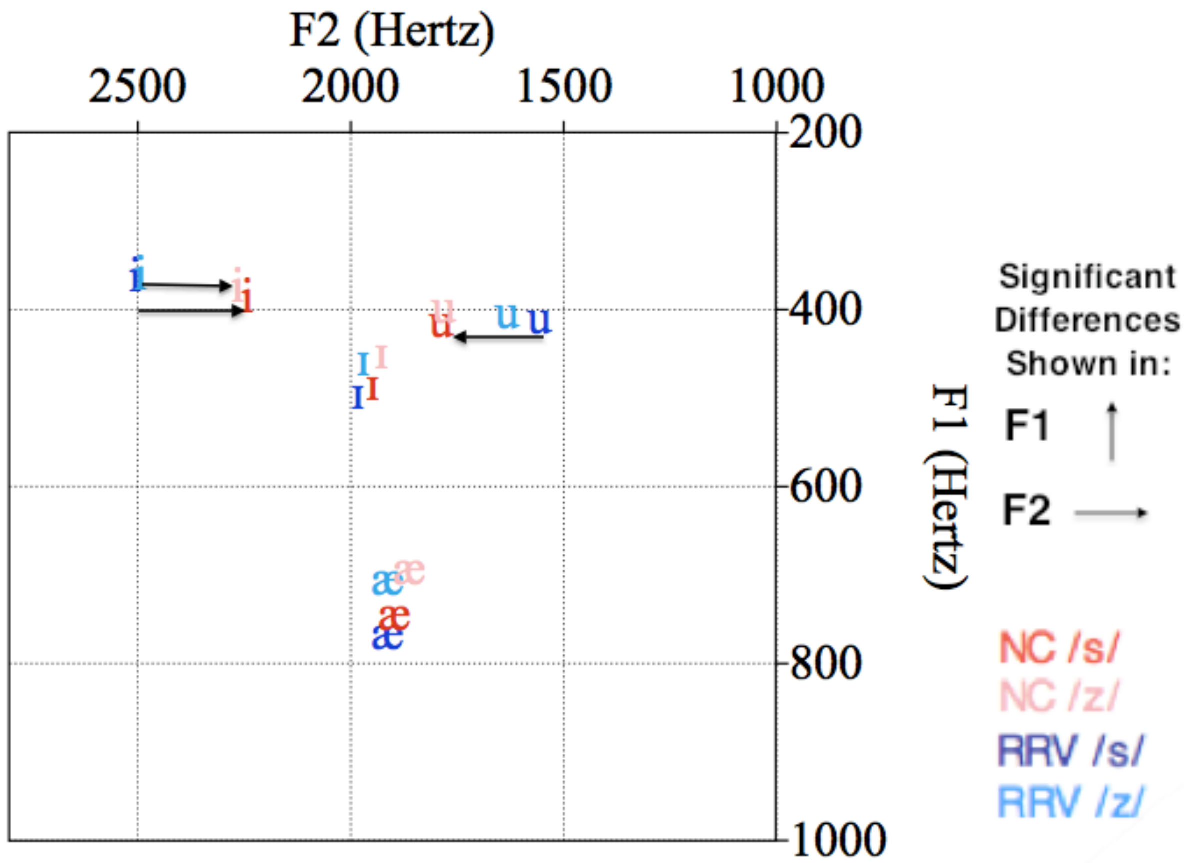

Figure 41: Vowels at 20% of Duration (RRV and NC)

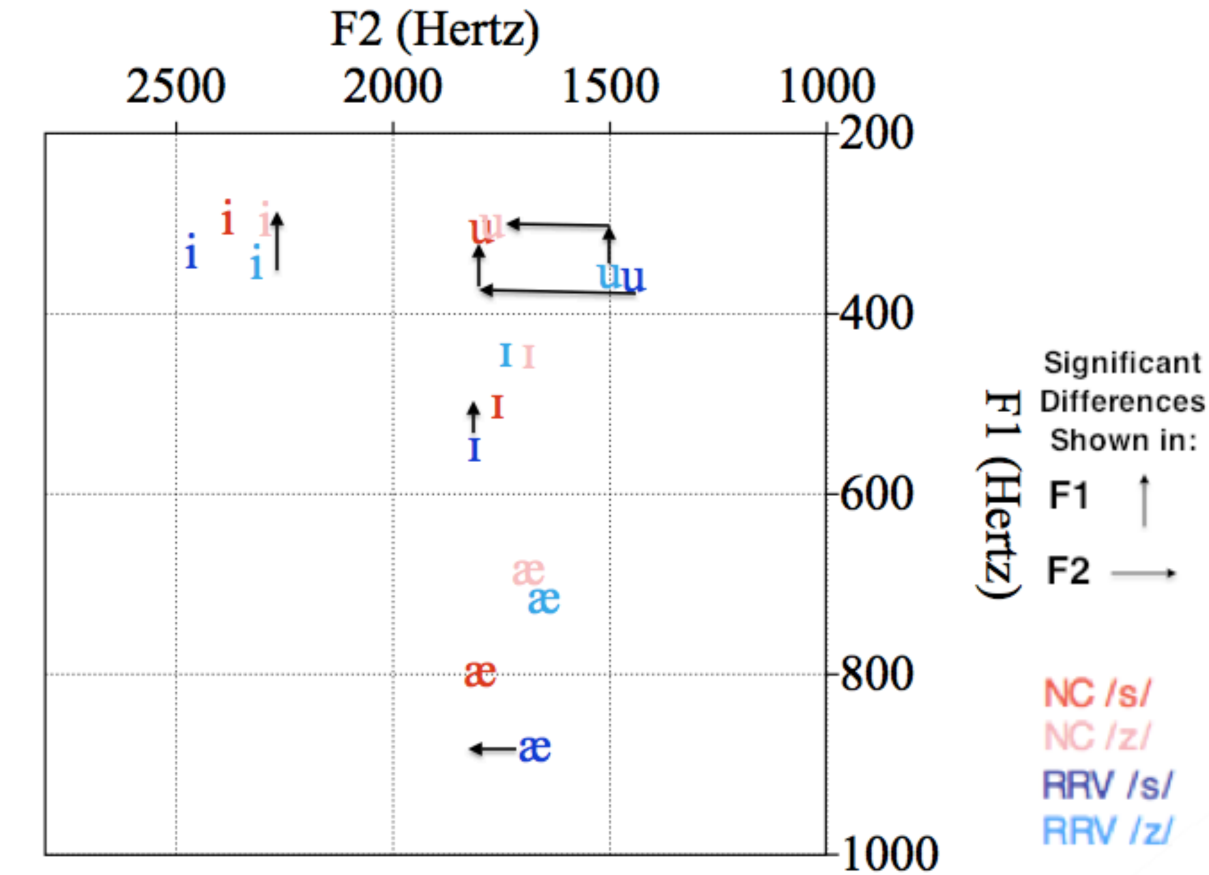

Figure 42: Vowels at 80% of Duration (RRV and NC)

	RRV		NC	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	1.006	0.969	1.036	0.998
/u/	1.011	1.014	1.039	1.024
/I/	1.085	1.246	1.078	1.129
/æ/	1.087	1.229	1.072	1.167

Table 69: RRV and NC Average F_1 Ratios (S-word/Z-word). Unshaded cells represent significant differences between test and control speakers.

	RRV		NC	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	1.005	1.064	0.991	1.039
/u/	0.954	0.963	1.004	1.015
/I/	1.005	1.041	1.012	1.043
/æ/	0.999	1.013	1.019	1.067

Table 70: RRV and NC Average F_2 Ratios (S-word/Z-word). Unshaded cells represent significant differences between test and control speakers.

		20%		80%	
		χ^2	p Value	χ^2	p Value
S-word	/i/	1.65	0.199	2.31	0.129
	/u/	0.01	0.927	5.94	0.015
	/I/	0.46	0.496	5.64	0.018
	/æ/	0.64	0.423	2.66	0.103
Z-word	/i/	0.73	0.393	5.78	0.016
	/u/	0.47	0.494	6.44	0.011
	/I/	0.30	0.586	0.01	0.940
	/æ/	0.20	0.656	0.85	0.355
Ratios	/i/	0.81	0.369	1.08	0.299
	/u/	0.87	0.351	0.36	0.548
	/I/	0.08	0.774	15.06	< 0.001
	/æ/	0.42	0.517	3.03	0.082

Table 71: Significance for F_1 in RRV vs. NC. $p < 0.05$ is held to be significant.

		20%		80%	
		χ^2	p Value	χ^2	p Value
S-word	/i/	10.83	0.001	2.50	0.114
	/u/	4.28	0.039	8.63	0.003
	/I/	0.07	0.796	0.66	0.415
	/æ/	0.04	0.849	10.18	0.001
Z-word	/i/	14.57	< 0.001	0.01	0.913
	/u/	2.03	0.154	4.62	0.032
	/I/	0.37	0.545	0.68	0.411
	/æ/	0.41	0.523	0.73	0.394
Ratios	/i/	0.65	0.419	2.49	0.115
	/u/	11.20	< 0.001	5.03	0.025
	/I/	0.08	0.780	0.00	0.954
	/æ/	4.43	0.035	6.80	0.009

Table 72: Significance for F_2 in RRV vs. NC. $p < 0.05$ is held to be significant.

5.3.3.1.2 RRVSc and RRVNS

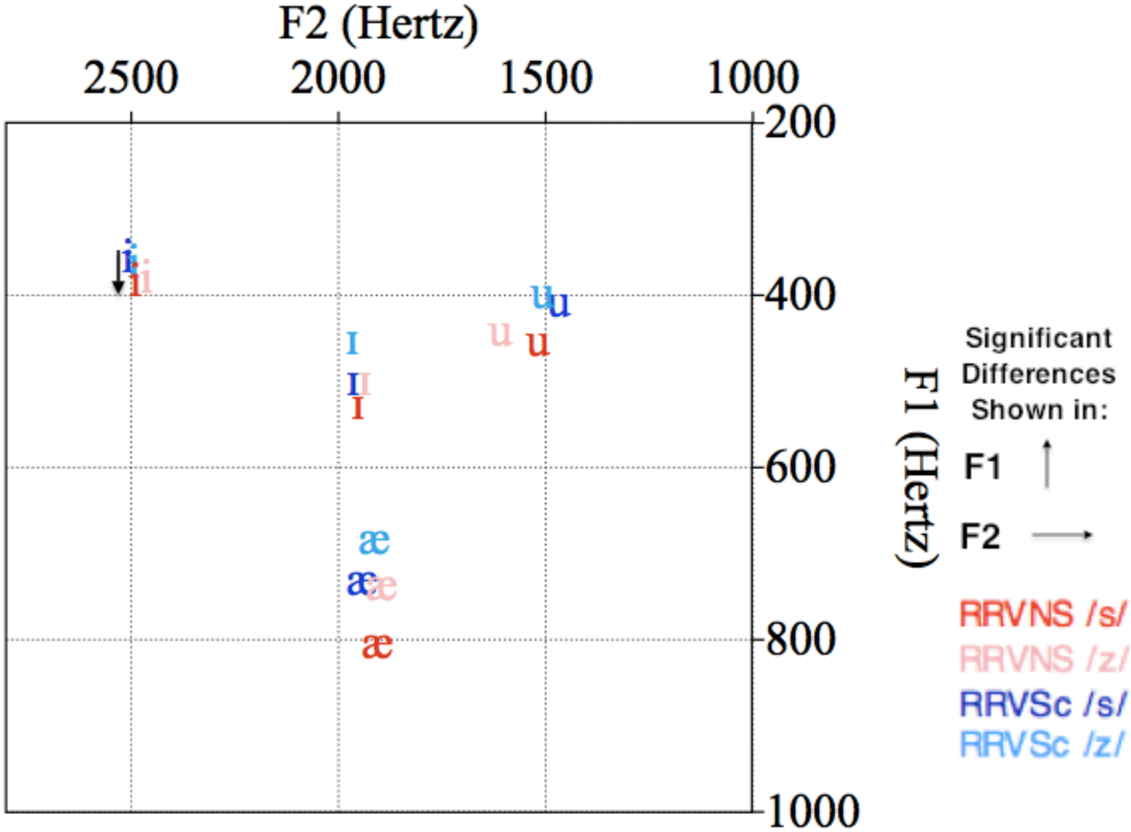

Figure 43: Vowels at 20% of Duration (RRVSc and RRVNS)

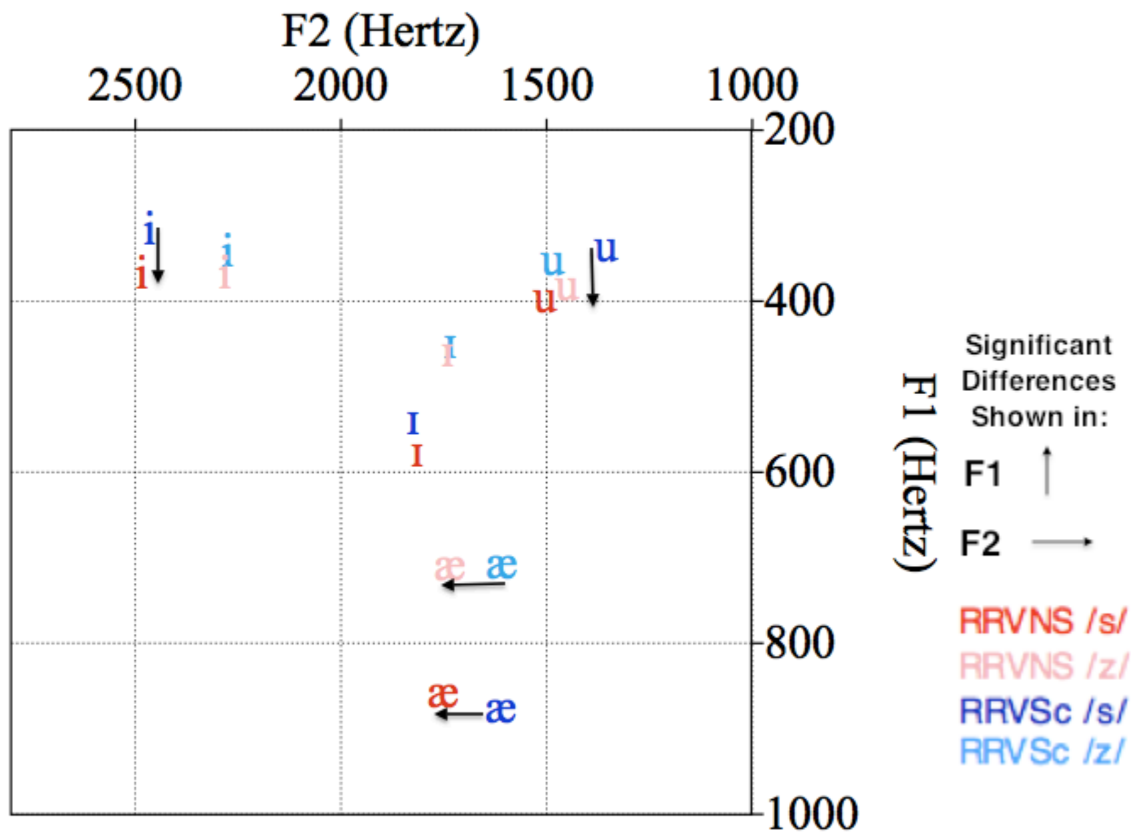

Figure 44: Vowels at 80% of Duration (RRVSc and RRVNS)

	RRVSC		RRVNS	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	0.987	0.921	1.010	1.005
/u/	1.031	0.954	1.035	1.047
/I/	1.107	1.222	1.062	1.267
/æ/	1.075	1.240	1.098	1.223

Table 73: RRVSc and RRVNS Average F_1 Ratios (S-word/Z-word). Unshaded cells represent significant differences between test and control speakers.

	RRVSC		RRVNS	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	0.964	1.057	1.010	1.092
/u/	1.031	0.912	0.945	1.051
/I/	0.995	1.044	1.009	1.044
/æ/	1.015	1.015	1.006	1.011

Table 74: RRVSc and RRVNS Average F_2 Ratios (S-word/Z-word). Unshaded cells represent significant differences between test and control speakers.

		20%		80%	
		χ^2	p Value	χ^2	p Value
S-word	/i/	3.98	0.046	3.86	0.049
	/u/	2.41	0.121	6.37	0.012
	/I/	0.99	0.319	0.97	0.325
	/æ/	1.50	0.221	0.06	0.802
Z-word	/i/	2.08	0.149	2.15	0.142
	/u/	1.90	0.168	1.95	0.163
	/I/	2.44	0.118	0.24	0.625
	/æ/	0.69	0.407	0.00	0.981
Ratios	/i/	1.08	0.298	3.68	0.055
	/u/	0.10	0.751	9.94	0.002
	/I/	5.07	0.024	0.83	0.362
	/æ/	0.38	0.538	0.49	0.486

Table 75: Significance for F_1 in RRVSc vs. RRVNS. $p < 0.05$ is held to be significant.

		20%		80%	
		χ^2	p Value	χ^2	p Value
S-word	/i/	0.02	0.893	0.02	0.892
	/u/	0.15	0.701	2.30	0.129
	/I/	0.02	0.902	0.02	0.894
	/æ/	0.24	0.623	5.65	0.017
Z-word	/i/	0.06	0.804	0.00	0.969
	/u/	0.72	0.397	0.10	0.755
	/I/	0.17	0.679	0.03	0.858
	/æ/	0.08	0.784	4.12	0.043
Ratios	/i/	0.12	0.732	0.04	0.839
	/u/	0.70	0.402	6.28	0.012
	/I/	0.35	0.553	1.02	0.313
	/æ/	0.75	0.388	0.38	0.536

Table 76: Significance for F_2 in RRVSc vs. RRVNS. $p < 0.05$ is held to be significant.

5.3.3.2 Task 2

The Task 2 results conform very closely to the general trends discussed above at both level of speaker comparison. There are fewer significant results, but none of them depart from the overall pattern.

5.3.3.2.1 RRV and NC

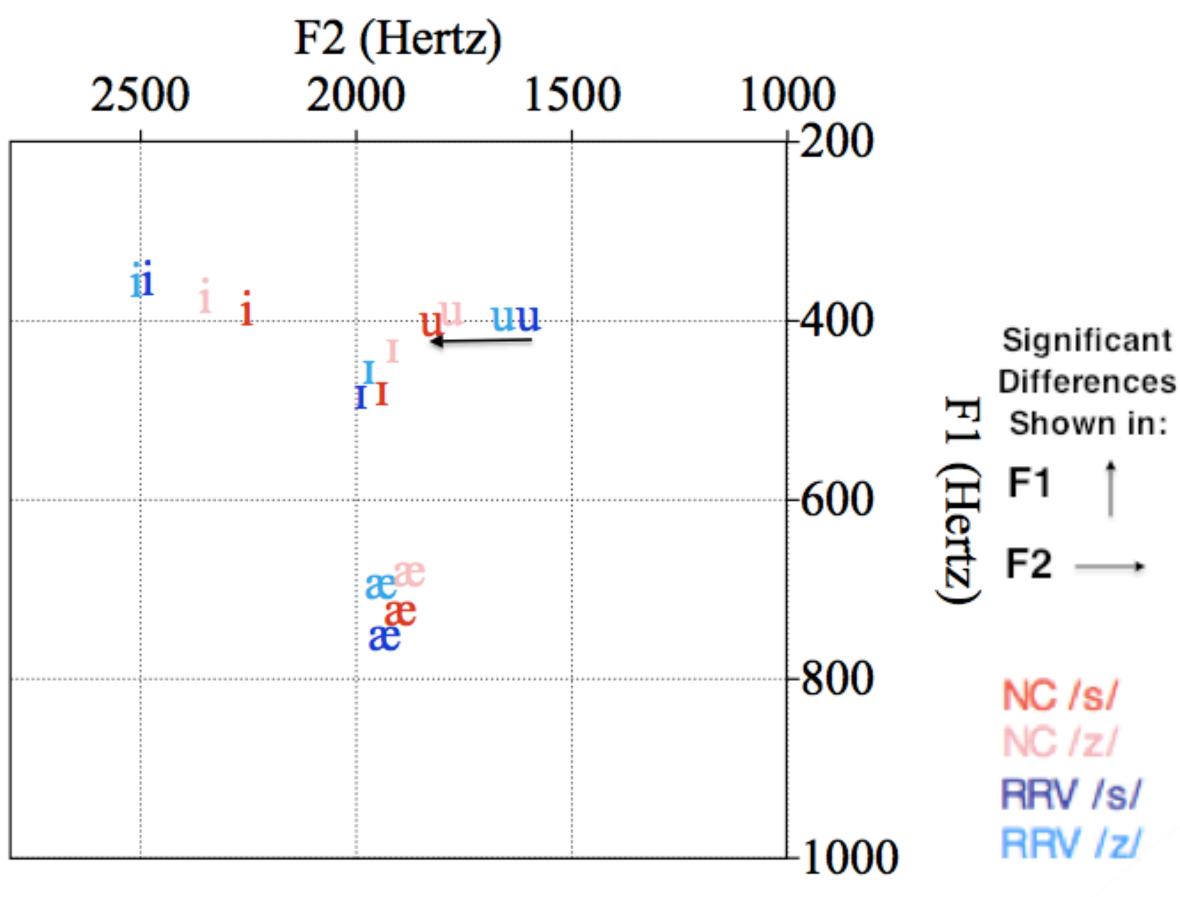

Figure 45: Vowels at 20% of Duration (RRV and NC), Task 2

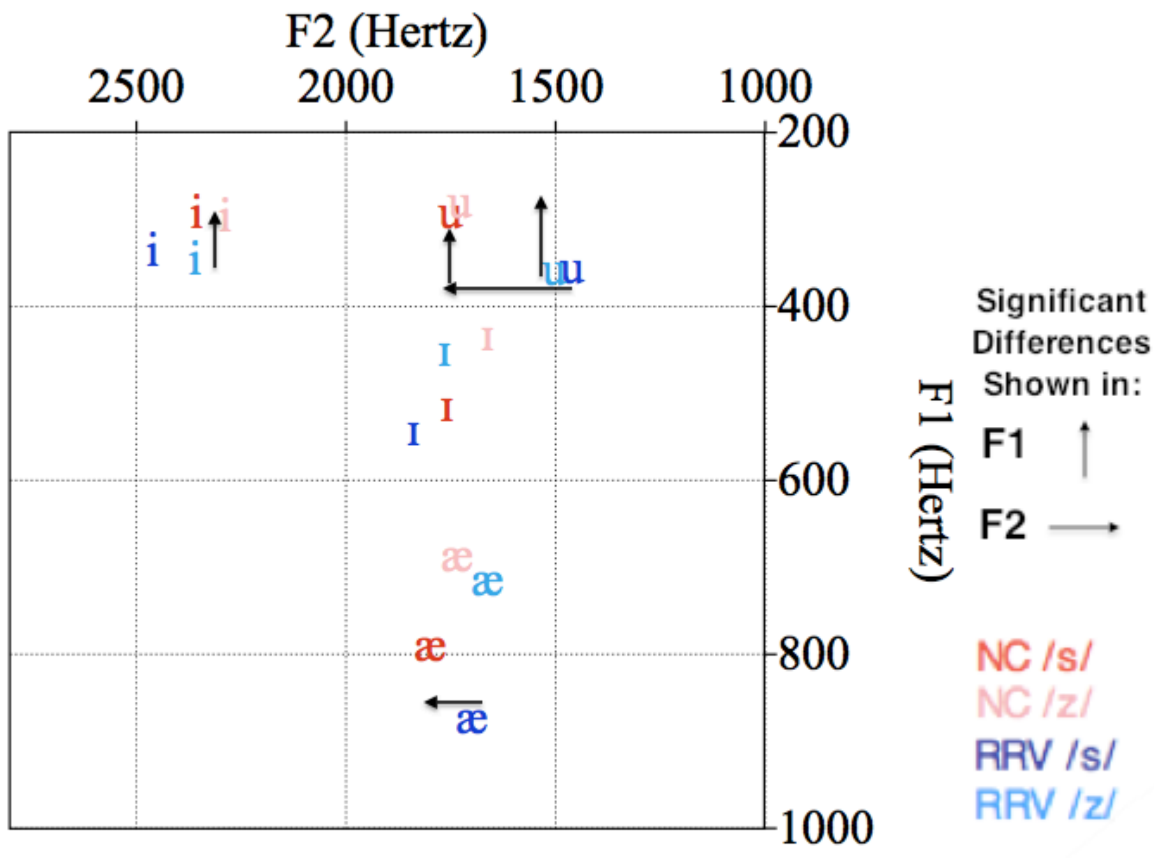

Figure 46: Vowels at 80% of Duration (RRV and NC), Task 2

	RRV		NC	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	1.00	0.97	1.03	0.99
/u/	1.01	1.00	1.03	1.01
/I/	1.06	1.22	1.11	1.20
/æ/	1.09	1.23	1.06	1.15

Table 77: RRV and NC Average F_1 Ratios (S-word/Z-word), Task 2. Unshaded cells represent significant differences between test and control speakers.

	RRV		NC	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	0.99	1.04	0.95	1.04
/u/	0.97	0.98	1.03	1.00
/I/	1.01	1.04	1.01	1.06
/æ/	1.00	1.02	1.01	1.04

Table 78: RRV and NC Average F_2 Ratios (S-word/Z-word), Task 2. Unshaded cells represent significant differences between test and control speakers.

		20%		80%	
		χ^2	p Value	χ^2	p Value
S-word	/i/	1.29	0.256	3.28	0.070
	/u/	0.01	0.927	5.57	0.018
	/I/	0.21	0.646	1.12	0.290
	/æ/	0.71	0.401	1.52	0.217
Z-word	/i/	1.02	0.313	6.86	0.009
	/u/	0.35	0.553	11.15	< 0.001
	/I/	1.85	0.174	1.08	0.299
	/æ/	0.20	0.657	0.52	0.472
Ratios	/i/	0.89	0.347	0.56	0.454
	/u/	0.04	0.841	1.40	0.237
	/I/	2.63	0.105	0.10	0.751
	/æ/	0.39	0.532	2.49	0.115

Table 79: Significance for F_1 in RRV vs. NC, Task 2. $p < 0.05$ is held to be significant.

		20%		80%	
		χ^2	p Value	χ^2	p Value
S-word	/i/	1.78	0.182	2.87	0.090
	/u/	4.16	0.041	5.17	0.023
	/I/	0.15	0.702	1.37	0.242
	/æ/	0.24	0.621	7.81	0.005
Z-word	/i/	3.00	0.083	0.69	0.406
	/u/	1.13	0.288	2.39	0.122
	/I/	0.57	0.451	1.58	0.208
	/æ/	0.37	0.542	2.65	0.104
Ratios	/i/	0.37	0.543	2.49	0.115
	/u/	8.88	0.003	0.80	0.370
	/I/	0.03	0.872	0.37	0.541
	/æ/	0.22	0.637	0.81	0.368

Table 80: Significance for F_2 in RRV vs. NC, Task 2. $p < 0.05$ is held to be significant.

5.3.3.2.2 RRVSc and RRVNS

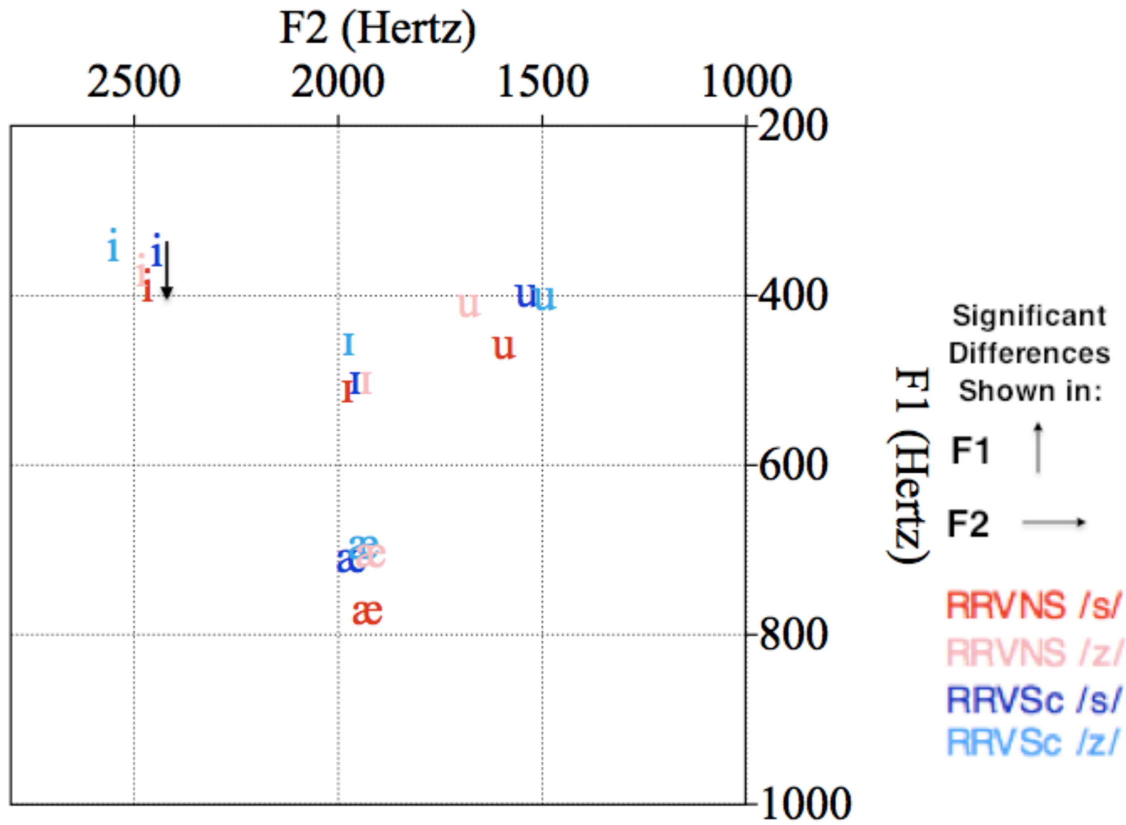

Figure 47: Vowels at 20% of Duration (RRVSc and RRVNS), Task 2

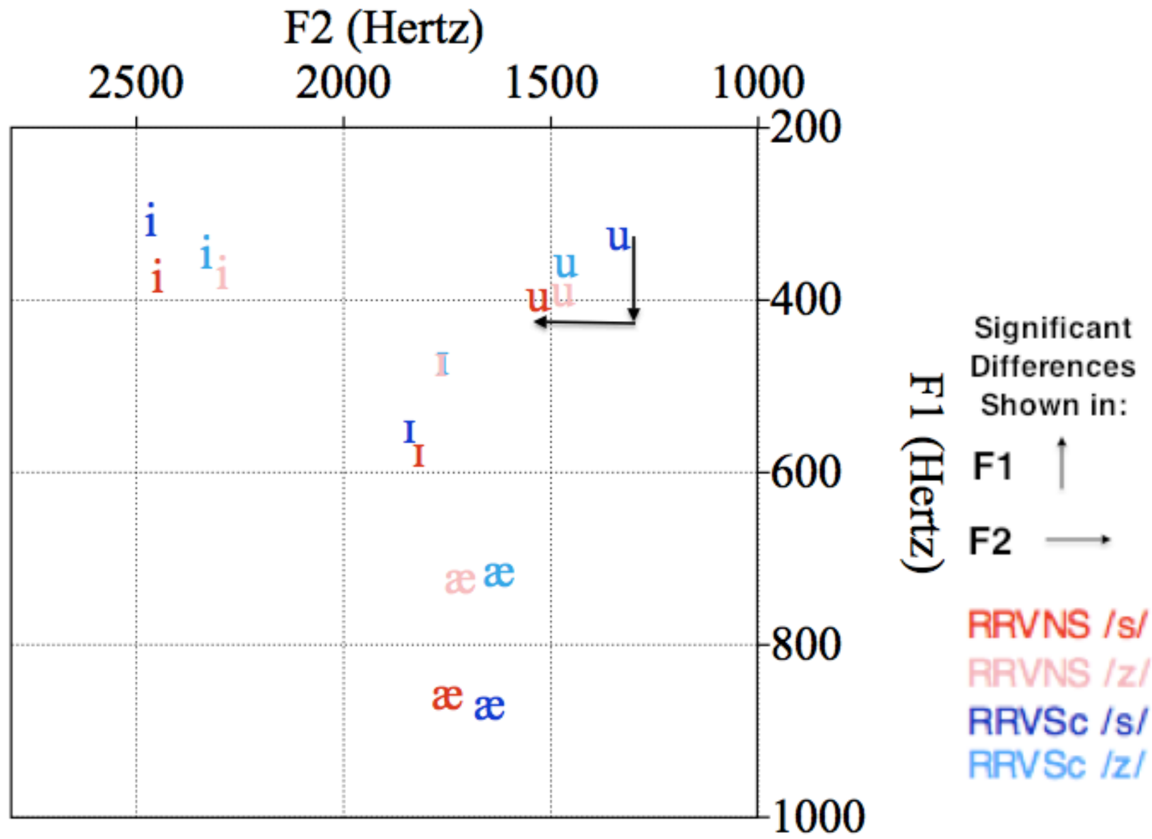

Figure 48: Vowels at 80% of Duration (RRVSc and RRVNS), Task 2

	RRVSC		RRVNS	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	1.02	0.88	1.05	1.01
/u/	1.01	0.91	1.12	1.02
/I/	1.10	1.19	1.02	1.24
/æ/	1.03	1.22	1.11	1.19

Table 81: RRVSc and RRVNS Average F_1 Ratios (S-word/Z-word), Task 2. Unshaded cells represent significant differences between test and control speakers.

	RRVSC		RRVNS	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	0.96	1.06	0.99	1.07
/u/	1.03	0.91	0.95	1.06
/I/	0.99	1.04	1.02	1.03
/æ/	1.01	1.01	1.00	1.02

Table 82: RRVSc and RRVNS Average F_2 Ratios (S-word/Z-word), Task 2. Unshaded cells represent significant differences between test and control speakers.

		20%		80%	
		χ^2	p Value	χ^2	p Value
S-word	/i/	4.06	0.044	3.81	0.051
	/u/	3.04	0.081	5.33	0.021
	/I/	0.06	0.813	0.50	0.479
	/æ/	1.36	0.244	0.03	0.870
Z-word	/i/	2.40	0.121	1.51	0.218
	/u/	0.05	0.821	1.55	0.213
	/I/	1.88	0.171	0.27	0.606
	/æ/	0.02	0.899	0.02	0.885
Ratios	/i/	0.68	0.409	5.45	0.020
	/u/	4.86	0.028	2.95	0.086
	/I/	7.13	0.008	0.26	0.607
	/æ/	1.47	0.226	0.54	0.464

Table 83: Significance for F_1 in RRVSc vs. RRVNS, Task 2. $p < 0.05$ is held to be significant.

		20%		80%	
		χ^2	p Value	χ^2	p Value
S-word	/i/	0.02	0.891	0.02	0.901
	/u/	0.24	0.627	4.60	0.032
	/I/	0.02	0.884	0.06	0.809
	/æ/	0.27	0.601	3.03	0.082
Z-word	/i/	0.15	0.695	0.15	0.696
	/u/	2.77	0.096	0.00	0.961
	/I/	0.17	0.681	0.09	0.771
	/æ/	0.05	0.820	2.29	0.130
Ratios	/i/	0.97	0.325	0.14	0.708
	/u/	11.73	< 0.001	7.66	0.006
	/I/	1.32	0.250	2.62	0.105
	/æ/	0.72	0.397	0.03	0.865

Table 84: Significance for F_2 in RRVSc vs. RRVNS, Task 2. $p < 0.05$ is held to be significant.

5.3.3.3 Task 3, Position 1

This position is notable because there are almost twice as many significant differences in the formant values as in either other position; they all conform to the trends discussed above. Target words in this position generally received the highest stress, which may have served to emphasize regional differences. However, the same cannot be said of the voicing distinction, shown in the ratios. Here, the first position of Task 3 elicited the fewest significant differences between speaker groups.

5.3.3.3.1 RRV and NC

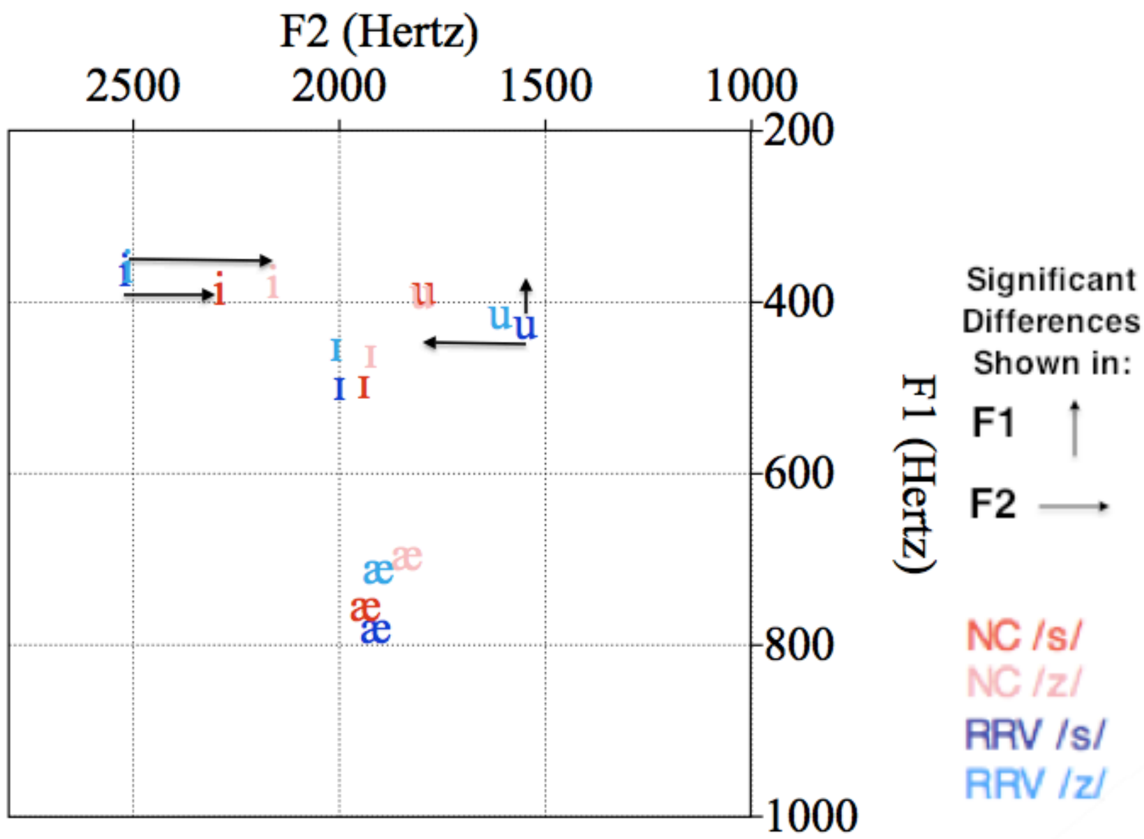

Figure 49: Vowels at 20% of Duration (RRV and NC), Task 3, Position 1

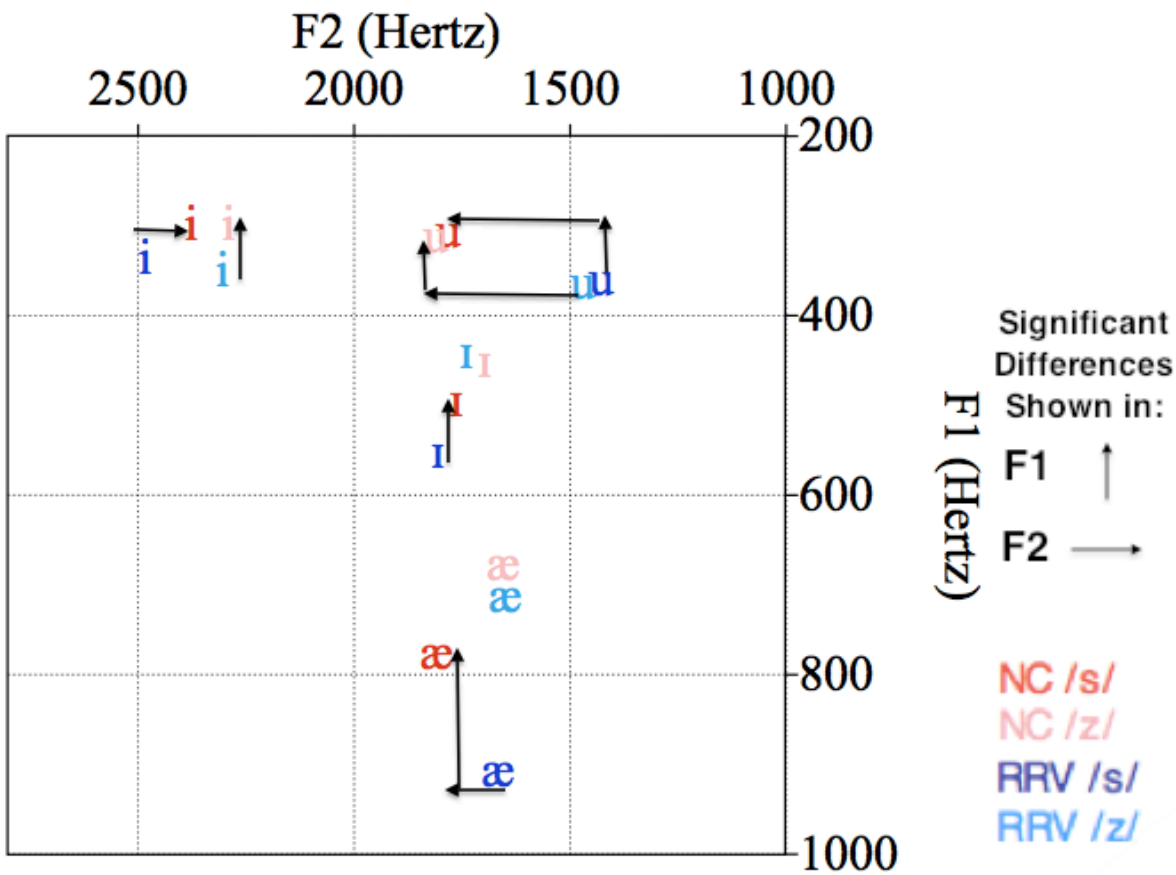

Figure 50: Vowels at 80% of Duration (RRV and NC), Task 3, Position 1

	RRV		NC	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	1.01	0.96	1.03	1.00
/u/	1.04	1.00	1.03	0.99
/I/	1.10	1.28	1.08	1.11
/æ/	1.10	1.28	1.09	1.16

Table 85: RRV and NC Average F_1 Ratios (S-word/Z-word), Task 3, Position 1. Unshaded cells represent significant differences between test and control speakers.

	RRV		NC	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	1.00	1.08	1.07	1.04
/u/	0.97	0.98	1.00	0.99
/I/	1.00	1.04	1.01	1.03
/æ/	1.00	1.01	1.05	1.11

Table 86: RRV and NC Average F_2 Ratios (S-word/Z-word), Task 3, Position 1. Unshaded cells represent significant differences between test and control speakers.

		20%		80%	
		χ^2	p Value	χ^2	p Value
S-word	/i/	2.33	0.127	2.40	0.122
	/u/	8.44	0.004	6.04	0.014
	/I/	0.03	0.857	13.28	< 0.001
	/æ/	0.75	0.388	6.34	0.012
Z-word	/i/	1.71	0.191	6.20	0.013
	/u/	2.17	0.141	5.21	0.022
	/I/	0.02	0.895	0.06	0.813
	/æ/	0.39	0.532	1.76	0.185
Ratios	/i/	0.27	0.601	1.31	0.253
	/u/	2.47	0.116	0.00	0.968
	/I/	0.18	0.671	11.72	< 0.001
	/æ/	0.11	0.736	4.87	0.027

Table 87: Significance for F_1 in RRV vs. NC, Task 3, Position 1. $p < 0.05$ is held to be significant.

		20%		80%	
		χ^2	p Value	χ^2	p Value
S-word	/i/	15.13	< 0.001	4.48	0.034
	/u/	4.72	0.030	8.57	0.003
	/I/	0.36	0.551	0.40	0.527
	/æ/	0.03	0.866	7.86	0.005
Z-word	/i/	18.23	< 0.001	0.00	0.995
	/u/	2.98	0.085	6.50	0.011
	/I/	1.49	0.223	0.43	0.511
	/æ/	1.03	0.309	0.01	0.924
Ratios	/i/	1.73	0.188	2.74	0.098
	/u/	1.84	0.175	0.13	0.720
	/I/	0.29	0.589	0.01	0.926
	/æ/	1.68	0.196	3.44	0.064

Table 88: Significance for F_2 in RRV vs. NC, Task 3, Position 1. $p < 0.05$ is held to be significant.

5.3.3.3.2 RRVSc and RRVNS

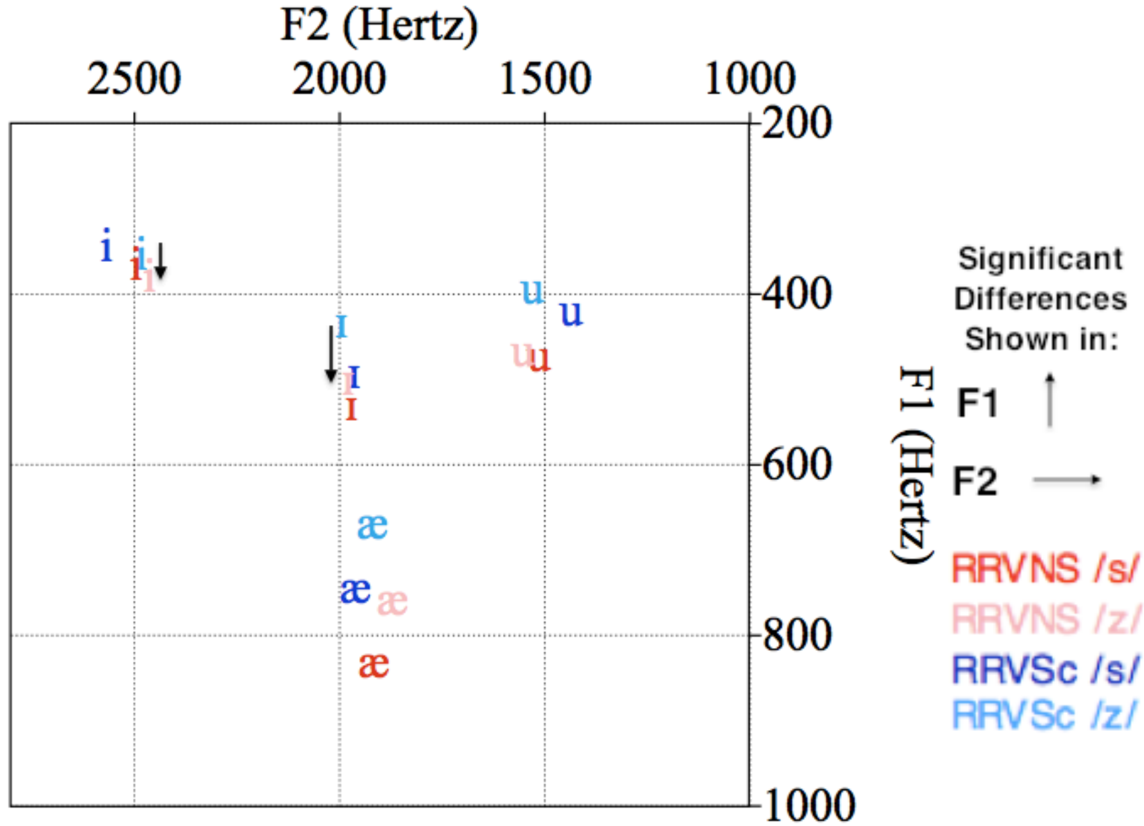

Figure 51: Vowels at 20% of Duration (RRVSc and RRVNS), Task 3, Position 1

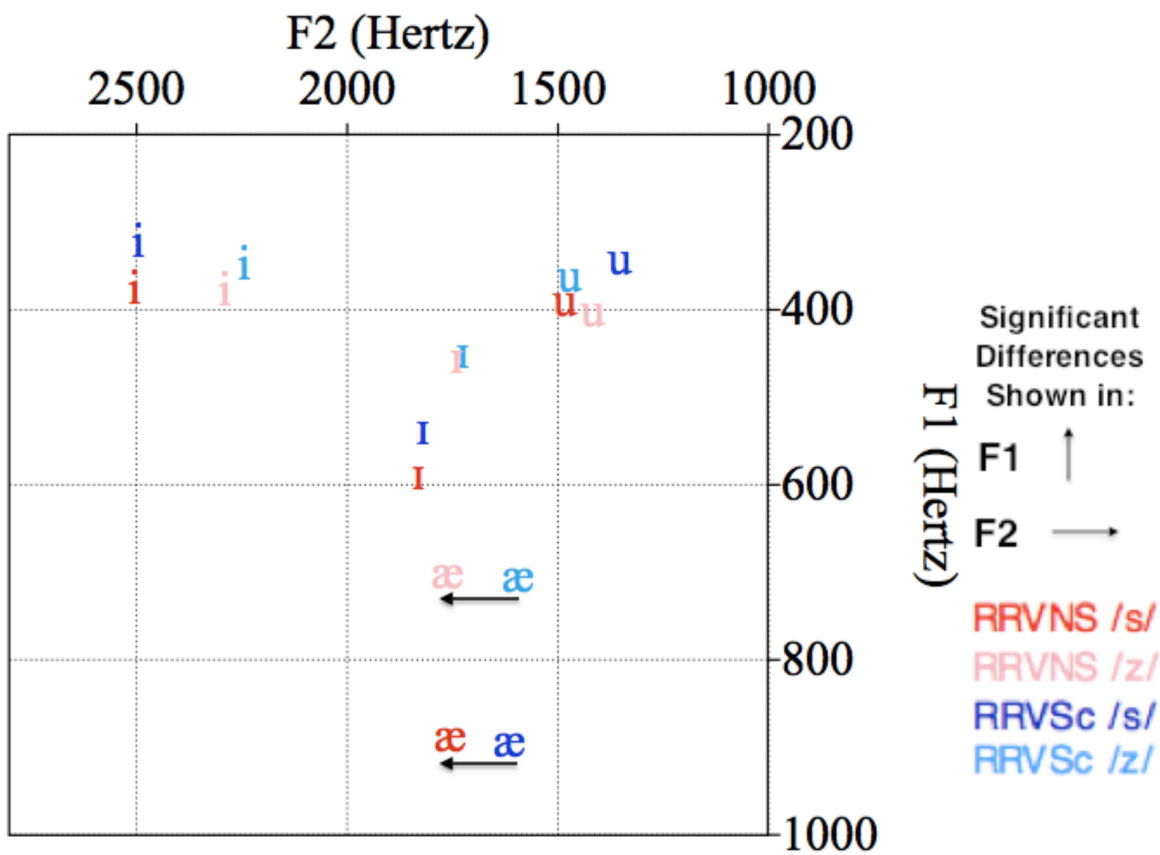

Figure 52: Vowels at 80% of Duration (RRVSc and RRVNS), Task 3, Position 1

	RRVSC		RRVNS	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	0.97	0.93	0.97	1.00
/u/	1.08	0.94	1.02	0.98
/I/	1.14	1.24	1.07	1.30
/æ/	1.11	1.27	1.10	1.28

Table 89: RRVSc and RRVNS Average F_1 Ratios (S-word/Z-word), Task 3, Position 1. Unshaded cells represent significant differences between test and control speakers.

	RRVSC		RRVNS	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	1.03	1.11	1.01	1.10
/u/	0.94	0.92	0.99	1.06
/I/	0.98	1.06	0.99	1.05
/æ/	1.02	1.02	1.03	1.00

Table 90: RRVSc and RRVNS Average F_2 Ratios (S-word/Z-word), Task 3, Position 1. Unshaded cells represent significant differences between test and control speakers.

		20%		80%	
		χ^2	p Value	χ^2	p Value
S-word	/i/	1.34	0.247	3.43	0.064
	/u/	3.01	0.083	3.05	0.081
	/I/	1.54	0.215	1.80	0.180
	/æ/	1.47	0.225	0.02	0.897
Z-word	/i/	4.24	0.039	1.72	0.189
	/u/	2.32	0.128	3.08	0.079
	/I/	4.21	0.040	0.04	0.840
	/æ/	1.93	0.165	0.01	0.917
Ratios	/i/	0.08	0.778	1.72	0.190
	/u/	0.89	0.344	0.36	0.548
	/I/	4.53	0.033	1.61	0.205
	/æ/	0.12	0.733	0.00	0.973

Table 91: Significance for F_1 in RRVSc vs. RRVNS, Task 3, Position 1. $p < 0.05$ is held to be significant.

		20%		80%	
		χ^2	p Value	χ^2	p Value
S-word	/i/	0.25	0.620	0.01	0.931
	/u/	0.44	0.509	1.55	0.213
	/I/	0.00	0.968	0.00	0.998
	/æ/	0.29	0.592	5.28	0.022
Z-word	/i/	0.04	0.850	0.11	0.743
	/u/	0.02	0.889	0.17	0.679
	/I/	0.04	0.845	0.03	0.855
	/æ/	0.44	0.508	6.45	0.011
Ratios	/i/	0.56	0.456	0.28	0.600
	/u/	0.32	0.573	3.70	0.054
	/I/	0.18	0.673	0.15	0.700
	/æ/	0.02	0.891	2.19	0.139

Table 92: Significance for F_2 in RRVSc vs. RRVNS, Task 3, Position 1. $p < 0.05$ is held to be significant.

5.3.3.4 Task 3, Position 2

This position conforms in most cases to the results already presented, but provides the minor exceptions in the F_2 ratios in /u/ mentioned above; in Table 94, the NC ratio is 0.99, while in Table 97 the RRVSc ratio is 1.01.

5.3.3.4.1 RRV and NC

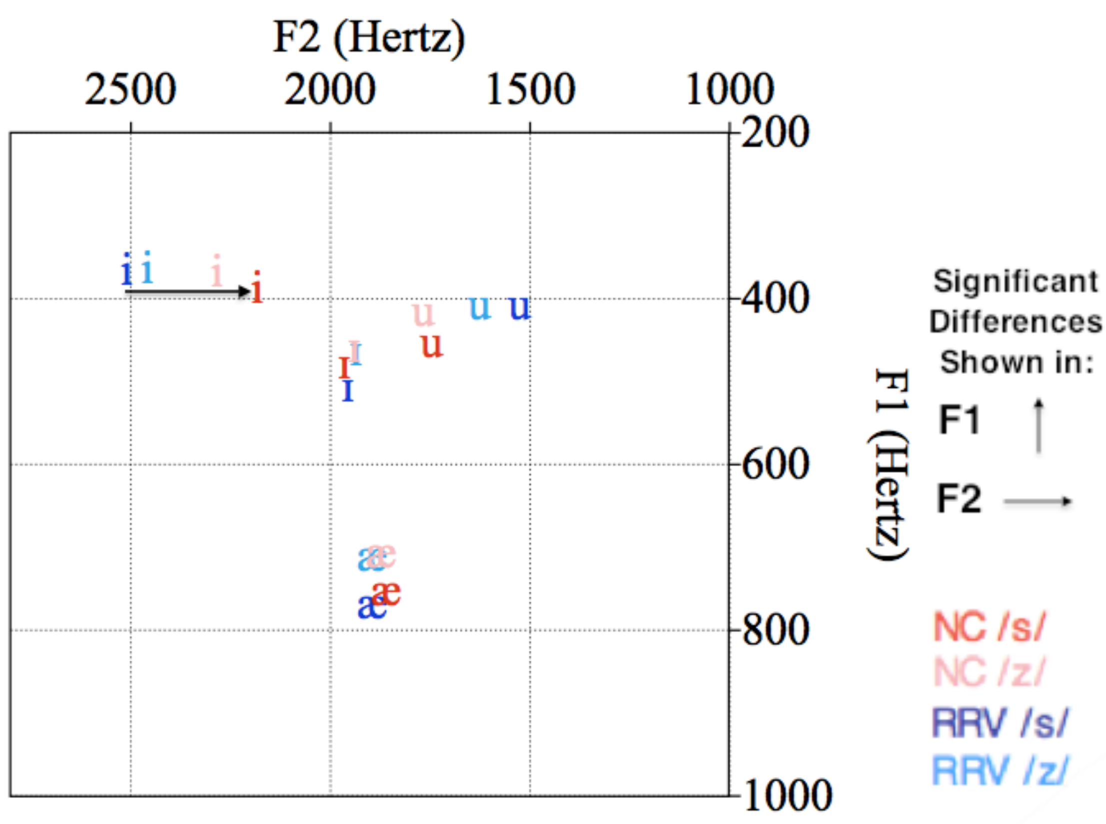

Figure 53: Vowels at 20% of Duration (RRV and NC), Task 3, Position 2

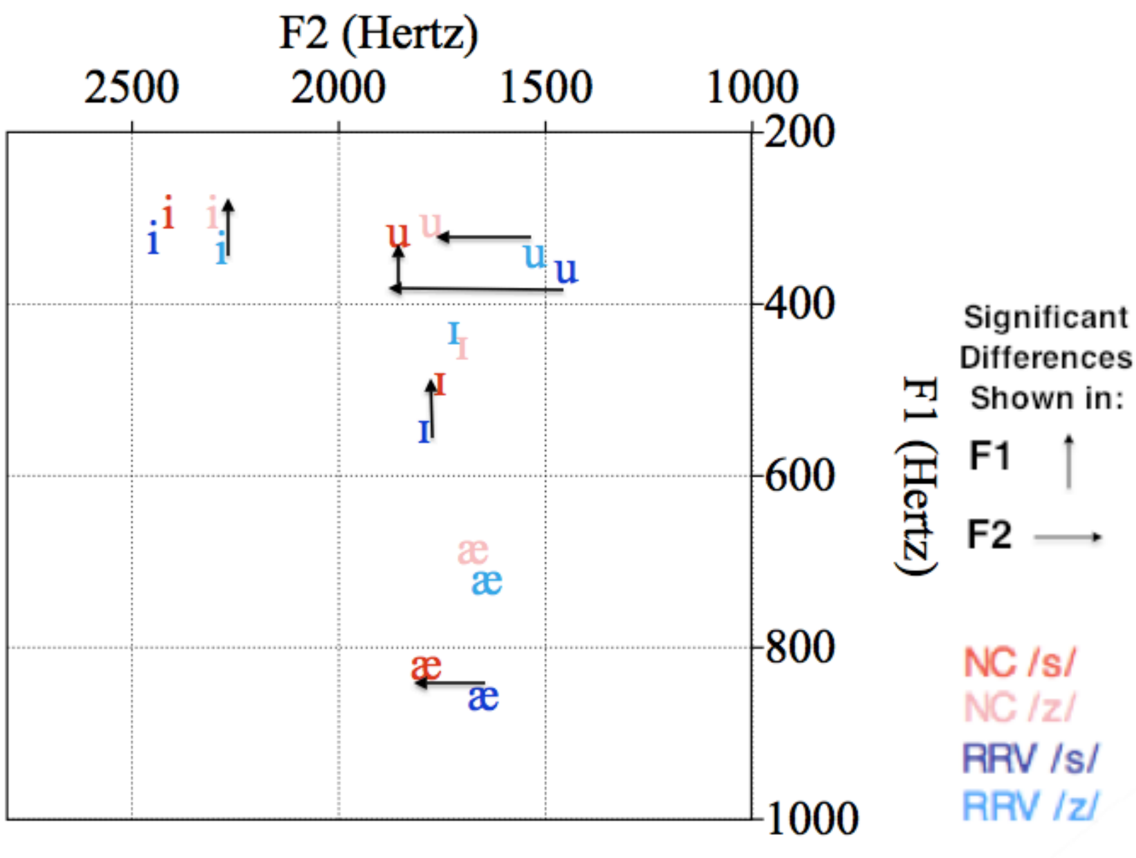

Figure 54: Vowels at 80% of Duration (RRV and NC), Task 3, Position 2

	RRV		NC	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	1.01	0.98	1.05	1.00
/u/	1.00	1.07	1.09	1.04
/I/	1.10	1.29	1.05	1.09
/æ/	1.09	1.20	1.07	1.21

Table 93: RRV and NC Average F_1 Ratios (S-word/Z-word), Task 3, Position 2. Unshaded cells represent significant differences between test and control speakers.

	RRV		NC	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	1.02	1.07	0.96	1.05
/u/	0.94	0.96	0.99	1.05
/I/	1.01	1.05	1.01	1.02
/æ/	1.00	1.01	0.99	1.07

Table 94: RRV and NC Average F_2 Ratios (S-word/Z-word), Task 3, Position 2. Unshaded cells represent significant differences between test and control speakers.

		20%		80%	
		χ^2	p Value	χ^2	p Value
S-word	/i/	0.38	0.538	1.22	0.270
	/u/	1.11	0.291	4.87	0.027
	/I/	2.27	0.132	5.94	0.015
	/æ/	0.27	0.604	0.71	0.399
Z-word	/i/	0.01	0.927	3.90	0.048
	/u/	0.01	0.931	2.75	0.097
	/I/	0.16	0.687	0.34	0.559
	/æ/	0.05	0.828	0.55	0.457
Ratios	/i/	0.99	0.321	0.55	0.459
	/u/	9.25	0.002	1.09	0.296
	/I/	2.01	0.156	10.03	0.002
	/æ/	0.52	0.471	0.02	0.883

Table 95: Significance for F_1 in RRV vs. NC, Task 3, Position 2. $p < 0.05$ is held to be significant.

		20%		80%	
		χ^2	p Value	χ^2	p Value
S-word	/i/	18.66	< 0.001	0.38	0.536
	/u/	3.68	0.055	12.69	< 0.001
	/I/	0.02	0.881	0.29	0.588
	/æ/	0.15	0.699	8.90	0.003
Z-word	/i/	3.23	0.072	0.17	0.676
	/u/	2.13	0.144	4.85	0.028
	/I/	0.04	0.850	0.08	0.771
	/æ/	0.07	0.785	0.52	0.470
Ratios	/i/	5.08	0.024	1.21	0.270
	/u/	4.86	0.028	8.88	0.003
	/I/	0.00	0.986	0.42	0.518
	/æ/	0.13	0.721	5.57	0.018

Table 96: Significance for F_2 in RRV vs. NC, Task 3, Position 2. $p < 0.05$ is held to be significant.

5.3.3.4.2 RRVSc and RRVNS

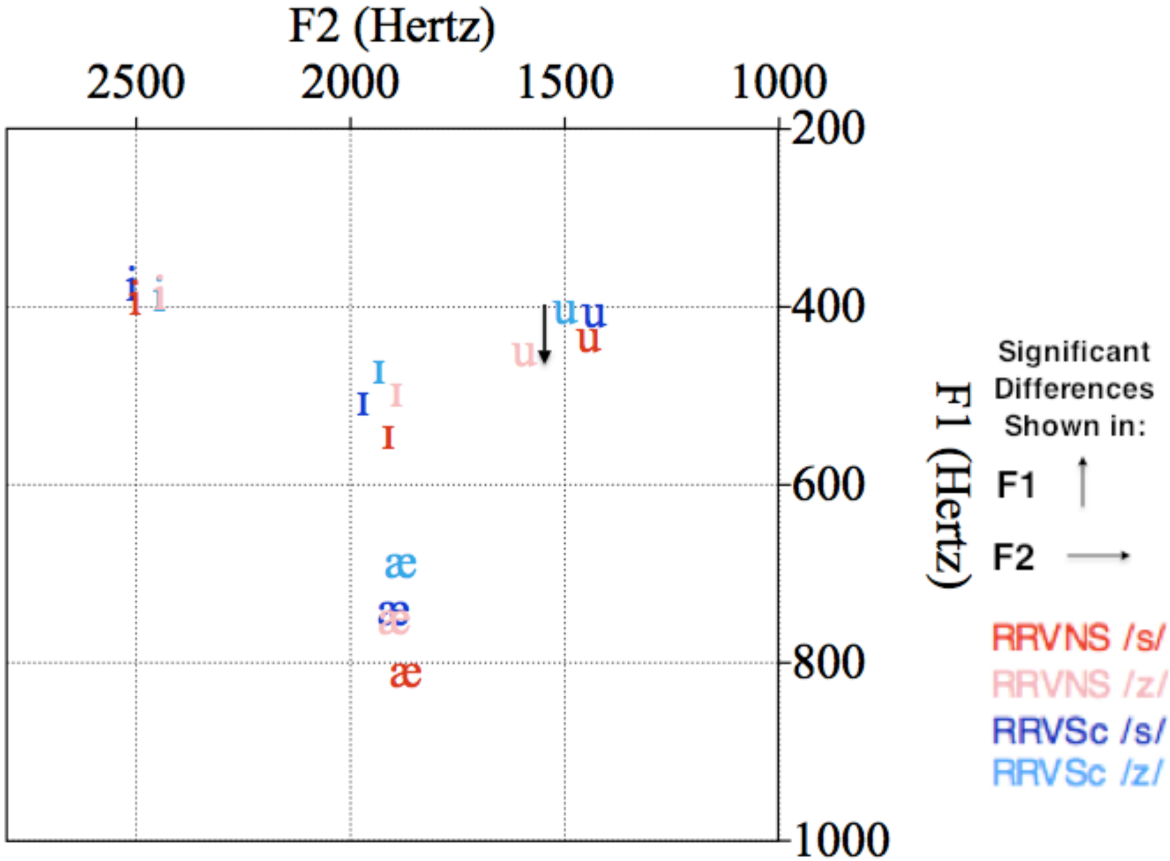

Figure 55: Vowels at 20% of Duration (RRVSc and RRVNS), Task 3, Position 2

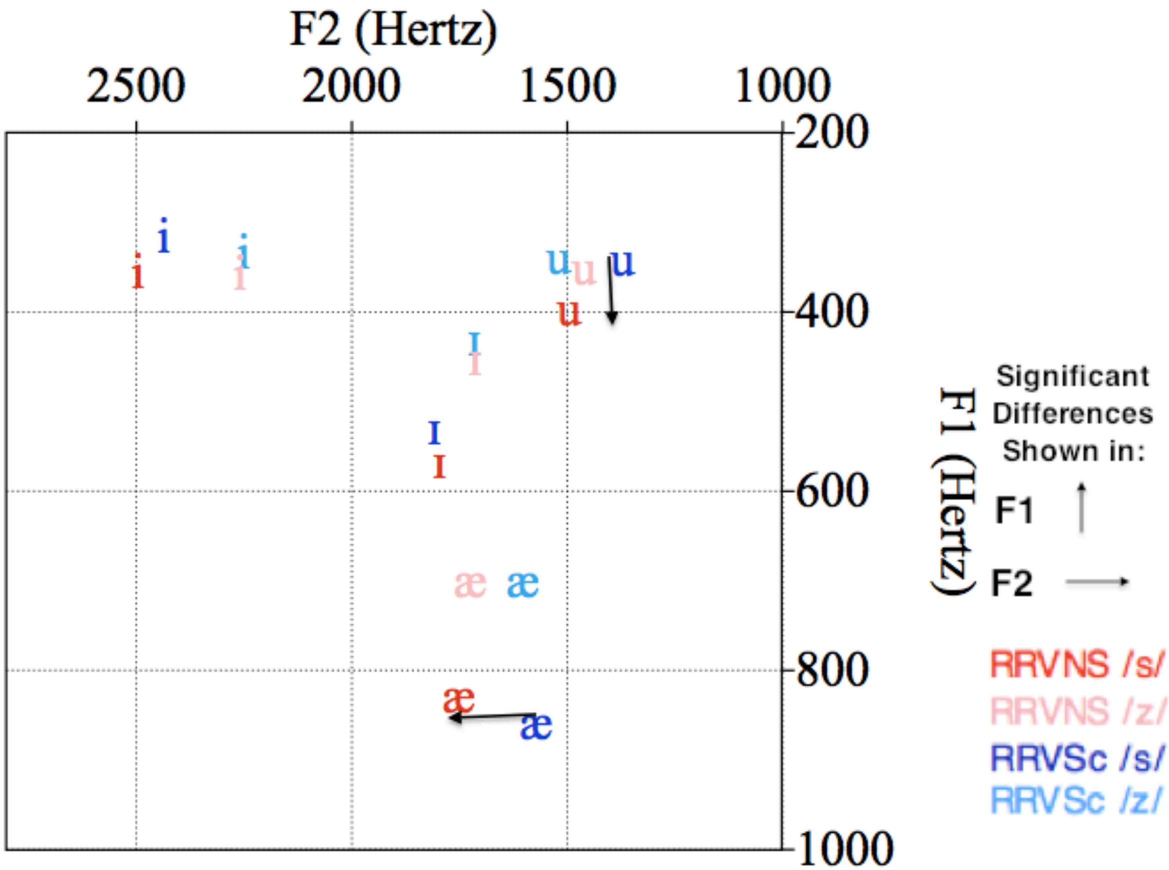

Figure 56: Vowels at 80% of Duration (RRVSc and RRVNS), Task 3, Position 2

	RRVSC		RRVNS	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	0.97	0.95	1.01	1.00
/u/	1.01	1.01	0.96	1.14
/I/	1.08	1.25	1.09	1.26
/æ/	1.08	1.23	1.08	1.20

Table 97: RRVSc and RRVNS Average F_1 Ratios (S-word/Z-word), Task 3, Position 2. Unshaded cells represent significant differences between test and control speakers.

	RRVSC		RRVNS	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	1.03	1.08	1.02	1.11
/u/	0.95	0.92	0.90	1.03
/I/	1.02	1.05	1.01	1.05
/æ/	1.01	0.98	0.99	1.02

Table 98: RRVSc and RRVNS Average F_2 Ratios (S-word/Z-word), Task 3, Position 2. Unshaded cells represent significant differences between test and control speakers.

		20%		80%	
		χ^2	p Value	χ^2	p Value
S-word	/i/	1.60	0.206	2.50	0.114
	/u/	0.77	0.382	6.16	0.013
	/I/	2.60	0.107	0.59	0.442
	/æ/	1.16	0.282	0.16	0.694
Z-word	/i/	0.02	0.898	1.34	0.248
	/u/	5.40	0.020	0.38	0.540
	/I/	0.98	0.323	0.38	0.539
	/æ/	1.06	0.304	0.00	0.987
Ratios	/i/	6.76	0.009	1.09	0.296
	/u/	0.74	0.391	25.43	< 0.001
	/I/	0.09	0.766	0.12	0.725
	/æ/	0.00	0.992	0.99	0.321

Table 99: Significance for F_1 in RRVSc vs. RRVNS, Task 3, Position 2. $p < 0.05$ is held to be significant.

		20%		80%	
		χ^2	p Value	χ^2	p Value
S-word	/i/	0.00	0.956	0.19	0.665
	/u/	0.01	0.937	1.17	0.279
	/I/	0.45	0.504	0.03	0.871
	/æ/	0.13	0.714	7.42	0.006
Z-word	/i/	0.00	0.982	0.00	0.958
	/u/	0.93	0.335	0.21	0.647
	/I/	0.28	0.597	0.00	0.986
	/æ/	0.03	0.855	3.15	0.076
Ratios	/i/	0.01	0.920	0.49	0.482
	/u/	0.60	0.440	4.42	0.036
	/I/	0.47	0.492	0.18	0.676
	/æ/	2.24	0.134	3.62	0.057

Table 100: Significance for F_2 in RRVSc vs. RRVNS, Task 3, Position 2. $p < 0.05$ is held to be significant.

5.3.4 Pitch

Pitch data shows a stronger trend throughout all overall and task results than either of the formants in that, in all of the ratio results that are significantly different between speaker groups, the directionality is the same in all but one (refer to Table 106, Table 114, Table 119, and Table 130; the exception is in Table 103). The test groups always have S-word to Z-word ratios of greater than one, which matches the predictions of the literature given in §3.3. Unforeseen by the literature, however, control groups have ratios of less than one in most cases; where their ratios are greater than one, they are still less than those of the test speakers in all but the exception noted above. These significant differences occur between groups at both levels of comparison, but they are more numerous between the RRV subgroups, indicating an intra-regional variation. That the RRVSc speakers cleave more closely to what is described as either a feature of General American English may be an example of hypercorrection, as Purnell, Salmons, and Tepeli (2005) reported for glottal pulsing in Watertown /z/.

Significant differences in the pitch itself, although they are few, are also consistent. These pitch distinctions occur almost exclusively in Task 2, and will be discussed in §5.3.4.2.

5.3.4.1 Aggregate Data

As with the formants, the pitch data was calculated at the 20% mark of the vowel's duration for those vowels following the fricative and at 80% when preceding the fricative. Results are given in tables for the F_0 values and for the ratios of the S-word value over the Z-word value, with significant results ($p < 0.05$) left unshaded. Significance tables comparing values for the test and control group speakers are also included.

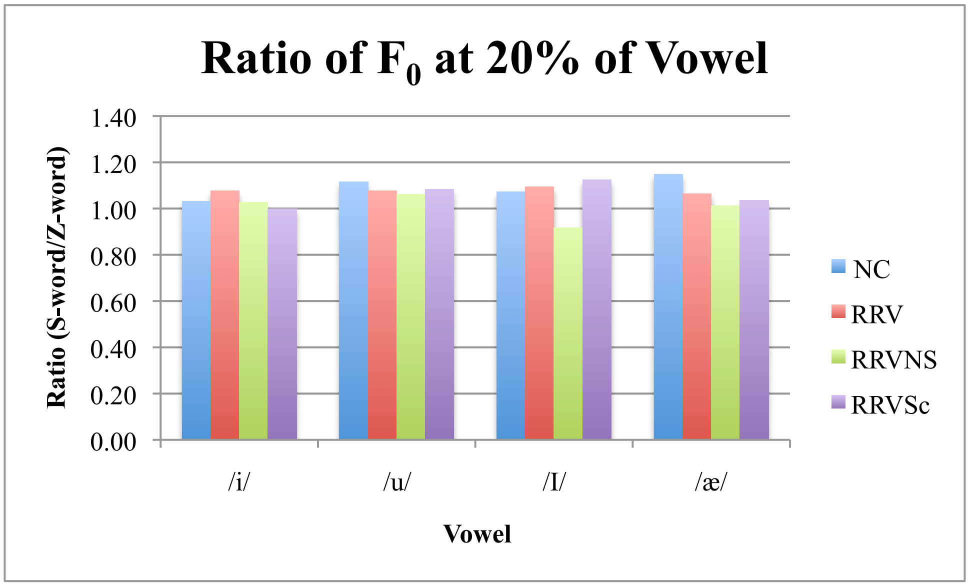

Figure 57: Ratio of F_0 at 20% of Vowel

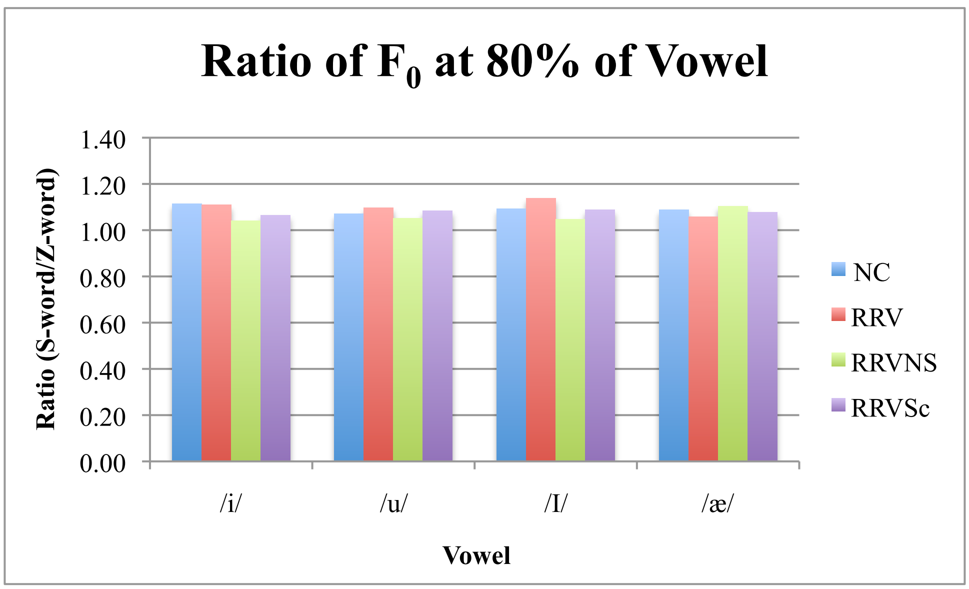

Figure 58: Ratio of F_0 at 80% of Vowel

	RRV		NC	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	197	190	178	173
/u/	211	198	190	172
/I/	206	190	185	190
/æ/	166	156	165	170

Table 101: RRV and NC F_0 values in S-words (Hz). Unshaded cells represent significant differences between test and control speakers.

	RRV		NC	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	185	184	174	160
/u/	198	187	169	169
/I/	188	176	170	176
/æ/	158	154	144	155

Table 102: RRV and NC F_0 values in Z-words (Hz). Unshaded cells represent significant differences between test and control speakers.

	RRV		NC	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	1.076	1.109	1.032	1.114
/u/	1.076	1.098	1.115	1.07
/I/	1.095	1.138	1.072	1.092
/æ/	1.063	1.057	1.149	1.089

Table 103: RRV and NC Average F_0 Ratios (S-word/Z-word). Unshaded cells represent significant differences between test and control speakers.

	RRVSC		RRVNS	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	194	199	201	188
/u/	220	207	220	199
/I/	210	196	185	190
/æ/	159	163	169	166

Table 104: RRVSc and RRVNS F_0 values in S-words (Hz). Unshaded cells represent significant differences between test and control speakers.

	RRVSC		RRVNS	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	192	190	196	194
/u/	203	191	210	194
/I/	185	183	200	183
/æ/	156	153	168	158

Table 105: RRVSc and RRVNS F_0 values in Z-words (Hz). Unshaded cells represent significant differences between test and control speakers.

	RRVSC		RRVNS	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	1.000	1.065	1.028	1.041
/u/	1.083	1.085	1.061	1.052
/I/	1.125	1.088	0.918	1.048
/æ/	1.035	1.078	1.012	1.104

Table 106: RRVSc and RRVNS Average F_0 Ratios (S-word/Z-word). Unshaded cells represent significant differences between test and control speakers.

		20%		80%	
		χ^2	p Value	χ^2	p Value
S-word	/i/	0.75	0.388	0.58	0.447
	/u/	1.04	0.309	1.44	0.230
	/I/	0.60	0.437	0.00	0.987
	/æ/	0.00	0.954	0.28	0.597
Z-word	/i/	0.49	0.486	1.48	0.225
	/u/	3.77	0.052	0.49	0.483
	/I/	1.20	0.274	0.01	0.927
	/æ/	1.12	0.290	0.00	0.992
Ratios	/i/	0.39	0.530	1.02	0.313
	/u/	0.90	0.342	0.25	0.616
	/I/	0.24	0.628	0.02	0.886
	/æ/	8.64	0.003	0.26	0.609

Table 107: Significance for F_0 in RRV vs. NC. $p < 0.05$ is held to be significant.

		20%		80%	
		χ^2	p Value	χ^2	p Value
S-word	/i/	0.04	0.834	0.46	0.496
	/u/	0.00	0.999	0.08	0.780
	/I/	0.73	0.394	0.13	0.723
	/æ/	0.47	0.492	0.07	0.792
Z-word	/i/	0.03	0.862	0.04	0.843
	/u/	0.05	0.817	0.01	0.920
	/I/	0.46	0.496	0.00	0.964
	/æ/	0.59	0.441	0.12	0.729
Ratios	/i/	0.02	0.879	2.09	0.148
	/u/	0.25	0.619	9.00	0.003
	/I/	9.17	0.003	2.46	0.116
	/æ/	0.21	0.647	0.08	0.776

Table 108: Significance for F_0 in RRVSc vs. RRVNS. $p < 0.05$ is held to be significant.

5.3.4.2 Task 2

Differences in the pitch values are much more prominent in Task 2 than in Task 3 or overall. In regional comparisons, the RRV pitch is greater than the NC pitch, whereas in the RRV subgroups the test and control positions are reversed, with RRVNS speakers producing higher pitch than RRVSc speakers. In all cases both groups share responsibility for the difference; for example, NC speakers always have a lower, pitch in significantly different vowels than in the matching non-significant vowels in other tasks, and RRV's pitch is always higher in the same conditions. Task 2 especially seems to incite the speaker groups to opposite extremes. While the emphasis on the /s ~ z/ contrast was greater in Task 3, Task 2 did put stress on the word itself. Perhaps there are prosodic conditions at play in the manner in which the different speaker groups produce emphasis in the given sentence structures, but this would be beyond the scope of this paper.

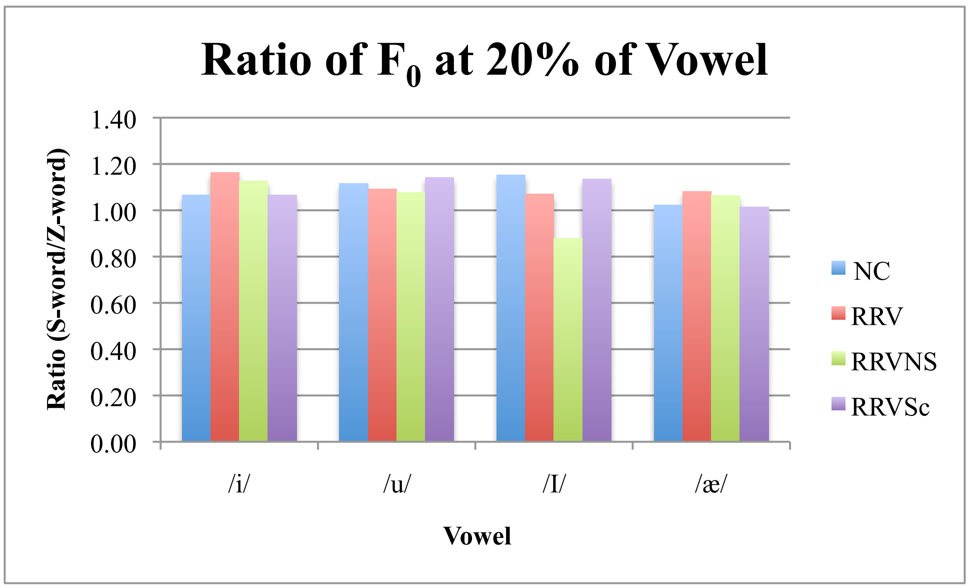

Figure 59: Ratio of F_0 at 20% of Vowel, Task 2

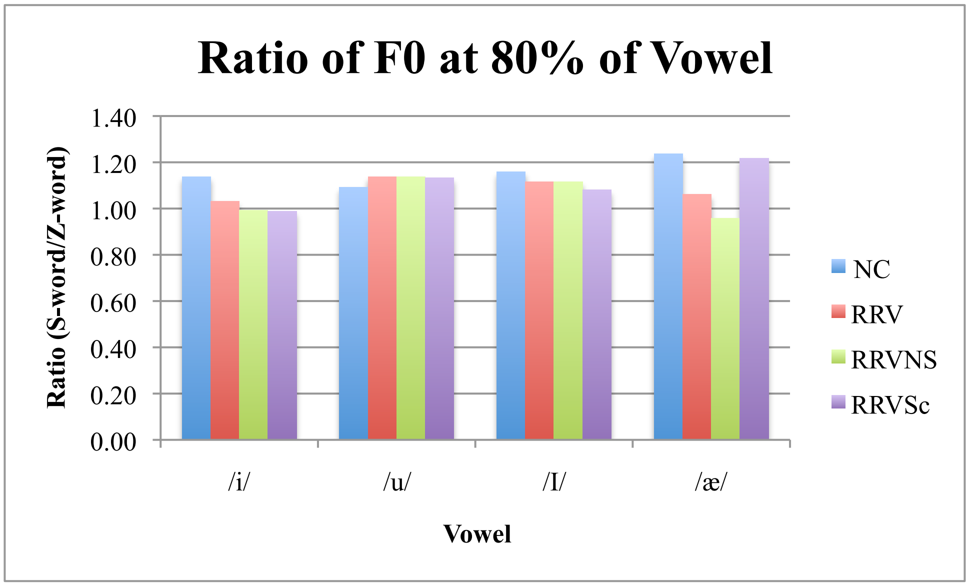

Figure 60: Ratio of F_0 at 80% of Vowel, Task 2

	RRV		NC	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	223	201	198	185
/u/	233	218	177	187
/I/	225	219	198	209
/æ/	174	174	134	162

Table 109: RRV and NC F_0 values in S-words (Hz), Task 2. Unshaded cells represent significant differences between test and control speakers.

	RRV		NC	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	191	207	181	171
/u/	214	202	160	177
/I/	208	202	172	181
/æ/	164	169	133	144

Table 110: RRV and NC F_0 values in Z-words (Hz), Task 2. Unshaded cells represent significant differences between test and control speakers.

	RRV		NC	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	1.16	1.03	1.07	1.14
/u/	1.09	1.14	1.12	1.09
/I/	1.07	1.12	1.15	1.16
/æ/	1.08	1.06	1.02	1.24

Table 111: RRV and NC Average F_0 Ratios (S-word/Z-word), Task 2. Unshaded cells represent significant differences between test and control speakers.

	RRVSC		RRVNS	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	185	212	213	190
/u/	187	237	227	216
/I/	209	223	189	218
/æ/	162	193	180	170

Table 112: RRVSc and RRVNS F_0 values in S-words (Hz), Task 2. Unshaded cells represent significant differences between test and control speakers.

	RRVSC		RRVNS	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	196	215	188	211
/u/	215	210	216	200
/I/	196	205	211	201
/æ/	158	166	169	184

Table 113: RRVSc and RRVNS F_0 values in Z-words (Hz), Task 2. Unshaded cells represent significant differences between test and control speakers.

	RRVSC		RRVNS	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	1.07	0.99	1.13	0.99
/u/	1.14	1.13	1.08	1.14
/I/	1.14	1.08	0.88	1.12
/æ/	1.01	1.22	1.06	0.96

Table 114: RRVSc and RRVNS Average F_0 Ratios (S-word/Z-word), Task 2. Unshaded cells represent significant differences between test and control speakers.

		20%		80%	
		χ^2	p Value	χ^2	p Value
S-word	/i/	0.47	0.493	0.39	0.533
	/u/	8.39	0.004	1.97	0.160
	/I/	0.63	0.429	0.11	0.740
	/æ/	2.56	0.110	0.60	0.438
Z-word	/i/	0.25	0.617	2.44	0.118
	/u/	7.23	0.007	0.58	0.445
	/I/	3.56	0.059	0.85	0.356
	/æ/	5.73	0.017	2.34	0.126
Ratios	/i/	0.57	0.452	2.68	0.102
	/u/	0.04	0.834	0.27	0.600
	/I/	3.49	0.062	0.57	0.451
	/æ/	0.08	0.783	0.70	0.404

Table 115: Significance for F_0 in RRV vs. NC, Task 2. $p < 0.05$ is held to be significant.

		20%		80%	
		χ^2	p Value	χ^2	p Value
S-word	/i/	0.01	0.930	0.82	0.365
	/u/	0.52	0.473	0.36	0.548
	/I/	0.70	0.401	0.03	0.862
	/æ/	4.92	0.027	1.43	0.232
Z-word	/i/	0.15	0.695	0.02	0.881
	/u/	0.00	0.973	0.07	0.793
	/I/	0.25	0.616	0.05	0.830
	/æ/	0.37	0.543	1.04	0.309
Ratios	/i/	0.03	0.863	1.39	0.239
	/u/	1.03	0.311	0.34	0.560
	/I/	4.32	0.038	0.02	0.882
	/æ/	1.32	0.250	3.96	0.047

Table 116: Significance for F_0 in RRVSc vs. RRVNS, Task 2. $p < 0.05$ is held to be significant.

5.3.4.3 Task 3, Position 1

This position has no significant differences in pitch, and the ratio results conform to the general patterns already discussed. All distinctions between groups occur at the regional level, with no differences between the RRV subgroups.

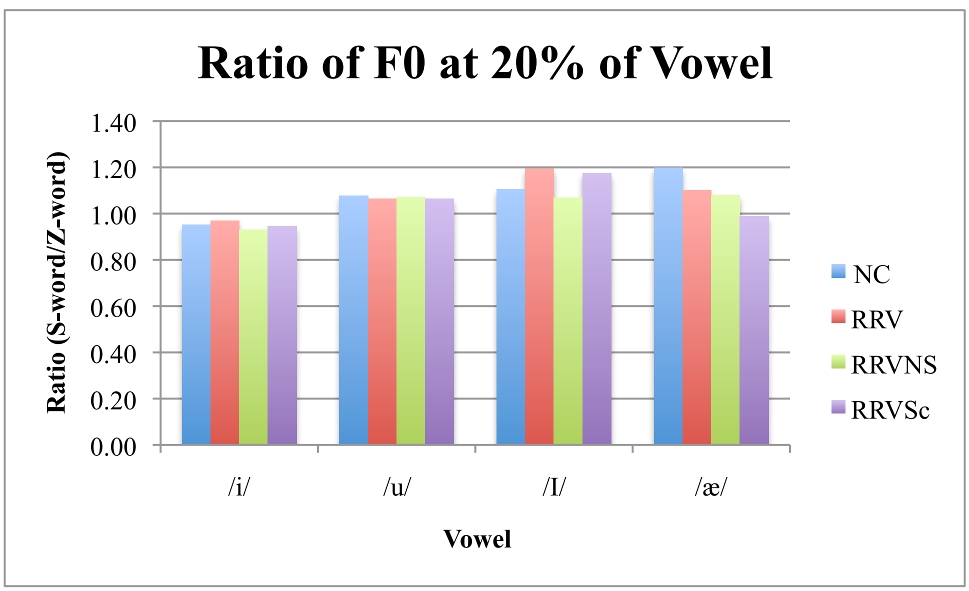

Figure 61: Ratio of F_0 at 20% of Vowel, Task 3, Position 1

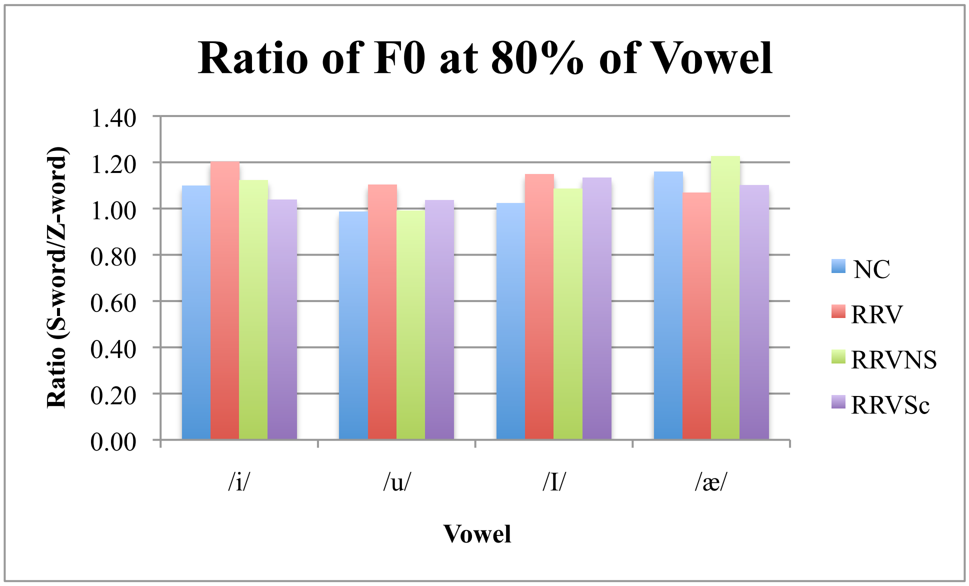

Figure 62: Ratio of F_0 at 80% of Vowel, Task 3, Position 1

	RRV		NC	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	187	202	165	175
/u/	209	204	191	173
/I/	221	187	204	183
/æ/	172	163	189	168

Table 117: RRV and NC F_0 values in S-words (Hz), Task 3, Position 1. Unshaded cells represent significant differences between test and control speakers.

	RRV		NC	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	192	184	183	163
/u/	198	190	175	183
/I/	185	174	180	182
/æ/	157	157	157	160

Table 118: RRV and NC F_0 values in Z-words (Hz), Task 3, Position 1. Unshaded cells represent significant differences between test and control speakers.

	RRV		NC	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	0.97	1.20	0.95	1.10
/u/	1.07	1.10	1.08	0.99
/I/	1.19	1.15	1.11	1.02
/æ/	1.10	1.07	1.20	1.16

Table 119: RRV and NC Average F_0 Ratios (S-word/Z-word), Task 3, Position 1. Unshaded cells represent significant differences between test and control speakers.

	RRVSC		RRVNS	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	181	201	198	211
/u/	213	204	239	207
/I/	215	195	216	201
/æ/	164	172	168	176

Table 120: RRVSc and RRVNS F_0 values in S-words (Hz), Task 3, Position 1. Unshaded cells represent significant differences between test and control speakers.

	RRVSC		RRVNS	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	191	196	212	197
/u/	200	198	223	210
/I/	180	182	201	192
/æ/	164	158	156	150

Table 121: RRVSc and RRVNS F_0 values in Z-words (Hz), Task 3, Position 1. Unshaded cells represent significant differences between test and control speakers.

	RRVSC		RRVNS	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	0.94	1.04	0.93	1.12
/u/	1.06	1.04	1.07	0.99
/I/	1.18	1.13	1.07	1.08
/æ/	0.99	1.10	1.08	1.23

Table 122: RRVSc and RRVNS Average F_0 Ratios (S-word/Z-word), Task 3, Position 1. Unshaded cells represent significant differences between test and control speakers.

		20%		80%	
		χ^2	p Value	χ^2	p Value
S-word	/i/	1.30	0.254	1.17	0.280
	/u/	0.88	0.347	1.77	0.184
	/I/	0.14	0.704	0.08	0.774
	/æ/	0.49	0.486	0.01	0.919
Z-word	/i/	0.29	0.592	1.89	0.169
	/u/	3.60	0.058	0.17	0.678
	/I/	0.08	0.783	0.03	0.862
	/æ/	0.00	0.985	0.04	0.847
Ratios	/i/	0.22	0.641	0.00	0.993
	/u/	0.28	0.596	4.15	0.042
	/I/	0.19	0.659	4.75	0.029
	/æ/	0.93	0.334	0.01	0.903

Table 123: Significance for F_0 in RRV vs. NC, Task 3, Position 1. $p < 0.05$ is held to be significant.

		20%		80%	
		χ^2	p Value	χ^2	p Value
S-word	/i/	0.18	0.670	0.23	0.634
	/u/	0.64	0.424	0.01	0.912
	/I/	0.00	0.971	0.07	0.790
	/æ/	0.02	0.884	0.07	0.790
Z-word	/i/	0.62	0.432	0.00	0.994
	/u/	0.85	0.356	0.26	0.610
	/I/	1.60	0.205	0.18	0.669
	/æ/	0.18	0.675	0.14	0.708
Ratios	/i/	0.01	0.921	0.39	0.534
	/u/	0.02	0.898	0.73	0.393
	/I/	1.37	0.241	0.30	0.584
	/æ/	0.59	0.444	0.61	0.433

Table 124: Significance for F_0 in RRVSc vs. RRVNS, Task 3, Position 1. $p < 0.05$ is held to be significant.

5.3.4.4 Task 3, Position 2

The phrase-final position in Task 3 again follows the overall patterns. The one significant difference in pitch outside of Task 2 is found here.

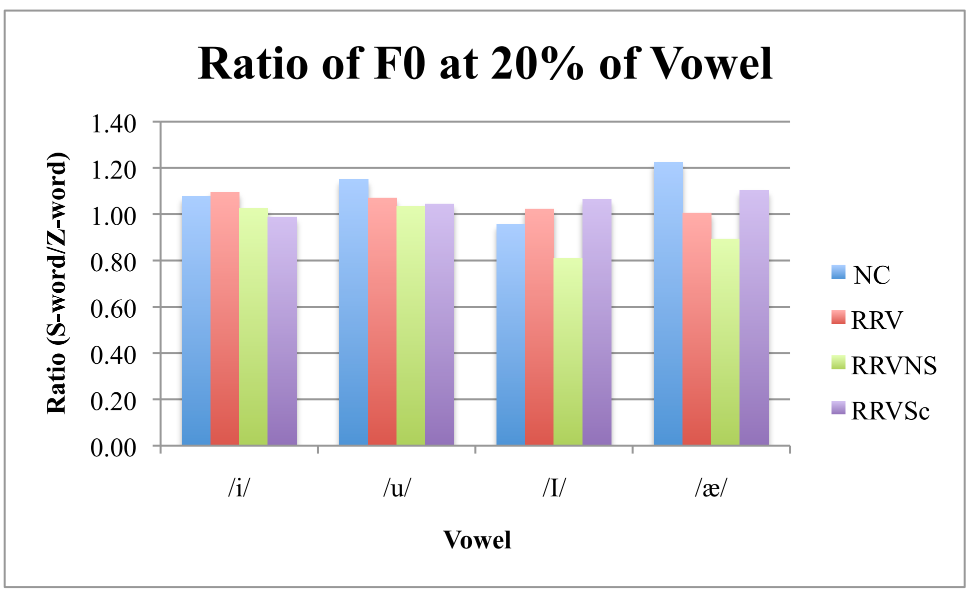

Figure 63: Ratio of F_0 at 20% of Vowel, Task 3, Position 2

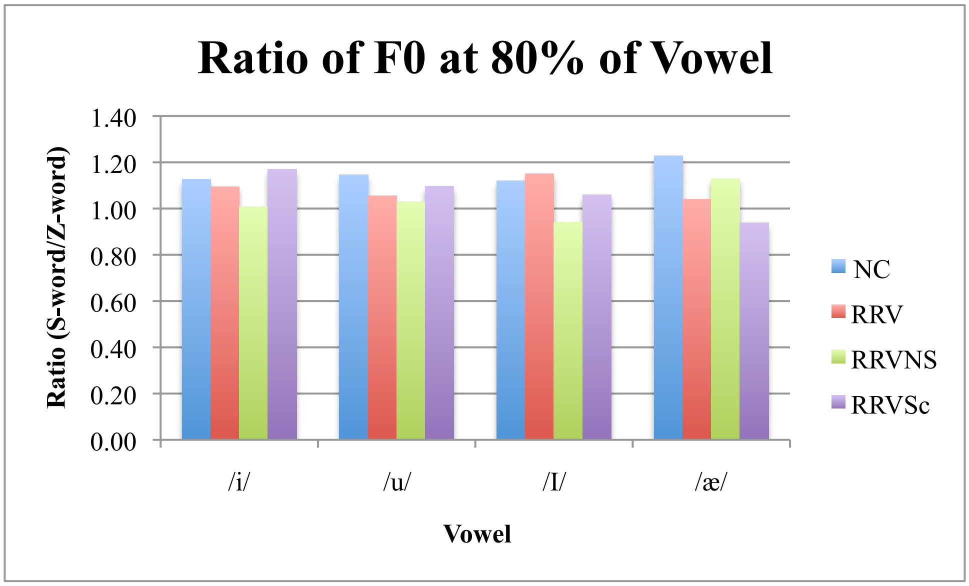

Figure 64: Ratio of F_0 at 80% of Vowel, Task 3, Position 2

	RRV		NC	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	182	167	171	158
/u/	192	171	202	156
/I/	172	163	153	178
/æ/	153	132	172	180

Table 125: RRV and NC F_0 values in S-words (Hz), Task 3, Position 2. Unshaded cells represent significant differences between test and control speakers.

	RRV		NC	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	172	162	160	147
/u/	182	168	171	146
/I/	170	151	160	165
/æ/	154	136	143	160

Table 126: RRV and NC F_0 values in Z-words (Hz), Task 3, Position 2. Unshaded cells represent significant differences between test and control speakers.

	RRV		NC	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	1.10	1.09	1.08	1.13
/u/	1.07	1.05	1.15	1.15
/I/	1.02	1.15	0.96	1.12
/æ/	1.01	1.04	1.22	1.23

Table 127: RRV and NC Average F_0 Ratios (S-word/Z-word), Task 3, Position 2. Unshaded cells represent significant differences between test and control speakers.

	RRVSC		RRVNS	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	185	183	192	163
/u/	200	180	196	172
/I/	188	170	150	149
/æ/	159	123	157	151

Table 128: RRVSc and RRVNS F_0 values in S-words (Hz), Task 3, Position 2. Unshaded cells represent significant differences between test and control speakers.

	RRVSC		RRVNS	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	189	158	188	176
/u/	195	165	189	171
/I/	177	161	187	157
/æ/	146	135	177	141

Table 129: RRVSc and RRVNS F_0 values in Z-words (Hz), Task 3, Position 2. Unshaded cells represent significant differences between test and control speakers.

	RRVSC		RRVNS	
VOWEL	AVG. 20%	AVG. 80%	AVG. 20%	AVG. 80%
/i/	0.99	1.17	1.02	1.01
/u/	1.04	1.10	1.03	1.03
/I/	1.06	1.06	0.81	0.94
/æ/	1.10	0.94	0.89	1.13

Table 130: RRVSc and RRVNS Average F_0 Ratios (S-word/Z-word), Task 3, Position 2. Unshaded cells represent significant differences between test and control speakers.

		20%		80%	
		χ^2	p Value	χ^2	p Value
S-word	/i/	0.37	0.542	0.18	0.673
	/u/	0.07	0.788	0.49	0.485
	/I/	0.65	0.419	0.35	0.557
	/æ/	0.60	0.438	2.47	0.116
Z-word	/i/	0.69	0.405	0.46	0.499
	/u/	0.50	0.479	0.66	0.417
	/I/	0.85	0.357	0.43	0.513
	/æ/	0.67	0.414	0.92	0.338
Ratios	/i/	0.20	0.657	0.91	0.341
	/u/	1.45	0.229	0.27	0.601
	/I/	0.04	0.845	0.07	0.788
	/æ/	2.62	0.105	0.66	0.416

Table 131: Significance for F_0 in RRV vs. NC, Task 3, Position 2. $p < 0.05$ is held to be significant.

		20%		80%	
		χ^2	p Value	χ^2	p Value
S-word	/i/	0.08	0.783	1.41	0.235
	/u/	0.03	0.858	0.09	0.764
	/I/	2.73	0.098	1.10	0.294
	/æ/	0.01	0.908	2.08	0.150
Z-word	/i/	0.00	0.960	0.52	0.473
	/u/	0.04	0.843	0.07	0.785
	/I/	0.13	0.716	0.10	0.757
	/æ/	4.20	0.040	0.11	0.740
Ratios	/i/	1.74	0.187	8.35	0.004
	/u/	0.00	0.947	2.86	0.091
	/I/	22.76	< 0.001	2.00	0.157
	/æ/	6.50	0.011	2.13	0.144

Table 132: Significance for F_0 in RRVSc vs. RRVNS, Task 3, Position 2. $p < 0.05$ is held to be significant.

5.4 Discussion

The glottal pulsing results clearly indicate voicing variation not only regionally but also within the population of Grand Forks, ND/East Grand Forks, MN, when speakers were divided on the basis of the degree of their Scandinavian background (and therefore their likelihood to be exposed to speech patterns influenced by Scandinavian languages). Those with strong Scandinavian background (and speakers in the RRV region when taken as a whole compared to NC) produced less of a contrast between /s/ and /z/ when all other considerations were held equal than either those with no Scandinavian background or NC speakers. The null hypothesis, that there would be no distinction in the acoustic realization of the phonological voicing contrast between populations, is rejected. The nature of this distinction, however, is not always what we expect from previous descriptions of the unusually high degree of /z/ devoicing found in Scandinavian-Americans, summarized in §3.1.1. Although, as predicted, in most positions the test speakers produced less voicing in /z/ than the control speakers, the difference between the voicing in /s/ was greater, and this value was higher in the test speakers, not lower. Hypercorrection may be a possible explanation for the higher /s/ voicing in the test speakers; however, I would expect hypercorrection rather to cause higher voicing in /z/ instead of (or in addition to) /s/. When Purnell, Salmons, and Tepeli (2005) invoked hypercorrection in the Watertown glottal pulsing results, it was due to the higher contrast between voiced and voiceless obstruents. Glottal pulsing in /s/, where the test speakers can be said to "overshoot the mark", is not a prestige or standard feature.

Voiceless fricatives are more abundant cross-linguistically than their voiced counterparts (Ladefoged and Maddieson 1996). Given this preference, that a language with no voiced sibilants would influence speakers to produce extra voicing during a voiceless sibilant seems surprising and counterintuitive. However, if we frame the results in terms of the voicing contrast, it makes more sense: the lack of a voicing contrast in Scandinavian sibilants led to a population who make a smaller distinction in the voicing contrast of English /s ~ z/.

The data presented here raise as many questions about voicing in /s/ as about devoicing in /z/. Ladefoged and Maddieson (1996:49) discuss passive and active devoicing in stops, and distinguish between articulatory voicelessness, with glottal abduction, and acoustic voicelessness, which may involve glottal adduction but not vibration. While this study does not involve an examination of the articulatory processes involved, it seems reasonable to conceive of a similar distinction between the production of /s/ in the test and control speakers. Not only are the control speakers exerting more effort to maintain voicing in /z/, they are also making an effort to produce /s/ without voicing. The test groups do not exhibit completely passive voicing, as they do distinguish between /s/ and /z/ in the same contexts, but they do so to a considerably smaller degree than the control speakers. This suggests incomplete acquisition of the English /s ~ z/ contrast.

I was not able to find an acoustic or articulatory description of the rate of glottal pulsing in /s/ in native speakers of Scandinavian languages, but it is reasonable, since there is no counterpart that differs only in voicing, to assume that it behaves as what Bradley and Delforge (2006:27) describe as a neutral obstruent, with a phonological feature of [0voice]:

> …no articulatory gestures are made in order to realize neutral obstruents as voiced or voiceless because they need not be perceived as belonging to either category… Gradient voicing effects are expected in such cases, due to the interpolation of glottal activity from the surrounding context through the constriction period of the [0voice] obstruent.

What should we make of the previous reports of strong devoicing of /z/ in populations analogous to the current test subjects? One possible explanation for the mismatches between those reports and the present paper is sound change since the older studies were conducted. Moen's speakers who substituted [s] for /z/ ranged from first- to fourth-generation Norwegian-American, which seems to be analogous to the RRVSc speakers. Participants in this study were asked when their ancestors arrived in the RRV region, but not which generation immigrated; all members of the RRVSc group indicated that they were a first- or second-generation native English speaker, however. Given the difficulties of real-time studies discussed in §3.2.2, it is not possible to disprove sound change as the cause of the conflicting results, but as the participants of all studies were not far removed in year of birth, it is true that it does not seem the likeliest explanation. Nor can we identify a regional effect; Simley's subjects were in Crookston, MN, approximately 30 miles east of the site of the current recordings. While Moen included speakers from four states, he did not differentiate results by location, and one of the towns he visited, Hillsboro, ND, is 40 miles south of Grand Forks.

Assuming that these previous impressionistic reports and the current paper are describing the same phenomenon, what would lead Simley (1930) and Moen (1988) to identify /z/ as voiceless so frequently, when the current results show that the difference between mean /z/ glottal pulsing in the test and control groups are often less than 10%? As discussed before, the previous studies did not make any comparison with other populations, so it is possible that they were in reality describing a tendency toward devoicing of /z/ that is common in American English, but ascribed it instead to influence from Scandinavian languages because of their phonology. Recall that one of the brief accounts mentioned in §3.1.1, Allen (1973), specifically described word-final /z/ devoicing as being correlated with Scandinavian parentage, although final devoicing is not associated with Scandinavian languages, and occurs in General American English; as we saw in data from this study, the test speakers in fact produced more voicing in final /z/ than the control speakers. A similar effect was found by Niedzielski (1999), when two groups of listeners from Detroit reported different vowels in the same recording depending on whether they were told that the speaker (who was really from Detroit) was from Detroit or from Canada. As Niedzielski (1999:63) states, "Listeners use social information about a speaker in constructing that speaker's phonological space."

Chapter 6

CONCLUSION

While no previously observed correlates of the voicing contrast were found to be completely neutralized in any of the speaker groups, there were differences in the productions of speakers in North Carolina (NC) and in the Red River Valley (RRV), and in the RRV subgroups. The control groups, speakers in NC and those in RRV expected to have the least exposure to Scandinavian languages (RRVNS), exploited the contrast in the percentage of glottal pulsing to a greater degree. However, the primary distinction was not in the voicing of /z/ as expected from previous impressionistic reports. Rather, the test groups, those most likely to be influenced by Scandinavian languages because of region (RRV) or family background and self-identification (RRVSc), voiced /s/ more extensively than did NC or RRVNS participants. This lessened distinction may be due to a substrate effect from Scandinavian languages, one that is better understood as neutralizing the voicing contrast in sibilants rather than causing voiced sibilants to become unvoiced.

Vowel and fricative duration were quite similar in all groups and seemed to exhibit a trading relation with glottal pulsing. Almost all of these results patterned as expected, but in the case of the formants, there were competing predictions, the Hyperarticulation and the Low Frequency hypotheses. It was found that the formants of the control speakers show a stronger effect from the voicing contrast in most cases, and where they do they favor the Low

Frequency hypothesis. In the F_1 of /i/ and the F_2 of /u/, however, the test groups' productions behave as predicted by the Hyperarticulation hypothesis. These results suggest that neither hypothesis applies universally, but rather the formant behavior is subject to variation, as is the strength of the voicing effect.

Finally, differences in the effect of the voicing contrast on pitch were also found. Test speakers' pitch productions conformed more closely to the predictions made in the literature, while control speakers in most cases follow this behavior to a lesser degree or show the opposite patterns. This shows that the voicing effect on pitch is variable and may indicate hypercorrection in the test speakers, as they exploit this particular contrast to a greater extent that the control speakers in the study.

6.1 Directions for Further Research

The findings presented in this study beg further investigation on many fronts. Chief among these would be a comparison of these results (particularly glottal pulsing, where the voicing contrast was the least pronounced in the test speakers) with data from native Scandinavian speakers. With these speakers it would be useful to include analysis for both L1 Scandinavian languages and L2 English. It would also be informative to conduct similar research using spontaneous speech. The formant results would bear further study as well, including vowels from the entire vowel space.

APPENDIX A

RRV Questionnaire

1. What is your age group (for example, between 55 and 60)?

2. Where did you grow up?

3. What is your first language?

4. Do you speak any other languages? If so, when did you learn them, and how fluently do you speak them?

5. When did your ancestors arrive in the Red River Valley, and where did they come from?

6. What do you consider to be your ethnic background (e.g., French, Welsh, Polish, etc.)? Do you identify strongly with this background? What, if any, organizations or activities do you participate in related to your family background (e.g., cooking traditional holiday foods)?

7. When you were growing up, did most of your relatives, friends, and acquaintances share the same ancestral background as you? Do they now?

Do you participate in any activities (work, church, hobbies, etc.) where you would be especially likely or unlikely to be among people of the same background?

8. Did your parents grow up speaking another language?
Your grandparents?
Your great-grandparents?

APPENDIX B

Glottal Pulsing Script (Schweitzer)

Modified from Original Source

```
Read Strings from raw text file… files_spaces.txt
select Strings files_spaces
number_of_files = Get number of strings
for j from 1 to number_of_files
        select Strings files_spaces
        file_name$ = Get string… j
        Read from file… ‘file_name$’
        basename$ = selected$(“Sound”)

select Sound ‘basename$’
Filter (pass Hann band)… 0 500 100

bandname$ = selected$(“Sound”)

select Sound ‘bandname$’
soundDuration = Get end time
To PointProcess (periodic, cc)… 50 350
To TextGrid (vuv)… 0.025 0.01

select TextGrid ‘bandname$’
int = Get number of intervals… 1

select Sound ‘bandname$’
plus TextGrid ‘bandname$’

Edit
editor TextGrid ‘bandname$’

Move cursor to… 0
voiced = 0
unvoiced = 0

if int = 1

        label$ = Get label of interval
endeditor
                if label$ = “U”
                printline ‘file_name$’ Percentage voiced is 0
                else
                printline ‘file_name$’ Percentage voiced is 100
```

```
                endif

endif

if int > 1

        repeat
                label$ = Get label of interval
                length = Get selection length
                fin = Get end of selection

                        if label$ = "U"
                        unvoiced = unvoiced + length
                        else
                        voiced = voiced + length
                        endif

                Select next interval

        until fin = soundDuration

endeditor

percent=100*voiced/(voiced+unvoiced)
printline 'file_name$' Percentage voiced is 'percent'

endif

endfor

select all
Remove
```

APPENDIX C

Sound Duration Script

```
Sound Duration Script
numberOfIntervals = Get number of intervals... 2 for intervalNumber from 1 to
numberOfIntervals
endfor
startTime = Get start point... 2 intervalNumber endTime = Get end point... 2 intervalNumber
duration = endTime - startTime text$ = Get label of interval... 2 intervalNumber if text$ <>
""
endif
printline 'duration' 'text$'
```

APPENDIX D

Formant and Pitch Logging Script (Crosswhite)

Modified from Original Source

```
Read Strings from raw text file... files.txt
select Strings files
number_of_files = Get number of strings
for j from 1 to number_of_files
        select Strings files
        file_name$ = Get string... j
        Read from file... 'file_name$'
        basename$ = selected$("Sound")

      To Formant (burg)... 0.0025 5 5000 0.025 50

select Sound 'basename$'
To Pitch (cc)... 0 75 15 no 0.01 0.25 0.01 0.35 0.14 400

   Read from file... 'basename$'.TextGrid

   select TextGrid 'basename$'
   number_of_intervals = Get number of intervals... 2
   for b from 1 to number_of_intervals
      select TextGrid 'basename$'
       interval_label$ = Get label of interval... 2 'b'
       if interval_label$ <> ""
          begin_vowel = Get starting point... 2 'b'
          end_vowel = Get end point... 2 'b'

twenty = begin_vowel + ((end_vowel - begin_vowel) * 0.2)
          midpoint = begin_vowel + ((end_vowel - begin_vowel) / 2)

eighty = begin_vowel + ((end_vowel - begin_vowel) * 0.8)

          select Formant 'basename$'
          f1t1$ = Get value at time... 1 'twenty' Hertz Linear
          f1t2$ = Get value at time... 1 'midpoint' Hertz Linear
          f1t3$ = Get value at time... 1 'eighty' Hertz Linear
          f2t1$ = Get value at time... 2 'twenty' Hertz Linear
          f2t2$ = Get value at time... 2 'midpoint' Hertz Linear
          f2t3$ = Get value at time... 2 'eighty' Hertz Linear
          f3t1$ = Get value at time... 3 'twenty' Hertz Linear
          f3t2$ = Get value at time... 3 'midpoint' Hertz Linear
          f3t3$ = Get value at time... 3 'eighty' Hertz Linear
```

```
            select Pitch 'basename$'
             f0t1$ = Get value at time... 'twenty' Hertz Linear
             f0t2$ = Get value at time... 'midpoint' Hertz Linear
             f0t3$ = Get value at time... 'eighty' Hertz Linear

            fileappend "'basename$'formants.txt"
'interval_label$"tab$"f1t1$"tab$"f1t2$"tab$"f1t3$"tab$"f1"tab$"f2t1$"tab$"f2t2$"tab$"f2t3$"t
ab$"f2"tab$"f3t1$"tab$"f3t2$"tab$"f3t3$"tab$"f3"tab$"f0t1$"tab$"f0t2$"tab$"f0t3$"tab$"f0"t
ab$"newline$'

        endif

    endfor

    select all
    minus Strings files
    Remove

endfor

select all
Remove
clearinfo
print All files have been processed.  What next?

## written by Katherine Crosswhite
## crosswhi@ling.rochester.edu
```

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