Sociophonetic Deception: The Elements of Vocal Disguise

by
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Abstract

The focus of my research is vocal disguise within forensic linguistics. Specifically, I answer the question of what individuals are most likely to do with their voice when they do not want to be recognized by a listener. I also focus on whether specific sociolinguistic characteristics – gender and place of origin – have an effect on the disguise choices that individuals make. My research has found that participants show a preference for altering pitch and/or duration across conditions, as well as taking on a foreign accent. Gender and origin were found to be significant for respect to differences in duration, and significance was also found between origin and pitch. These results suggest that disguise might contain elements of style shifting, and that a speaker's choice is more systematic than random..

Acknowledgements

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Chapter 1: Introduction

1.1. Introduction

Over the last 45 years (Endres et al. 1971, Hollien and Majewski 1977, Dumas 1990), there has been an increasing amount of research focused on what it means to disguise one's voice. A disguised voice, such as that used by the perpetrator of a crime (Dumas 1990; French 1994; Hollien and Majewski 1977), might be achieved through simple changes to a speaker's inherent vocal properties like pitch range, phonation type, and degrees of nasality. Another way to disguise one's voice is to alter the socially learned properties of one's dialect by imitating features of a "foreign" accent. The range of accent-related options that speakers might choose from, as well as the range of variation that exists between speakers in the production of a disguised voice has not been subjected to a systematic study. In this project[1], I investigate vocal disguise using the variationist sociolinguistic framework (Labov 1966, Tagliamonte 2007), by testing the view that disguise is a form of style-shifting (Eckert and Rickford 2001): a situational change in the grammatical, phonological, phonetic and lexical properties used by a speaker. The general idea examined here is that a vocal disguise is not randomly executed by the speaker. Rather, it is a form of sociolinguistic style shifting, which draws on linguistic forms that are meaningful to members of a speech community. As such, disguises across members of a community will share similar properties. If such a connection exists, then it may be possible to extrapolate that individuals from a particular speech community will alter the same core group of linguistic features when disguising their voice, giving forensic linguists a point of reference with which to further develop their analyses.

To establish whether such a relationship does exist, I first examine how vowels are used in disguised speech. Second, to determine which sociolinguistic factors might govern or influence

1 Funded through a Bombardier Scholarship, Social Science and Humanities Research Council (#766 2013-4110).

phonetic shift between normal speaking styles and disguised voices, I consider the role that a speaker's gender plays in the selection of a voice disguise: do males alter the same phonetic features that females do? Third, I study how regional dialect variation is involved in disguising one's voice: do speakers of the same variety of English alter similar phonetic properties when asked to disguise their voices, and do speakers of different varieties select different properties? This study will provide an additional understanding of forensic linguistic theories regarding vocal deception with respect to the use of accent as a disguise. As well, it will establish a connection between the realms of forensic linguistics and sociolinguistics, in that it will consider vocal disguise as a form of situational style shifting.

1.2. Terminology and Background

I turn now to each of these aforementioned concepts, as well as to note some of the terminology used within forensic linguistics, particularly with reference to vocal disguise.

In this study, the term "modal" will be comparable with the words "normal," or "typical". That is, modal articulation is the form of articulation that a speaker uses most often when speaking normally, in a day-to-day setting. Similarly, modal voice and modal phonation are the speaking voice and phonation that a speaker would use in a typical setting. In this study, modal voice is the voice which is found in non-disguised speech.

On the opposite end of the voice spectrum lies voice disguise, which assumes that an individual will change the modal qualities of their voice in order to become less identifiable by a listener.

Chapter 2: Literature Reviews

2.1. Style Shifting in Variationist Sociolinguistics

This literature review has three aims: to examine (1) the topic of style shifting, (2) vocal disguise and its effect on acoustic features and properties, and finally, (3) how style shifting and vocal disguise are related.

The topic of speaking style and style-shifting, a central component to variationist sociolinguistic theory, has been examined extensively in early Labovian literature. Labov (1972) suggests that two general speech styles, careful speech and casual speech (p. 79), form a stylistic continuum. The latter is what one would expect to hear in everyday conversations between friends, and it is generally more relaxed in nature. Careful speech is more formal, and is what one would expect an individual to employ during job interviews, as well as in sociolinguistic interviews. It is not uncommon for people to style-shift depending on who they are speaking to. For example, as Labov (1972) reports, a participant shifted from a "careful, quiet, controlled style" when speaking to the interviewer, to a "louder, higher-pitched style" when speaking to her children (p. 89).

To this end, Labov (1972) studies how the absence (or presence) of [r] in New York English is influenced by different styles of speaking, and across different socioeconomic groups. Labov hypothesized that [r] deletion would occur more frequently among lower class individuals and in less-monitored speech styles, while it would rarely occur in higher class individuals and more formal speech styles. He obtained data by approaching workers at three different department stores and asking where a particular department was located (a department that was located on the *fourth floor*). After the worker responded, "fourth floor", Labov would then ask again, "Excuse me?", which would result in a more emphatic answer. For each interaction, Labov expected to receive at least four instances of [r]: fou**r**th floo**r** (casual speech) and fou**r**th floo**r**

(emphatic speech). Overall, Labov found that his hypothesis was supported: as social class increased, so too did the usage of [r]. It was also found that production of [r] occurred more often across all classes in the second instance of "fourth floor," the emphatic production. In this way, regardless of class, style shifting has commonalities in the way individuals choose to shift depending on the situation. If vocal disguise is connected to style shifting, then this may indicate that there could be similar situational commonalities across speakers when disguising one's voice. That is, all speakers may be likely to alter the same features when asked to disguise their voice.

While Labov's view of style explains some patterns of linguistic variation, more recently, style has been re-examined as something more than simply attention-paid-to-speech. Bell (2001) analyzed the speech of eight individuals, four of whom were interviewers, and four of whom were interviewees. Each group of four was comprised of a male and female Maori, as well as a male and female Pakeha[2]. All of the individuals were similar in age, class, education, and place of origin. Three interviews were conducted: a baseline interview (same gender and same ethnicity), a cross gender interview in which topics focused on gender identity, and a cross-ethnic interview in which discussion was focused on ethnic identity. Bell's hypothesis was simple: that individuals speak differently depending on who they are speaking to, and how much they have in common with who they are speaking to.

Bell found that use of the "eh" marker, which is thought to be a marker of male Maori men, was most commonly used in the Male Maori x Male Maori interview, and used subsequently less with each individual difference (Female Maori > Male Pakeha > Female Pakeha). He found that the Male Maori interviewer produced the least number of "eh" markers in his speech, and thus by consequence, his interviewees produced very few "eh" markers as well. This indicates that

2 New Zealanders of Caucasian descent.

individuals accommodate their speech to match the speech of their conversation partner(s).

Accordingly, Bell views style as having the four main properties:

1. Style is what an individual speaker does with a language in relation to other people (p.141)
2. Style derives its meaning from the association of linguistic features with particular social settings (p. 142)
3. Speakers have a fine-grained ability to design their style for a range of different addressees, as well as for other audience members (p. 146)
4. Style shifting according to topic or setting derives its meaning and direction of shift from from the underlying association of topics or settings with typical audience members (p. 146)

Each of these points are examined in more detail below. The goal is to apply them to elements of vocal disguise in order to see how a disguise, such as that used by the perpetrator of a crime, might be understood as a form of style shifting.

More recent research related to style shifting has been widespread: a 2011 article by Allan Bell and Andy Gibson offers an overview of several topics related to the sociolinguistic factors of performance speech, including stylization, audience and referee design, indexicality, enregisterment, and discursive culture. One in particular, stylization, will be discussed in further detail below.

According to their article, there are two types of performance speech: everyday and staged. Examples of everyday performance speech are reported speech and quotative speech, though Coupland (2007) explains that instances of everyday performance speech can occur spontaneously in conversation, when performer-audience situations arise. Staged performance speech is scheduled, and typically involves one or more speakers performing on a stage or in

front of a camera or microphone. Examples of this form of speech include a play, concert, or a radio show. To this end, it is expected that staged performances are linguistically stylized. The importance of performance language has been called into question in the past (Trudgill 1986), but Coupland argues that with the growing presence of media in our day-to-day lives, the likelihood of a connection between everyday and performed speech seems more plausible.

Stylization – the concept of taking on the voice of another speaker – revolves around the idea that every instance of language use that one experiences will carry on to influence one's own language (Bakhtin 1981). In this way, if one has similar instances of a language experience (i.e., a specific accent, the voice of a parent or a particular actor), then one should have a larger frame of reference from which to draw upon when stylizing one's voice, and therefore one's stylization should be more similar to the production of the actual voice. This is relevant to the study at hand. Speakers who have similar linguistic experiences (i.e. share a common variety) might be more likely to implement similar linguistic properties in their stylized, performed speech, such as vocal disguise.

Gibson and Bell (2010) outline four sociophonetic processes that may occur when a speaker is not fully familiar with a particular variety of speech: selectivity, mis-realization, overshoot, and undershoot. Selectivity is the process of taking on certain features of a speech style but ignoring others, likely due to the fact that certain features are more salient than others in speech. Mis-realization is when one fails to accurately portray features of speech due to incapability. Overshooting is when a characteristic or feature is exaggerated beyond its normal production, while undershooting is the opposite. These processes are important to keep in mind because it may be that they influence the production of a participant's disguise in the study at hand.

Up to this point, I have outlined some of the terminology used within forensic linguistics. I have explained how style shifting is related to casual and formal speech through Labov (1972) and Bell (2001), and I have touched on several topics such as stylization and selectivity and how they may potentially influence one's ability to disguise one's voice. So as to extend these concepts of style shifting to vocal disguise, I now present a review of recent research conducted on vocal disguise. I follow this with my argument that disguise is a form of style shifting and that like style shifting, is influenced by sociolinguistic factors such as a speaker's gender as well as his/her linguistic background.

2.2. Vocal Disguise

This section looks at selected works dealing with acoustic features of disguised voices. The tendency for speakers to alter certain phonetic features, as shown here, will be examined according to Bell's stylistic elements outlined above.

Zhang (2007) explores a total of nine voice disguises, such as "raised and lowered pitch, fast and slow speech, pinched nostrils, masking on mouth, and the use of bite blocks" (p. 155). The aim of her study was to see how these disguises alter the features, acoustic properties, and among other things, the overall accuracy of the ability of an individual to identify the speaker. Eleven speakers read ten sentences a total of ten times: once in their normal voice, and then once in each of the previously mentioned disguises. Praat was then used to measure parameters such as pitch, duration, and formant frequency.

Zhang first chose the speaker who seemed the most skilled in vocal disguise and analyzed her recordings acoustically. She discovered that when the voice is disguised, there is greater variation within speech than when a voice is undisguised. Zhang notes that vocal disguise can

only alter one's voice so much, as the physical anatomy of a speaker's vocal tract plays a large role in just how much one can manipulate their voice.

Next, Zhang conducted an acoustic and statistical analysis by comparing the disguised speech of all eleven speakers to their normal speech productions. This investigation showed that there is little consistency across parameter changes, as some are more influenced by vocal disguise (e.g., pitch), while others are not as sensitive to disguise parameters (e.g., formants).

Zhang's final stage of investigation analyzed the disguised speech of all eleven participants through an Automatic Speaker Recognition System. This system was designed to match a disguised voice with the appropriate non-disguised voice of each speaker. Overall, it was found that correct identification of a speaker was significantly lower when a voice was disguised, although identification was still possible in cases outside of mouth-masking and whispering. Zhang concluded by noting that one's disguising skill likely has an impact on identification: if a speaker is more highly skilled in vocal disguise, then they are probably less likely to be identified correctly.

Numerous aspects of Zhang's report are relevant to my study. First, Zhang presents which tactics are more likely to be employed by participants during a disguise. It also provides me with the understanding that certain participants are likely to be inherently better at disguising their voices, and thus my results may show larger parameter shifts in certain individuals than in others. To this end, sheer talent as well as the idea that one's vocal tract shape may influence how well they are able to disguise their voice is also an interesting point to consider. The concept of disguise being not only a mental choice but also a physical ability could be argued as being similar to style shifting: in order for style shifting to occur successfully, both the speaker and the listener must understand which linguistic variant is being spoken. It is conceivable, then, that certain individuals may be better at shifting their speech style (e.g. maintaining r-fullness when

speaking to an individual from upperclass New York City), while others may not have the physical or mental capability to shift their speech in such a way.

Zhang's thesis also presents the idea that parameter changes affect acoustic features to different degrees: pitch is most sensitive to disguise parameters, while F1 and F2 are less sensitive. This is a possible pattern that may be portrayed in my results. Similarly, because certain features are more influenced than others, this means that there is less variation possible within disguise tactics when compared to modal voice variation. With respect to my own results, this may mean that I will see the same disguise tactics being used across participants.

We turn now to data from forensic phonetics that uses the analysis of voice recordings to identify a suspect in a court case (French 1994). As per Masthoff (1996), when an anonymous voice sample is undergoing analysis for forensic identification, it is assumed that the speaker may be disguising their voice. In Masthoff's study, participants were instructed to read a sentence in their normal (modal) voice, and then again with the instruction, "Imagine being a blackmailer who is to transmit a spoken message by telephone. Obscure your identity to the best of your knowledge by disguising your voice..." (p. 162). The author was interested in determining the preferred forms of disguise, as well as if there were any similarities between one's modal voice and their disguised voice. Findings revealed the following: 20% of participants altered their modal articulatory patterns; 15% altered their modal phonation and manner of speaking; 35% chose to alter only their modal phonation; and 55% used single disguises (choosing to only alter one of the four categories between phonation, respiration, articulation, and manner of speaking) over multiple disguises. Masthoff also found that only males chose to raise their pitch (F0), while only females lowered their pitch. The most common ways in which participants of either gender disguised their voices at the phonation level was through the alteration of speaking fundamental frequency (pitch) or through the employment of whispering. Interestingly, of the twenty

participants in the study, only three disguised their voices in such a way that it successfully masked the properties of their modal voice – many speakers whose accents had strong regional features did not attempt to alter them, making them more easily identifiable.

Masthoff's study is relevant to my research because it uses an experimental design that will be replicated here (see Chapter 4). As well, potentially relevant to my study is the fact that Masthoff found multiple participants who spoke with strong regional accents who did not make any attempt to obscure them. As many of my participants are from Newfoundland, there are numerous regional accents and salient dialectal features to pay attention to and see whether the speakers change between their modal and disguise conditions.

With respect to dialect and accent-specific studies in vocal deception, there has been little research to date. Sjöström et al. (2006) indicate that a listener is less likely to correctly identify an individual when the individual switches dialects, but this research is based on aural identification rather than through the use of computerized identification software. The authors claim that if a perpetrator were to use different dialects at the time of the offense versus at the time of a voice line-up, then it is likely the witness would have a high degree of difficulty in correctly identifying the suspect. This suggests that dialect/accent related features outrank other disguise features, such as pitch.

While my study does not focus on voice identification, it is interesting to note the claim that changing one's dialect makes one harder to identify.

Up to this point, this literature review has given an overview of style and style-shifting within sociolinguistics. It has summarized what disguise is: altering the linguistic features and/or acoustic properties of one's voice with the intent of misidentification. It has also shown how pitch and foreign accent or dialect change are of particular importance to vocal disguise. Finally, it has presented numerous predictions for the outcome of this particular study:

1. That disguise is related to imitation and a form of style shifting (Labov 1972)

2. That certain parameters are more likely to be altered than others (i.e., pitch is more likely to be altered than formant frequencies) (Zhang 2007)

3. That males will raise their pitch while females will lower their pitch when disguising their voice (Masthoff 1996). In this same vein, it is conceivable that a number of participants may choose to alter their dialect or accent over a specific feature such as pitch or creakiness as dialectal features are more salient to a listener.

4. That I am likely to see changes in accent or dialect than in choosing a specific feature to alter (Sjöström et al. 2006).

2.3. Style Shifting vs. Vocal Disguise

Let's return now to Bell's four elements of style and identify how they apply to vocal disguise. The first, that style is what an individual speaker does with a language in relation to other people (p.141) is essentially what happens in disguise. Individuals manipulate linguistic features as a result of needing to communicate with other people. The obvious point here is that while these speakers wish to communicate specific informational content they do not want their linguistic features to reveal their identity. This also ties in with Bell's element that speakers have a fine-grained ability to design their style for a range of different addressees, as well as for other audience members (p. 146). This ability is clearly demonstrated by the experimental studies presented above that show that some acoustic properties are implicated in a disguise. Second, style derives its meaning from the association of linguistic features with particular social settings (p. 142). Following the first point, the second point makes it clear that some linguistic features carry social meaning. It seems likely then that the linguistic features that carry the most or most obvious social meaning (i.e. have the ability to identify a speaker) are the ones that are subject to

stylistic shifting. This also relates to Bell's final element, that style shifting according to (topic or) setting derives its meaning and direction of shift from from the underlying association of (topics or) settings with typical audience members (p. 146). When a speaker uses a disguise, he or she will shift away from sociolinguistically meaningful features and towards those that have no meaning in the social context in which the disguise is used.

As we have already seen with Labov and Bell, individuals style shift in different ways based on who they are speaking to. It is reasonable to assume the same is true for individuals that are disguising their voice: if disguise is viewed as a style, then there should be similarities in the shift-choices of people that are disguising their voice in the same way that speakers accommodated r-lessness/r-fullness in Labov's study.

This theory is supported by Zhang and Masthoff: both conclude in their studies that pitch is the most sensitive parameter in vocal disguise and that individuals appear to be most likely to employ pitch alteration in their choice of disguise. This suggested pattern will be further discussed in Chapter 5.

We will now move to the analytical framework of the current study.

Chapter 3: Framework

3. Framework

This study follows a quantitative approach (Labov 1966, Tagliamonte 2007). A quantitative analysis focuses on statistical patterns of linguistic behaviour rather than on individual occurrences of linguistic forms. This pattern is what sociolinguists use to create a representation of the underlying variable grammar of both the speaker and the speaker's speech community.

Tagliamonte explains that quantitative analysis allows researchers to see how the studied (dependent) variable is influenced by social and grammatical factors. Social factors, or external factors, are generally analyzed first, followed by grammatical (internal) factors, such as tense and grammatical person. After all of the relevant factors have been examined, statistical analysis may begin.

Tagliamonte identifies three types of evidence that can be used for the interpretation of a variable rule analysis. First is statistical significance: through the use of a statistical test such as an ANOVA test, factors are assigned a value. In general, factors which are found to be at or below the .05 level are considered statistically significant to the study, while factors which have a value above .05 are not. Next is constraint ranking, in which factors are assigned factor weights, and from these values the researcher is able to construct a hierarchy of factors, beginning with the highest weight, and ending with the lowest. Finally, Tagliamonte turns to relative strength. Using the factor weights found in the previous step, each factor group has the lowest weight subtracted from the highest weight, and then all of the groups are compared to each other. The group with the highest range is determined to be the strongest constraint, while the weakest constraint is the group with the lowest range. Similarly, looking at the multiple regression allows one to identify the order of selection factors.

Within my study, I believe the most important factor of the three will be statistical significance. I am interested in understanding the significance of the features that participants choose to alter when disguising their voices, both within the same speech community and across different speech communities.

Researchers using a quantitative analysis are advised to compare findings across several conditions. For example, it is not only important to look at an individual's results, but the individual's results in comparison to everyone else that partook in the study. One may also compare across ethnic groups, or across an age range with a particular participant, or conversely, an entire population in an apparent time/real time analysis.

These points are important to my own study as I plan to not only analyze the speech of individual speakers, but to compare speakers across gender lines and across dialect region. This will tell me if gender or dialect region has an influence on how an individual chooses to disguise their voice.

Chapter 4: Methodology

4. Methodology

This study consisted of 21 participants (13 women, 8 men) who took part in a vocal disguise experiment. One of the participants, Speaker 019 (Female from Newfoundland), did not speak clearly enough for her recording to be analyzed, so it was excluded from the data analysis.

	NL	PEI	AB	USA	TAN	MAL	**TOTAL**
Male	5	0	0	2	1	0	**8**
Female	8	2	1	0	0	1	**12**
							20

Table 1: Participant Breakdown

Recruitment was completed through several means: posters were placed around the Memorial University campus, announcements were made via social media, and in-person recruitment was initiated through classroom visits[3].

Participants were invited to meet at the Speech Science and Language Acquisition Lab (SSLAL) and asked to read and fill out two forms: a consent form and a brief survey indicating their gender, age, and place of origin.

Each recording process was as follows: participants were brought into a sound attenuated room in the SSLAL. Participants were shown a printed copy of Comma Gets a Cure (Honorof et al., 2000) and instructed to read the text two times straight through: the first time in their normal

3 Ethics approval was obtained from Memorial University's Research Ethics Board (ICEHR) in January 2014 (#20140994-AR).

speaking voice, and the second time in a disguise of their own choosing. They were told that the disguise could be as simple or as elaborate as they wanted, but that the disguise was to remain the same from the beginning to the end of their reading. Should a participant make a mistake while reading, they were told to go back a couple of words and continue reading. Participants were given two-to-three minutes to briefly familiarize themselves with the passage and then asked if they had any questions. The recording then took place. Once both recordings were completed, the researcher (author) returned to the room and turned off the recorder, and if the participant had no questions regarding their involvement, they were free to go.

Recordings were made using an Audio Technica AT831b condenser microphone and Marantz PMD 670 solid state recorder, and sampled at a frequency of 22kHz and a 16 bit depth to uncompressed WAV format. All recordings were transferred from the recorder to a MacBook Pro. Each sound file was renamed to ensure both anonymity and organization (eg. Speaker_001). Each sound file underwent preliminary steps to prepare for statistical analysis. First, each recording of Comma Gets a Cure was broken down into individual sentences, and timestamps were added for each version of the participants' readings. Then, each sentence was isolated and automatically segmented and aligned using Prosodylab-aligner (Gorman et al., 2011). Finally, using a script composed in Praat (Boersma and Weenink, 2010), intensity, duration, F0, F1, and F2 were automatically measured at the midpoints of each stressed vowel. Midpoint values for both the disguise and non-disguise condition were extracted, normalized using Lobanov (1971) via the NORM website (Thomas and Kendall, 2007), and statistically compared with the program R (R Core Team, 2015) as described below, and presented in Chapter 5.

First, I look at descriptive statistics to determine if speakers shifted either pitch, F1, F2 or duration across normal and disguised speech. Second, these descriptive statistics are followed by multiple linear regression modelling to examine the effect of two social factors (gender, origin)

on dependant variables (normalized F1, F2). The mean value for each F1, F2 vowel pair was calculated using the means function in the *plyr* package in R. Based on these mean normalized values, difference scores for each F1, F2 vowel pair were calculated. This resulted in 16 observations for each of the 20 speakers, for a total N=320 tokens. For each of the 16 vowel categories, separate Linear Regression models were built with normalized F1 and F2 as dependant variables. Gender and Origin and their interaction served as independent variables. F0 was examined separately for males and females (given the tendency for sex differences in pitch), as was duration (given the tendency for speakers to speak at different rates). The third and final analysis presented in Chapter 5 takes a closer look at each individual speaker's vocal disguises from an acoustic and impressionistic viewpoint. There, I consider both the frequency at which phonetic properties are used in vocal disguise as well idiosyncratic preferences for each speaker.

Chapter 5: Results

5.1. Analysis of Gender and Origin on Vocal Disguise

We begin by looking at whether the acoustic properties F1, F2, duration and pitch were altered in any systematic ways across the experimental conditions, and whether or not such differences were influenced by the gender and/or origin of the speaker.

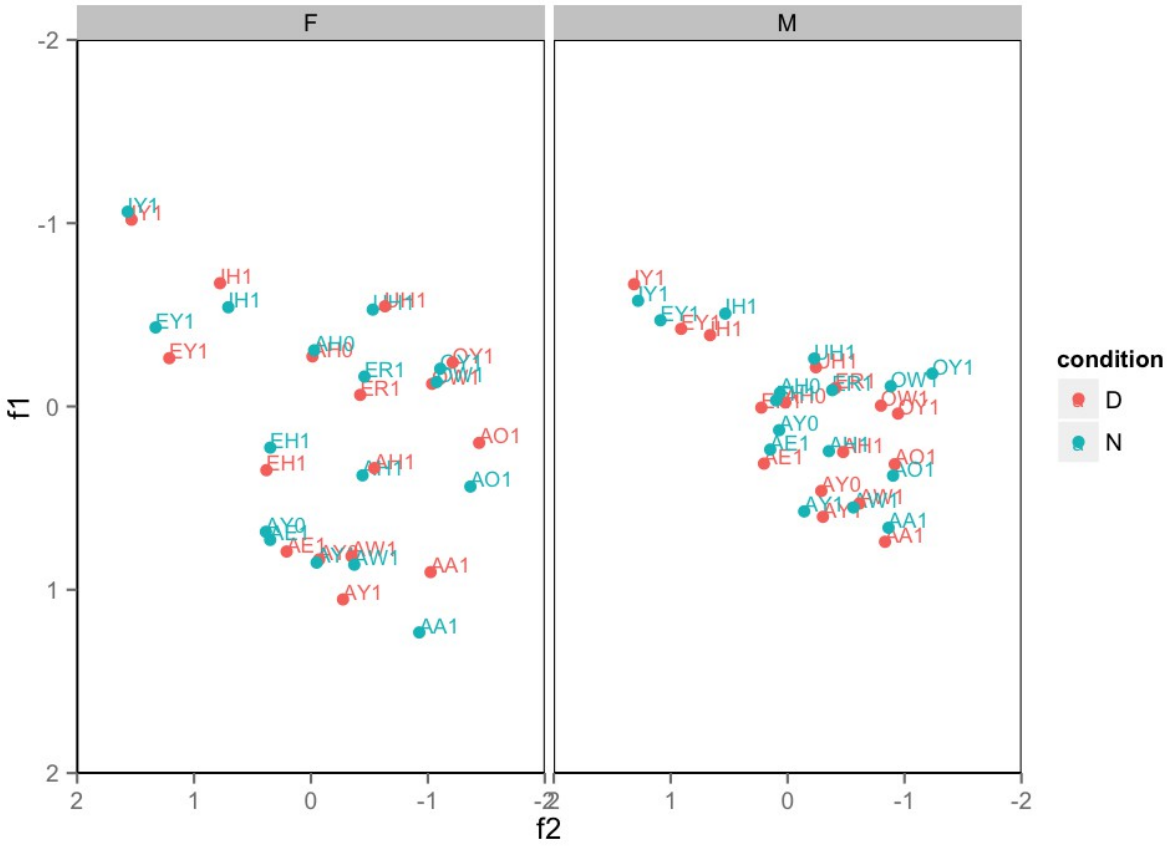

Illustration 1: Mean F1/F2 Positions of Each Vowel Across Normal and Disguise Conditions for Female and Male Speakers

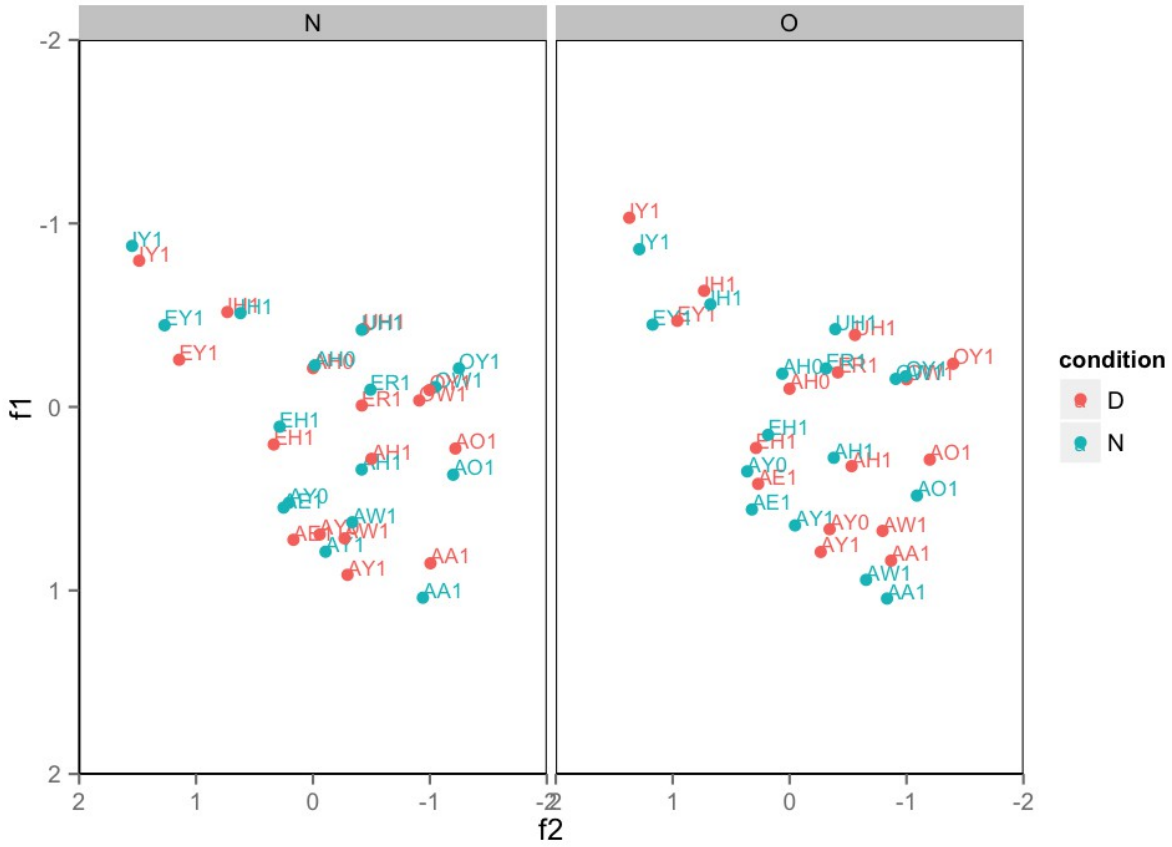

Illustration 2: Mean F1/F2 Positions of Each Vowel Across Normal and Disguise Conditions for Newfoundland and Labrador vs. Other Speakers

Starting with F1 and F2, Illustrations 1 and 2 present the vowels examined here under Normal and Disguise conditions. In both graphs, red circles indicate mean values taken from the Disguise condition, and an aquamarine circle represents a mean value from the Normal condition. In Illustration 1, the left panel illustrates the vowel spaces for Female speakers, and the right, Male speakers. In Illustration 2, the panels distinguish Newfoundland and Labradorian speakers from Other regions of origin. What these figures show is a general tendency for vowels to shift slightly across conditions. This is true for both Gender and Origin.

However, results from the linear regression models reveal no significant effects due to Gender or Origin on the F1 or F2 difference values, indicating that neither the speakers' genders, nor their origins significantly influenced any of the models used to predict the patterns of variation. The output of the linear regression analyses for normalized F1 and F2 differences scores are found in the Appendix.

We now shift our attention to the next set of phonetic properties, vowel duration and pitch. Illustrations 3 and 4 show the median duration values for each vowel across both Normal (N) and Disguise (D) conditions for male and female speakers, respectively.

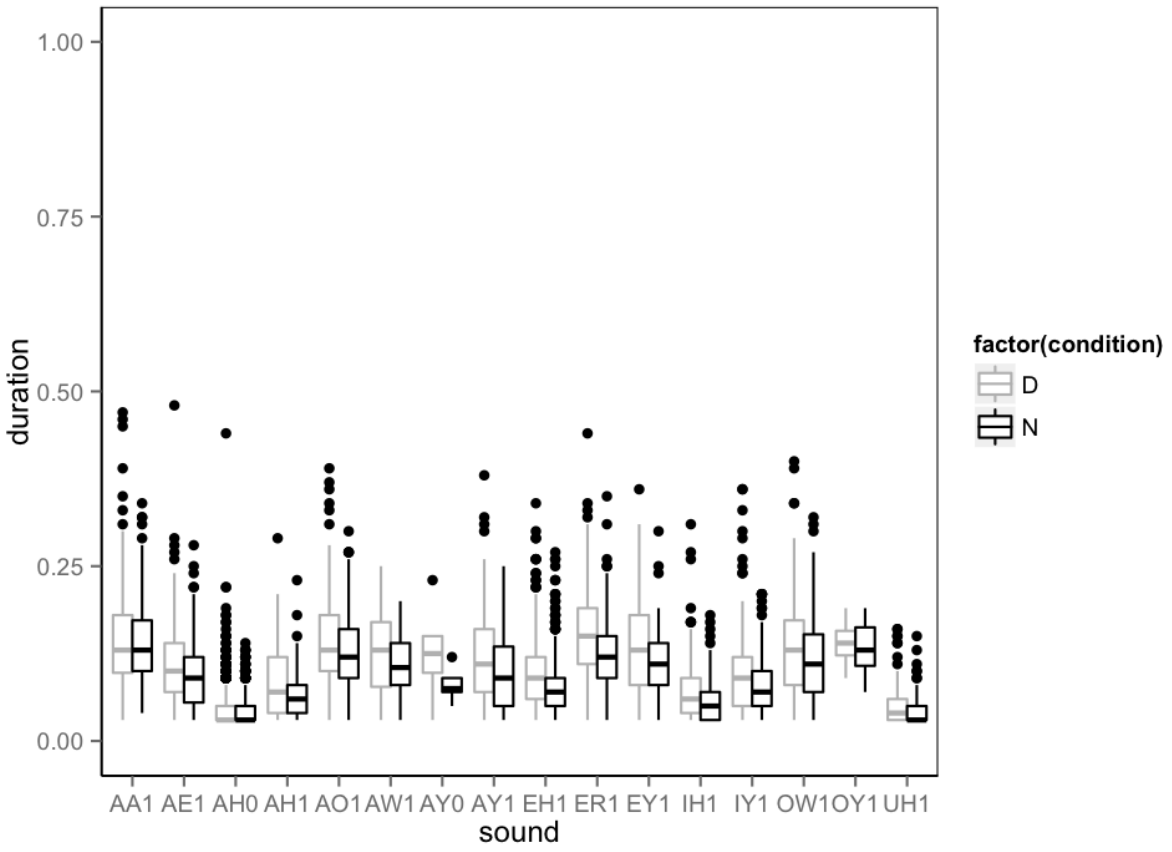

Illustration 3: Duration Values for Male Speakers

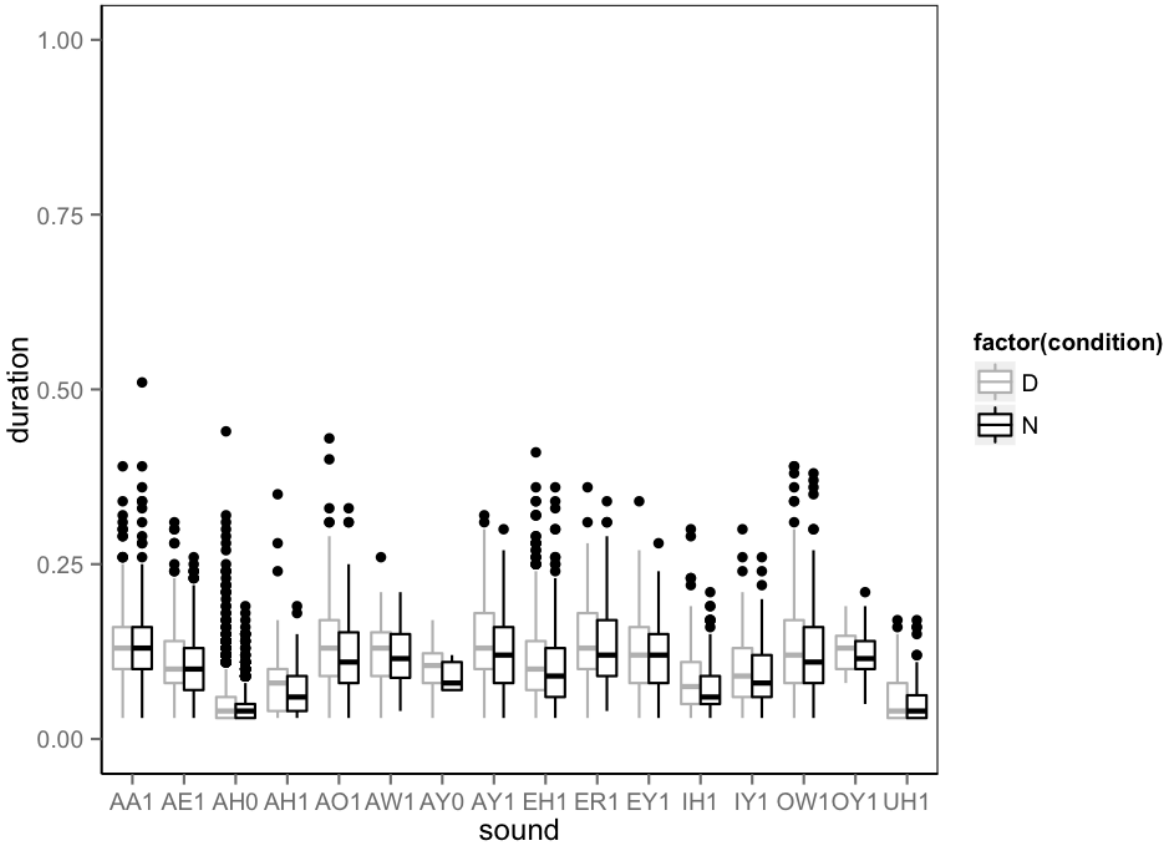

Illustration 4: Duration Values for Female Speakers

Fixed Effects			
	Estimate	Std. Error	t value
(Intercept)	0.1070670	0.0042170	25.39
genderM	-0.0022449	0.0049916	-0.450
conditionN	-0.0087502	0.0009888	-8.85
genderM:conditionN	-0.0063236	0.0015618	-4.05

Table 2: Fixed Effects Co-efficients for Gender from Linear Mixed Effects Model of Duration

Variation in vowel duration was modelled using a mixed-effects, linear, regression model with interaction between Gender and Condition as Fixed Factors, and Word and Speaker set as Random Factors. The results are shown in Table 2. An F-test (ANOVA) yielded a significant difference ($p < .05$) between this model, specifying an interaction term between Region and Condition, and an alternative model which excluded this interaction term. This suggests that Males and Females showed a significant effect on durational difference across conditions in that both genders tended to lengthen their duration when under the disguise condition, though the co-efficient value is small.

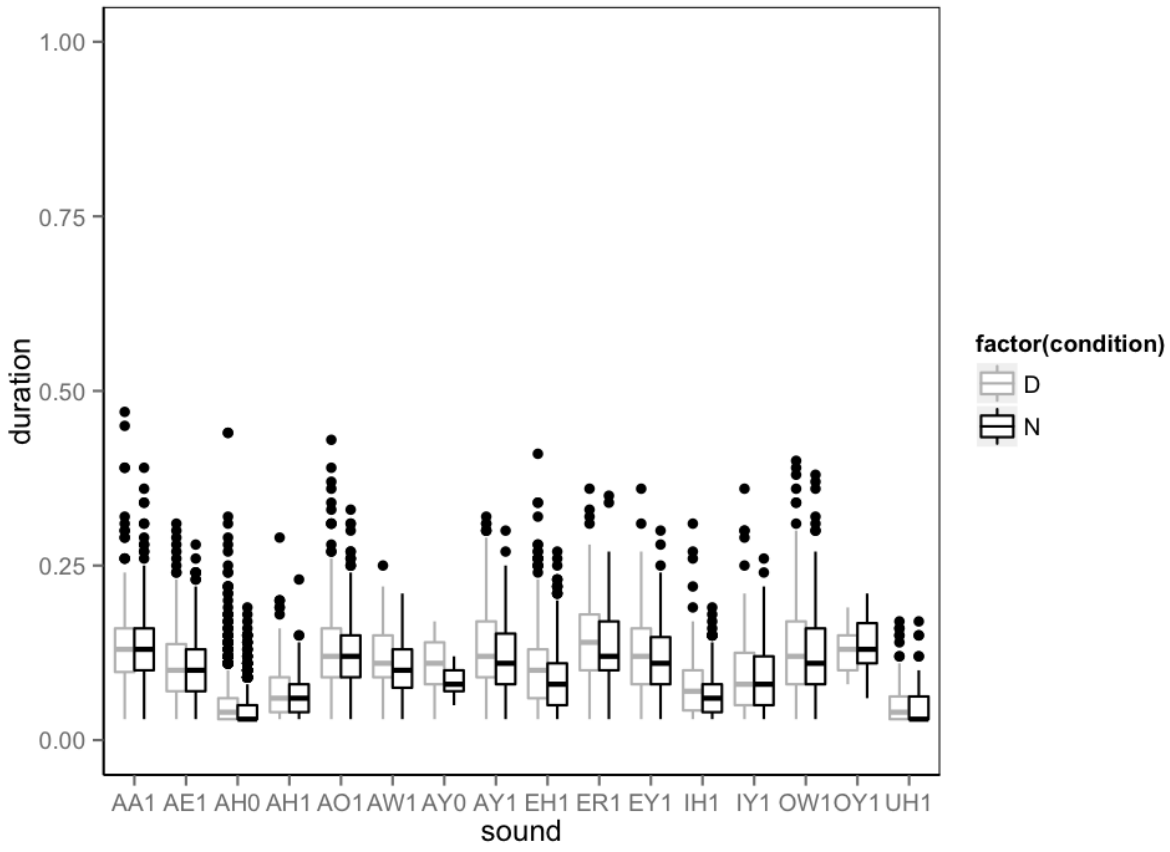

Illustration 5: Duration (sec) Across Condition Types for Speakers from Newfoundland.

Duration differences across conditions are shown for speakers from Newfoundland and Labrador in Illustration 5. Illustration 6 presents the vowel duration for speakers from outside of NL (Other).

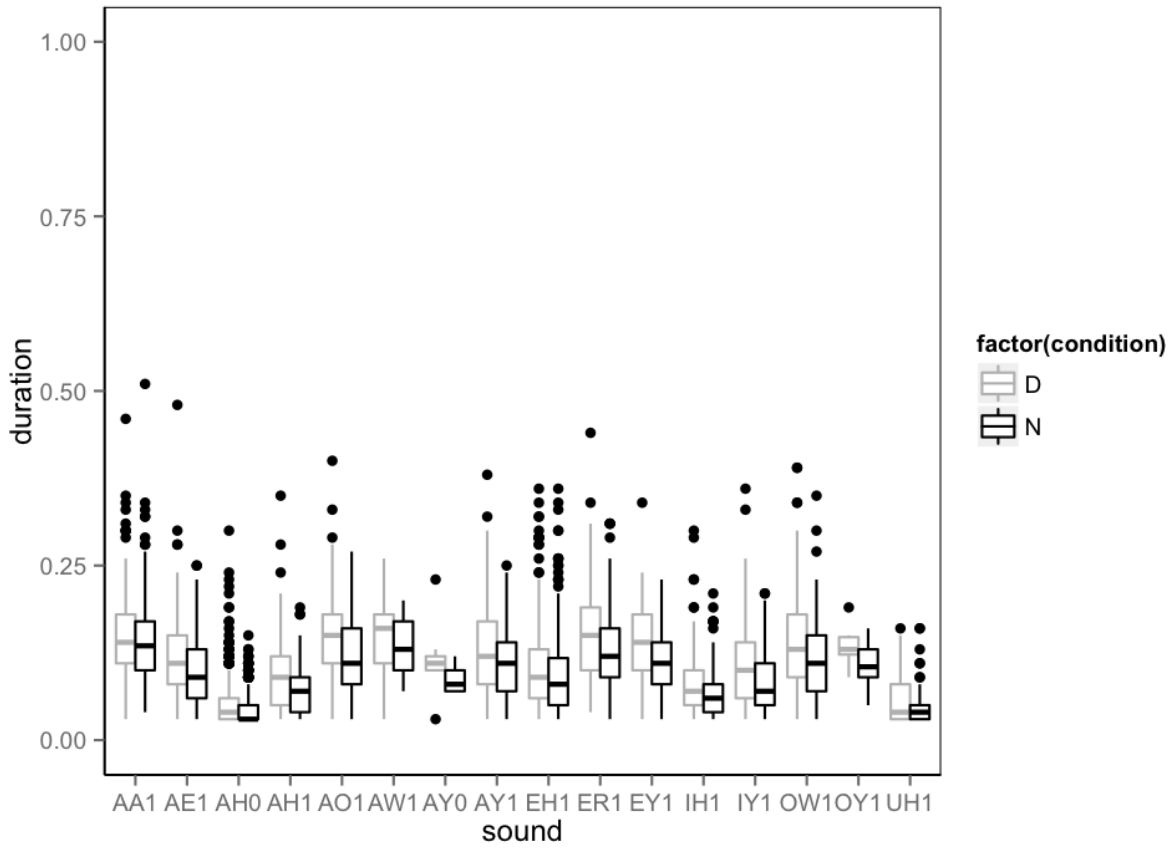

Illustration 6: Duration (sec) Across Condition Types for Speakers from Other (beyond Newfoundland).

Table 3 outlines the results of the mixed-effects, linear, regression model that looked at the effect of Region on vowel duration.

Fixed Effects			
	Estimate	Std. Error	t value
(Intercept)	0.1035715	0.0041687	24.845
regionO	0.0073860	0.0052249	1.414
conditionN	-0.0085658	0.0009502	-9.015
regionO:conditionN	-0.0077387	0.0016029	-4.83

Table 3: Fixed Effects Co-efficients for Region from Linear Mixed Effects Model of Duration

Like the model for Gender, the F-test statistic yielded a significant difference ($p < .05$) between this model and the alternative model which excluded an interaction term between Region and Condition. This suggests that NL and Other showed a significant effect on durational difference across conditions, though the effect size, shown by the estimate here, is also small. The exact effect that is shown is that Other speakers have shorter vowels than Newfoundland speakers under disguise conditions.

Illustrations 7 and 8 show the median pitch values for each vowel across both Normal (N) and Disguise (D) conditions for male and female speakers, respectively. These figures reveal that both male and female speakers tended to raise their pitch in the disguise condition.

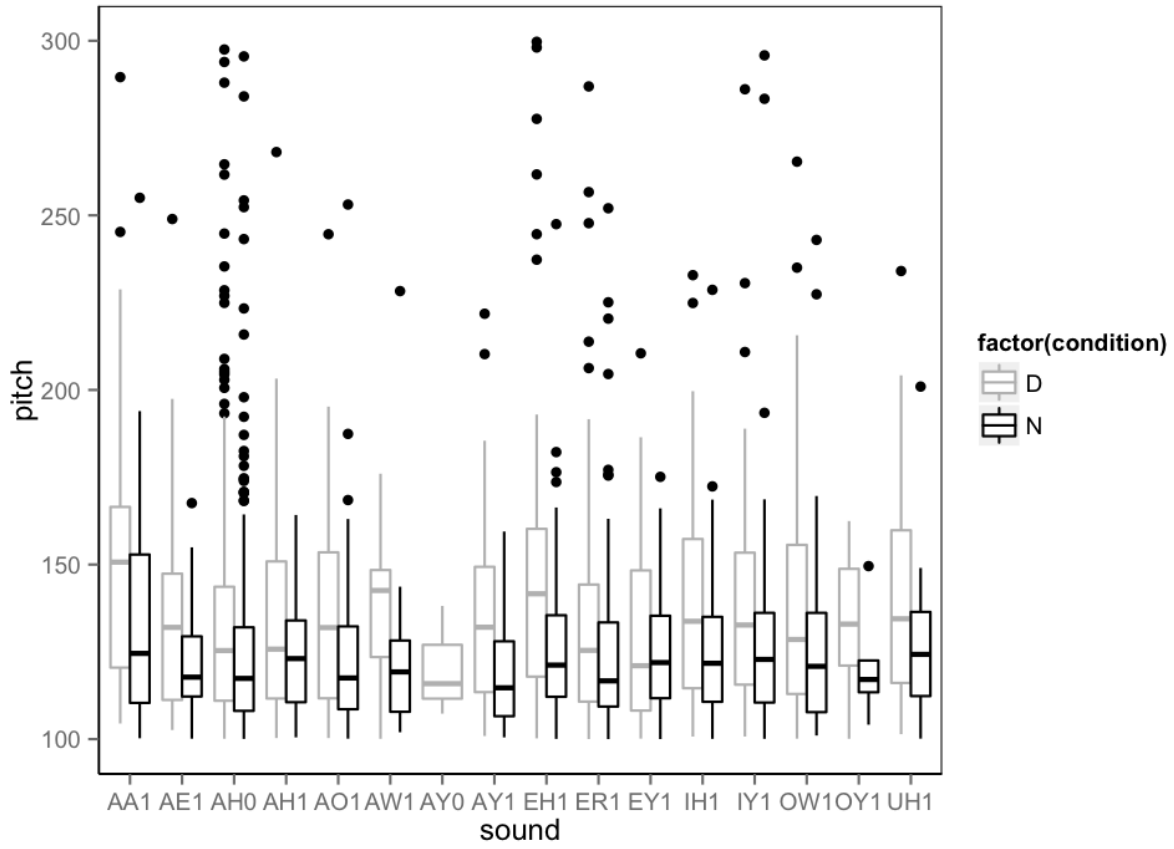

Illustration 7: Pitch Values for Male Speakers

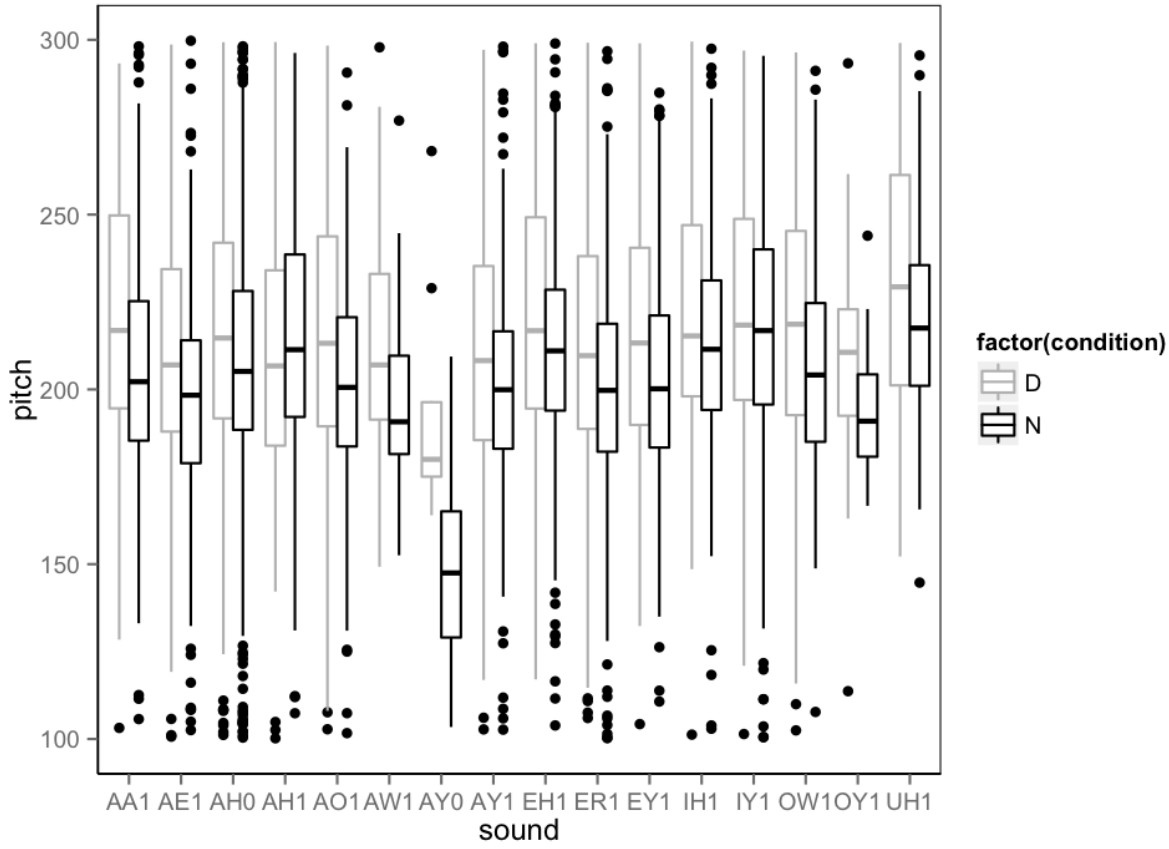

Illustration 8: Pitch Values for Female Speakers

Illustrations 9 and 10 show the median pitch values for each vowel across both Normal (N) and Disguise (D) conditions for each region, NL and Other, respectively. They show that generally, participants from both regions tended to raise their pitch during the disguise condition, although NL speakers showed lowering in six vowels in the disguise condition, and Other speakers showed lowering in seven vowels.

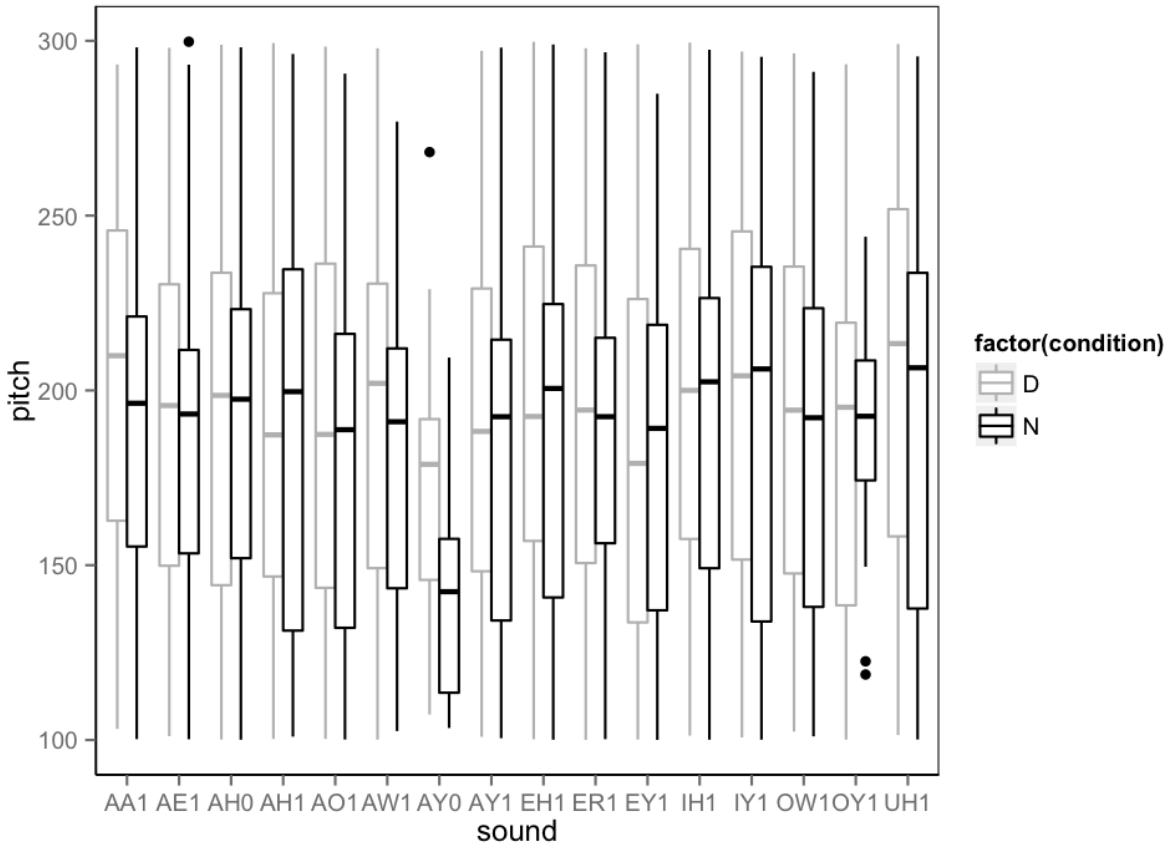

Illustration 9: Pitch Values For Newfoundland And Labrador Speakers

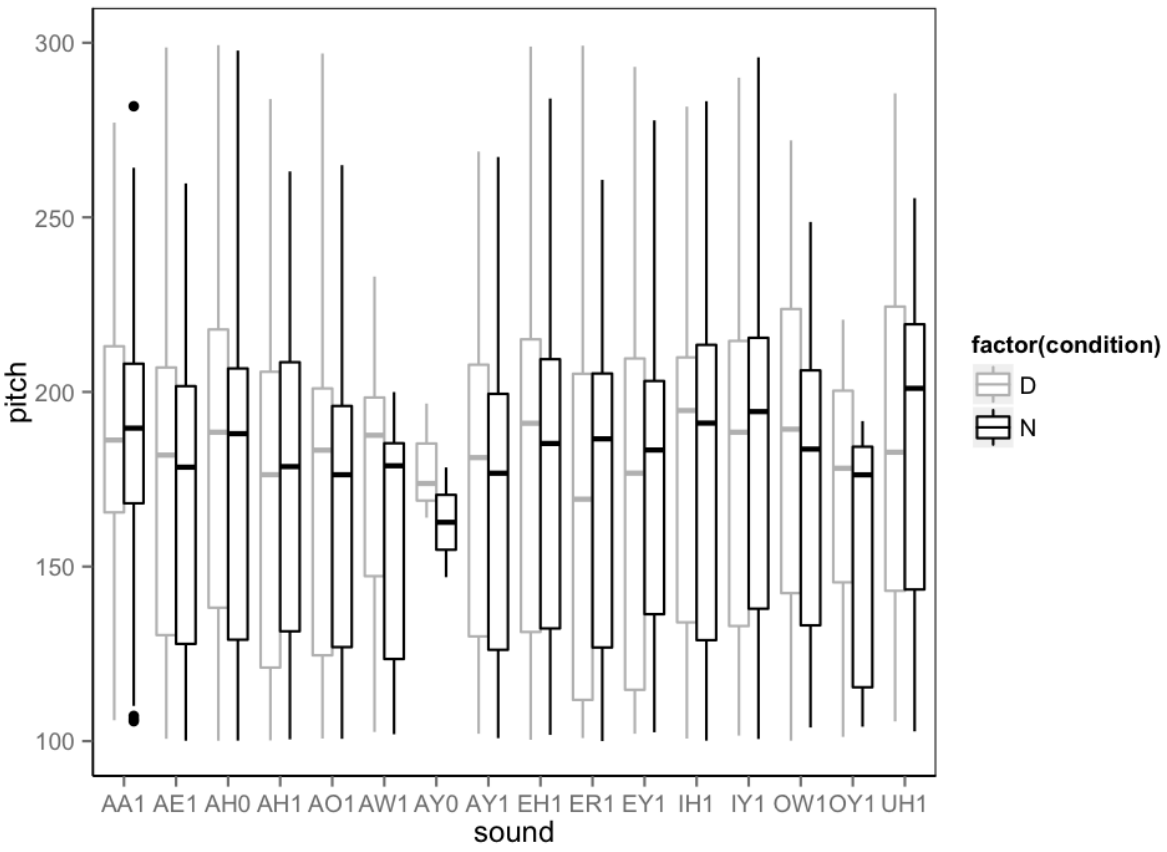

Illustration 10: Pitch Values For Other Speakers

The co-efficients from the linear, mixed-effects, model of pitch for male speakers is found in Table 4. Here we see that males tended to raise their pitch in the Disguise condition. The interaction between Region and Condition shows lowering for males from outside of Newfoundland and Labrador in the Disguise condition.

Fixed Effects	Estimate	Std. Error	t value
Male (Intercept)	133.6043	5.9008	22.642
RegionO	-17.1663	9.5614	-1.795
ConditionN	-22.03	0.98	-22.45
RegionO:ConditionN	23.2266	1.6642	13.96

Table 4: Fixed Effects Co-efficients from Linear Mixed Effects Model of Male Pitch Values for Both Region and Condition

Mixed-effects results for female speakers are found in Table 5. Here we see that females also raised their pitch in the Disguise condition. Likewise, the interaction co-efficient for Region and Condition shows a relative lowering for females from outside of Newfoundland and Labrador in the Disguise condition.

Fixed Effects	Estimate	Std. Error	t value
Female (Intercept)	227.860	4.445	51.26
RegionO	-27.548	7.157	-3.85
ConditionN	-21.309	1.09	-19.63
RegionO:ConditionN	13.219	1.87	7.06

Table 5: Fixed Effects Co-efficients from Linear Mixed Effects Model of Female Pitch Values for Both Region and Condition

This analysis of F1, F2, pitch and duration reveals that when speakers are asked to disguise their voice, there is a tendency for them to alter some properties over others. Vowel quality, as

defined by F1 and F2 values taken at the midpoint of the vowel was found to be rather stable over Normal and Disguise conditions. However, significant effects were found for both pitch and vowel duration. Moreover, these differences are influenced by the Gender and Region of the speaker. The strongest effects were found for F0/pitch. Both males and females tended to increase pitch values in the disguise condition. Region of Origin also interacted with Condition in that speakers from outside of NL tended to lower their pitch. This is true for both males and females.

I will discuss these results in light of the hypothesis that vocal disguise is a type of style shifting in the Chapter 6. The remainder of this chapter will examine the uniformity of disguises by looking at individual speakers to determine the occurrence of individual preferences.

5.2. Individual Analysis

The results presented in this section are based on t-tests conducted for each speaker, running each acoustic property and vowel pairing separately. Condition (Normal vs. Disguise) served as the independent variable. Where a significant difference was found ($p < .05$), it was tallied and put in Table 6 below. This table reports the overall frequency at which speakers use each lexical set and phonetic property in their disguised voices is presented.

As Table 6 shows, the vowels that participants altered most often were DRESS (11.6%), SCHWA (9.6%), KIT (8.0%), and LOT (8.0%), The vowels that were least likely to be altered were FLEECE stressed (4.7%), STRUT (4.3%), GOAT (4.0%), and FOOT (2.0%).

The acoustic property that was altered most often was pitch: of the 301 reported changes, participants altered their pitch between conditions roughly 39.5% of the time. Interestingly, all of the other acoustic properties were altered approximately equally: duration 21.3% of the time, F1 18.3% of the time, and F2 20.9% of the time.

Vowel	Lexical Set	Pitch	Duration	F1	F2	Total	%
EH1	DRESS	13	6	8	8	**35**	**11.6%**
AH0	SCHWA	10	9	6	4	**29**	**9.6%**
IH1	KIT stressed	12	3	4	5	**24**	**8.0%**
AA1	LOT	8	3	8	5	**24**	**8.0%**
IY0	FLEECE unstressed	8	4	2	8	**22**	**7.0%**
AY1	PRICE	8	5	3	5	**21**	**7.0%**
IH0	KIT unstressed	9	6	3	3	**21**	**7.0%**
AO1	THOUGHT	9	6	5	1	**21**	**7.0%**
EY1	FACE	9	3	6	3	**21**	**7.0%**
UW1	GOOSE	7	3	1	8	**19**	**6.3%**
AE1	TRAP	7	5	3	4	**19**	**6.3%**
IY1	FLEECE stressed	5	4	2	3	**14**	**4.7%**
AH1	STRUT	5	4	2	2	**13**	**4.3%**
OW1	GOAT	4	3	1	4	**12**	**4.0%**
UH1	FOOT	5	0	1	0	**6**	**2.0%**
Total		**119**	**64**	**55**	**63**	**301**	0
%		**39.5%**	**21.3%**	**18.3%**	**20.9%**		

Table 6: Breakdown of Acoustic Phonetic Properties and Vowels Used in the Disguise Condition, for All Speakers

5.2.2 Impressionistic Analysis

The final analysis looks at the different ways in which each individual disguised his or her own voice. A breakdown of each participant's disguise can be found below, in Table 7:

Speaker	Gender	Impressionistic Disguise Type
Speaker_001	F	Accent change (Stylized British)
Speaker_002	M	Accent change (Radio announcer), duration change, pitch change (lower)
Speaker_003	F	Accent change (British)
Speaker_004	M	Accent change (Australian), pitch change (higher)
Speaker_005	M	Pitch change (lower), duration change
Speaker_006	F	Accent change (Scottish), pitch change (lower)
Speaker_007	M	Intonation change
Speaker_008	F	Accent change (Southern USA), pitch change (lower)
Speaker_009	M	Accent change (Italian), pitch change (lower)
Speaker_010	F	Accent change (British)
Speaker_011	F	Accent change (British), pitch change (higher)
Speaker_012	M	Tempo change, accent change (Newfoundland)
Speaker_013	M	Accent change (Asian), pitch change (higher)
Speaker_014	F	Pitch change (higher)
Speaker_015	F	Accent change (Russian), added "v" to the beginning of most words
Speaker_016	F	Pitch change (lower)
Speaker_017	F	Accent change (Indian), pitch change (higher)
Speaker_018	F	Tempo change, accent change (Asian)
Speaker_020	F	Pitch change (lower), accent change (heightened pronunciation)
Speaker_021	M	Accent change (Irish), pitch change (higher)

Table 7: Impressionistic Breakdown of Participants

Impressionistically, 16 out of 20 speakers attempted to maintain a change in accent throughout the disguise condition. Also worth noting is that 13 out of 20 speakers altered their pitch while disguising their voice, sometimes in addition to taking on a change in accent. As well, despite duration being altered in nineteen speakers, only two speakers impressionistically sounded as

though they were attempting to alter their duration.

From here, we will now move on to the discussion of these results.

Chapter 6: Discussion

6.1. Vowel Categories

The vowels which exhibited the most change in this study did not coincide with the results found in De Decker (2015). First, DRESS was found to be altered the most in the present study, whereas it was the least changed vowel for De Decker's study. Similarly, GOAT experienced the most shifting in De Decker's study, but it was altered the least in this study. This could indicate that while vocal disguise and quotative speech may share certain properties at a sociolinguistic level, they are still two distinct functions of speech, and individuals view them as such when undertaking each task. This brings us to the idea that style shifting is not necessarily a two-point continuum, but a point with many potential directions to travel in, which could include a direction for quotative speech and another direction for vocal disguise. This idea will be revisited in Chapter 7.

6.2. Acoustic Properties

Pitch being the most commonly altered vowel property is not a surprising finding, as past research has shown that speakers are more likely to alter properties that are more salient, such as pitch (Masthoff 1996). There were no apparent gender differences when direction of pitch shift was taken into consideration: both males and females most often raised their pitch when disguising their voice, an outcome which does not correlate to Masthoff (1996). Instead, raising or lowering one's pitch seemed to pattern on an individual basis rather than by gender.

It may be that altering one's pitch becomes speaker dependent based on how high or low their modal voice is; that is, if a female speaker's pitch falls naturally in a lower register, then she may feel that her best chance at an unidentifiable disguise would be to raise her pitch when putting on a disguise. Similarly, if a male speaker has a naturally higher pitch, he may feel it is more beneficial to lower it for the disguise condition. This line of reasoning predicts that how one

alters their pitch correlates more closely to where their modal voice lies on the pitch spectrum. It may also be that the degree to which a speaker can alter his or her pitch is limited by the physicality of their vocal tract (Zhang 2007).

Participants also shortened their vowel duration in the disguise condition. Duration, like pitch, is a more salient acoustic feature, so it may that altering the speed of one's speech is simply viewed as an easy feature for individuals to manipulate.

The data collected for this project seem to support the theory outlined previously: that if disguise is a form of style shifting, there should be a general pattern that individuals follow when disguising their voice. In this case, it appears individuals opt to alter the most salient acoustic features, and thus altering one's pitch and/or duration is part of that general pattern.

6.3. Impressionistic Findings

An interesting point for future research is that impressionistically, most participants attempted to put on a foreign accent during the disguise condition. Accents are characterized by differences in vowel quality, and yet the F1 and F2 values across conditions do not appear to reflect these differences. Referring back to Zhang (2007), formants tend to be less influenced by the parameters of disguise. This offers a potential explanation for the general lack of change across participants' formant frequencies. However, it may also simply be that the participants in this study did NOT portray their choice of foreign accent well enough to indicate a significant change in formant values. Perhaps, as per Gibson and Bell (2010), a sociophonetic feature such as selectivity or mis-realization more heavily influenced F1 and F2, limiting the potential for a change in these particular formant frequencies. There is a definite possibility for further research focused specifically on the F1 and F2 data: it would be interesting to find an explanation for the significant adjustments in both the DRESS and LOT vowels across conditions, but given the breadth and time constraints of the current study, it wasn't possible at this time.

Comparing the impressionistic findings to the acoustic analysis yields interesting results: while pitch was the most commonly altered feature acoustically, it was only impressionistically identified as changing in 13 out of 20 participants. As well, while 16 out of 20 participants impressionistically altered their modal voice by way of dialect or accent change, there were no discernible patterns found in the F1 or F2 values of any speaker. However, despite there not being a particular pattern for the change, numerous participants were still found to alter their F1 and/or F2 between modal and disguise conditions, which is consistent with the impressionistic finding that there was a change in accent or dialect.

Contrary to Masthoff's finding that speakers with strong regional accents did not make any attempt to obscure them (164), participants here did make an effort to change their regional accent in this study. In particular, Speaker_001 exhibited a strong Newfoundland accent in her modal speech, but when under the disguise condition, she attempted to take on a more Standard English dialect.

Finally, as has been previously outlined, participants in this study did not tend to focus on single disguise techniques, but rather multiple techniques at once, such as altering both pitch and duration or taking on a foreign accent and altering pitch. This too goes against Masthoff's findings in which the majority of his subjects focused on a single disguise technique. The reason for this finding is as of yet unclear, and a conclusion will require further research.

6.4. Gender and Origin Findings

From the observations listed in Section 5.2, we can draw a correlation between vocal disguise and style shifting – however, this correlation does not apply to all features. In particular, F1 and F2 did not show any indication of being influenced by social patterns, while pitch and duration did to an extent. As was discussed in Chapter 5, both males and females lengthened their duration when in the disguise condition, but speakers from outside of Newfoundland still tended to have shorter

vowel durations than Newfoundlanders. As well, while both males and females tended to raise their pitch in the disguise condition, this occurred less so when only looking at speakers from outside of Newfoundland. In this way, vocal disguise does appear to be affected by social patterns, which is further evidence that it could be related to style shifting. This may indicate the beginnings of a pattern for which phonetic properties speakers tend to draw upon when disguising their voice.

Chapter 7: Conclusion – What is a Disguise, Anyway?

The results presented above provide some indication of what people think a disguise is. Certainly, it seems to be the case that for at least most of the individuals in this study, to disguise one's voice meant one of two things: to change one's pitch or duration, or (at least impressionistically) to alter one's accent. This is interesting, because as per Künzel (2000) and Mastoff (2013), there are numerous other ways in which to disguise one's voice. These include whispering, changing vocal register, 'pipesmoker' speech (using a bite block, etc.), and changing tempo, intonation, or word stress (Masthoff 1996, p. 161). Despite this, nearly no participants in my study deviated from the three most popular choices. As was previously outlined, the acoustic and impressionistic results show that speakers view pitch and duration change as recognizable parts of speech, and as a group, they appear to consistently alter them when asked to disguise their voice.

Since the experimental task boils down to avoiding sounding like one's self, results suggest that people see accent and pitch /duration change as analogous with disguise. It is true that accent and pitch features are more salient than formant features, and perhaps this is what prompted so many participants to imitate an accent during the disguise condition. There was large variation in the accents that were chosen and no one accent seemed to be chosen more than others. With one exception, participants who used a foreign accent seemed to choose any accent that was very different from their own (in most cases, this was some variant of Canadian or American English).

In the same way that it was previously suggested that vocal disguise and quotative speech, as well as quotative speech and style shifting are related, perhaps we should begin to view style shifting as less of a two-way, formal/informal continuum and as more of a multidirectional space in which the speaker may alter their voice to suit their needs: formally, informally, by quoting another speaker, or by disguising their own voice entirely.

There are still several questions that require further research before an answer can be found: there is first the question of whether one's modal pitch influences the probability that one will raise or lower their pitch when disguising their voice. Second, why individuals in this study often implemented multiple disguise tactics at once, rather than stick with just one as per Masthoff (1996). Finally, there is the question of why F1 and F2 did not show large shifts when almost all participants took an a foreign accent as their disguise. Each of these questions merit further research, and will offer even more information to the growing field of forensic linguistics.

Appendix 1

F1 Values

AA1		Estimate	Std. Error	t value	Pr(>|t|)
	(Intercept)	-0.37295	0.2095	-1.78	0.094
	regionO	0.01561	0.36287	0.043	0.966
	genderM	0.45137	0.33781	1.336	0.2
	regionO:genderM	-0.02565	0.56474	-0.045	0.964
					p = 0.4662

AE1		Estimate	Std. Error	t value	Pr(>|t|)
	(Intercept)	0.167562	0.127163	1.318	0.206
	regionO	-0.378185	0.220253	-1.717	0.105
	genderM	0.006406	0.205045	0.031	0.975
	regionO:genderM	0.027199	0.342791	0.079	0.938
					p = 0.2337

AH0		Estimate	Std. Error	t value	Pr(>|t|)
	(Intercept)	-0.03769	0.09688	-0.389	0.702
	regionO	0.26129	0.16781	1.557	0.139
	genderM	0.14244	0.15622	0.912	0.375
	regionO:genderM	-0.39218	0.26117	-1.502	0.153
					p = 0.4393

AH1		Estimate	Std. Error	t value	Pr(>|t|)
	(Intercept)	-0.14558	0.15123	-0.963	0.35
	regionO	0.08658	0.26194	0.331	0.745
	genderM	0.15726	0.24385	0.645	0.528
	regionO:genderM	-0.11955	0.40767	-0.293	0.773
					p = 0.9231

AO1		Estimate	Std. Error	t value	Pr(>|t|)
	(Intercept)	-0.2073	0.1289	-1.608	0.127
	regionO	-0.1605	0.2233	-0.719	0.483
	genderM	0.1641	0.2079	0.789	0.442
	regionO:genderM	0.1	0.3475	0.288	0.777
					p = 0.5965

AW1		Estimate	Std. Error	t value	Pr(>|t|)
	(Intercept)	0.07292	0.23915	0.305	0.764
	regionO	-0.3575	0.41423	-0.863	0.401
	genderM	0.03788	0.38562	0.098	0.923
	regionO:genderM	0.0037	0.64468	0.006	0.995
					p = 0.7402

AY0		Estimate	Std. Error	t value	Pr(>|t|)
	(Intercept)	0.0735	0.3222	0.228	0.822
	regionO	0.2318	0.5581	0.415	0.683
	genderM	0.2595	0.5196	0.499	0.624
	regionO:genderM	-0.2364	0.8686	-0.272	0.789

p = 0.9469

AY1		Estimate	Std. Error	t value	Pr(>|t|)
	(Intercept)	0.20649	0.18389	1.123	0.278
	regionO	-0.01152	0.3185	-0.036	0.972
	genderM	-0.21212	0.29651	-0.715	0.485
	regionO:genderM	0.09198	0.4957	0.186	0.86

p = 0.8928

EH1		Estimate	Std. Error	t value	Pr(>|t|)
	(Intercept)	0.13750	0.09149	1.503	0.152
	regionO	-0.04501	0.15846	-0.284	0.780
	genderM	-0.10789	0.14752	-0.731	0.475
	regionO:genderM	0.06789	0.24633	0.275	0.79

p = 0.8937

EY1		Estimate	Std. Error	t value	Pr(>|t|)
	(Intercept)	0.1995797	0.1682931	1.186	0.253
	regionO	-0.1021751	0.2914922	-0.351	0.731
	genderM	-0.0001853	0.2713645	-0.001	0.999
	regionO:genderM	0.3067632	0.4536636	0.676	0.51

p = 0.6224

IH1		Estimate	Std. Error	t value	Pr(>|t|)
	(Intercept)	0.08964	0.08947	-1.005	0.330
	regionO	-0.12433	0.15445	-0.805	0.433
	genderM	-0.23099	0.14378	1.607	0.128
	regionO:genderM	0.10546	0.24037	0.439	0.67

P = 0.156

IY1		Estimate	Std. Error	t value	Pr(>|t|)
	(Intercept)	0.05011	0.21503	0.233	0.819
	regionO	-0.01930	0.37245	-0.052	0.959
	genderM	0.07859	0.34673	0.227	0.824
	regionO:genderM	-0.54014	0.57966	-0.932	0.37

P = 0.6261

OW1		Estimate	Std. Error	t value	Pr(>|t|)
	(Intercept)	0.0.5216	0.09106	0.573	0.575

	regionO	-0.12669	0.15772	-0.803	0.434
	genderM	0.05489	0.14683	0.374	0.713
	regionO:genderM	0.12379	0.24547	0.504	0.62
					p = 0.7291
OY1		Estimate	Std. Error	t value	Pr(>|t|)
	(Intercept)	-0.02812	0.17213	-0.163	0.872
	regionO	-0.01975	0.3185	-0.066	0.948
	genderM	0.38092	0.29651	1.372	0.189
	regionO:genderM	-0.43438	0.4957	-0.936	0.36
					p = 0.48
UH1		Estimate	Std. Error	t value	Pr(>|t|)
	(Intercept)	-0.002547	0.107177	-0.024	0.981
	regionO	0.046797	0.185636	-0.252	0.804
	genderM	-0.005553	0.172818	-0.032	0.975
	regionO:genderM	0.194647	0.288915	0.674	0.51
					p = 0.864

Table 8: Results from Linear Regression Models of F1 for Each Vowel

Appendix 2

F2 Values

AA1		Estimate	Std. Error	t value	Pr(>|t|)
	(Intercept)	-0.10517	0.08772	-1.199	0.248
	regionO	-0.04749	0.15194	-0.313	0.759
	genderM	0.04749	0.14145	0.499	0.624
	regionO:genderM	-0.19818	0.23647	0.838	0.414
					p = 0.5149

AE1		Estimate	Std. Error	t value	Pr(>|t|)
	(Intercept)	-0.17221	0.08666	-1.987	0.0643
	regionO	0.02995	0.15009	0.200	0.8443
	genderM	0.24538	0.13973	1.756	0.0982
	regionO:genderM	-0.08144	0.23359	-0.349	0.7319
					p = 0.3136

AH0		Estimate	Std. Error	t value	Pr(>|t|)
	(Intercept)	0.01186	0.06019	0.197	0.846
	regionO	0.01805	0.10426	0.173	0.865
	genderM	0.01066	0.09706	0.110	0.914
	regionO:genderM	-0.22736	0.16226	-1.401	0.180
					P = 0.3228

AH1		Estimate	Std. Error	t value	Pr(>|t|)
	(Intercept)	-0.1398	0.1102	-1.268	0.223
	regionO	0.1207	0.1909	0.632	0.536
	genderM	0.1068	0.1777	0.601	0.556
	regionO:genderM	-0.3008	0.2971	-1.012	0.326
					p = 0.7954

AO1		Estimate	Std. Error	t value	Pr(>|t|)
	(Intercept)	-0.01269	0.03769	-0.172	0.865
	regionO	-0.16657	0.12764	-1.305	0.210
	genderM	0.02533	0.11883	0.213	0.834
	regionO:genderM	0.11627	0.19865	0.585	0.567
					p = 0.5405

AW1		Estimate	Std. Error	t value	Pr(>|t|)
	(Intercept)	0.08421	0.13977	0.602	0.555
	regionO	-0.18254	0.24209	-0.754	0.462
	genderM	-0.04841	0.22537	-0.215	0.833
	regionO:genderM	-0.05026	0.37677	-0.133	0.896
					p = 0.7116

AY1		Estimate	Std. Error	t value	Pr(>|t|)
	(Intercept)	-0.20017	0.12473	-1.605	0.128
	regionO	-0.08492	0.21694	-0.393	0.699
	genderM	0.01983	0.20112	0.099	0.923
	regionO:genderM	0.13067	0.33623	0.389	0.7

p = 0.9489

EH1		Estimate	Std. Error	t value	Pr(>|t|)
	(Intercept)	0.005993	0.078520	0.076	0.940
	regionO	0.085669	0.136001	0.630	0.538
	genderM	0.121697	0.126610	0.961	0.351
	regionO:genderM	0.084191	0.211665	-0.398	0.7

p = 0.7432

EY1		Estimate	Std. Error	t value	Pr(>|t|)
	(Intercept)	-0.09441	0.10206	-0.925	0.369
	regionO	-0.06811	0.17677	-0.385	0.705
	genderM	-0.11028	0.16457	-0.670	0.512
	regionO:genderM	0.06515	0.27512	0.237	0.82

p = 0.8945

IH1		Estimate	Std. Error	t value	Pr(>|t|)
	(Intercept)	0.04583	0.09726	0.471	0.644
	regionO	0.05486	0.16846	0.326	0.749
	genderM	0.17076	0.15683	1.089	0.292
	regionO:genderM	-0.30759	0.26219	-1.173	0.26

p = 0.6043

IY1		Estimate	Std. Error	t value	Pr(>|t|)
	(Intercept)	-0.1153	0.1129	-1.021	0.322
	regionO	0.2452	0.1956	1.253	0.228
	genderM	0.1577	0.1821	0.866	0.399
	regionO:genderM	-0.2704	0.3044	-0.888	0.39

p = 0.6261

OW1		Estimate	Std. Error	t value	Pr(>|t|)
	(Intercept)	0.08911	0.14912	0.598	0.558
	regionO	-0.15064	0.25828	-0.583	0.568
	genderM	0.12616	0.24045	0.525	0.607
	regionO:genderM	-0.19960	0.40198	-0.497	0.63

p = 0.6474

OY1		Estimate	Std. Error	t value	Pr(>|t|)
	(Intercept)	0.09969	0.21061	0.473	0.642

	regionO	-0.49856	0.36479	-1.367	0.191
	genderM	0.39481	0.33961	1.163	0.262
	regionO:genderM	-0.08060	0.56775	-0.142	0.89
					p = 0.1979
UH1		Estimate	Std. Error	t value	Pr(>|t|)
	(Intercept)	-0.04522	0.15315	-0.295	0.772
	regionO	-0.17700	0.26526	-0.667	0.514
	genderM	0.07922	0.24694	0.321	0.753
	regionO:genderM	0.04729	0.41284	0.115	0.91
					p = 0.8441

Table 9: Results from Linear Regression Models of F2 for Each Vowel

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