The Role of Acoustic Detail in the Production and Processing of Vowels in Spontaneous Speech

by

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Abstract

This dissertation examines the correlations between morphology and spontaneous speech production and perception. Specifically, this dissertation focuses on a subset of irregular English verbs and the production of vowel formants and the perception of vowel durations of those verbs. The dissertation is composed of three studies. Study 1 examines the patterns of formant movement in monosyllabic verbs. Both qualitative and quantitative analyses in Study 1 show that the spontaneously produced formant movement patterns are similar to the patterns found in more carefully controlled citation speech. The formant data gathered in Study 1 was then used in Study 2 to investigate the effect that morphology has on the production of vowels. Morphology was measured by determining whether a vowel appeared in the past or present tense, and by calculating the morphological support for a particular vowel through Naive Discriminant Learning metrics. It was predicted that vowels in the morphologically uncertain tense (past) and/or with a high level of morphological support would be produced with acoustic enhancement. To test these predictions, analyses of four related measures of acoustic detail were conducted: 1) F1 and F2 linear dispersion from vowel space centre; 2) F1 and F2 linear deviation from vowel onset; 3) F1 and F2 linear deviation from vowel offset; and 4) non-linear amount of F1 and F2 movement. Each measure was analyzed with all of the vowels pooled together (global analysis), and then vowel-by-vowel (fractionated analysis). The four main findings of Study 2 are: 1) the global analyses support the predictions; 2) this pattern is not uniform across all vowels in the vowel-by-vowel analyses; 3) the vowel-by-vowel analyses better model the formant data than the global analyses; and 4) the linear analyses also better model the formant data than the non-linear analyses. Study 2 discusses the need for granular models of morphological predictability that account for vowel-specific conditions, since global generalizations made about the relationship between morphology and formant production were not found to be uniform for every vowel. Study 3 builds upon Study 2 by testing whether acoustic details in speech are produced in a way that necessarily facilitates perception. Previous research in production has found there to be a correlation between the morphological support for an irregular verb and the duration of its vowel. In both lexical and morphological decision experiments, Study 3 tested whether this production-related correlation affects perception. To test this, the relationship between morphological support and vowel duration was reversed. It was predicted that production and processing are linked, thus disrupting this production-based relationship would lead to processing difficulty in the lexical and morphological decision tasks. Study 3 finds that processing indeed becomes more difficult, but only in certain tasks and under certain conditions. This indicates that there is a link between production and processing, though the link is weaker than predicted. As with Study 2, Study 3 discusses the implications of a global generalization that does not uniformly hold across all conditions. Taken together, the results of the three studies are discussed in terms of an understanding of the mental representation of acoustic detail, and how acoustic detail can weakly link production and perception.

Preface

The studies in this dissertation were conducted under ethics approval from the University of Alberta Research Ethics Board, Project Name “Responses to phonetic detail,” Project Number Pro00025509, from October 11, 2011 – October 8, 2015. The studies in this dissertation were funded by a Social Sciences and Humanities Research Council Insight Development Grant with Dr. Benjamin V. Tucker as the principle investigator. The research conducted in this dissertation was done in collaboration with Dr. Benajmin V. Tucker, Dr. Terrance M. Nearey, and Dr. R. Harald Baayen. Dr. Tucker was the supervisory author who assisted in formulating the research concept and experimental design. Dr. Nearey assisted with the contribution of phonetic models in the research design. Dr. Baayen assisted with statistical analyses and computational techniques. All three assisted in the editing of the entire dissertation. I was responsible for the conception of the research, experiment design, data collection, analysis, and manuscript writing. No part of this dissertation has been previously published.

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Chapter 1:

Introduction

Speech, as people encounter it on a daily basis, is often within the context of casual, everyday conversations. However, spontaneous speech has received relatively little attention in the linguistic literature (Cutler, 1998; Ernestus et al., 2002; Johnson, 2004; Ernestus and Warner, 2011). Previous research has tended to focus on carefully elicited or contextually controlled speech, referred to as 'laboratory speech.' The current dissertation adds to speech research by investigating the acoustic detail of spontaneous speech, and how morphological information can influence the production and processing of the acoustic speech signal.

Spontaneous speech poses a methodological issue because the acoustic speech signal contains acoustic variation far beyond what can be corrected for during analysis (see Ernestus and Warner, 2011, for a discussion). Because such acoustic variation can be better controlled for in laboratory speech, carefully produced speech is often used to investigate mental representations and the mental lexicon. However, research on laboratory speech is less ecologically valid than spontaneous speech since the speech signals people encounter on a daily basis come from inherently uncontrolled and acoustically variable conversational speech.

The current dissertation addresses this issue of ecological validity by investigating the acoustic detail in spontaneous speech under current theories of the mental lexicon. It is first necessary to establish the terminology used in this dissertation:

Acoustic detail refers to any quantifiable measure of the physical speech signal. The acoustic details discussed in this dissertation include segment and word durations, individual formant measurements, and continuous formant contours based on the individual formant measurements. **Acoustic variation** refers to statistically significant variation within one measure of acoustic detail. Formant measures at vowel onset compared to vowel offset are an example of acoustic variation (provided that F-onset and F-offset are significantly different from one another).

Linguistic property refers to any inherently variable linguistic phenomenon. A linguistic property may be either a grammatical or emergent property. Morphology (e.g., verb tense) is an example of a grammatical linguistic property; lexical frequency is an example of an emergent linguistic property. The variation of a linguistic property may be within a discrete closed class (e.g., morphology) or a data-dependent continuum (e.g., lexical frequency).

1.1 Research Questions and Outline of this Dissertation

The four broad research questions this dissertation asks are:

1) What do the acoustic details look like in spontaneous speech? (Chapter 2)

The first study of this dissertation centres around defining one measure of acoustic detail in spontaneous speech: the trajectories of the first and second formant from vowels in a corpus of conversational speech. The specific research questions for Chapter 2 are:

i. Are there regular patterns of formant trajectories in spontaneous speech?
ii. If so, are these patterns similar to those in citation speech?
iii. What model of formant trajectories best captures the patterns seen in spontaneous speech?

I address these questions through descriptive and statistical analyses of formant contours. The results of this Chapter indicate that there are regular patterns of formant movement in spontaneous speech that are comparable to those in controlled and carefully elicited citation speech. Moreover, models of formant trajectory patterns previously proposed based on data from citation speech continue to hold for the spontaneous speech data at hand. This indicates that acoustic detail in spontaneous speech is comparable to that in more extensively citation speech. The data and analyses from Chapter 2 provide the background for subsequent analyses of relationships between formant measurements and linguistic properties in Chapter 3.

2) Do linguistic properties systematically influence the production of acoustic detail? (Chapter 3)

The second study of this dissertation builds upon the previous by asking whether formant movement and vowel dispersion are modulated by morphology and Naive Discriminative Learning cue association strengths (Baayen et al., 2011; discussed in detail in the following sections). The specific research questions for Chapter 3 are:

i. Does morphology influence the amount of vowel dispersion and formant movement?
ii. Does paradigmatic strength (as determined by Naive Discriminative Learning cue associate strengths) influence the amount of vowel dispersion and formant movement?

I address these questions through a series of statistical models. The results of this Chapter indicate that, even though there is an overall effect of both morphology and paradigmatic strength on acoustic detail, the effects themselves vary between vowels and between formants. Thus, Chapter 3 argues for fractionation and variability in models of speech production. Chapter 4 explores whether this is also true for speech processing.

3) Do relationships between acoustic detail and linguistic properties link speech processing with production? (Chapter 4)

The last study of this dissertation tests an assumption made in the previous Study: acoustic details correlate with linguistic properties because they enable the listener to process the speech signal more easily. For this last study, I tested the relationship between vowel duration and Naive Discriminative Learning cue association strength. The specific research questions for Chapter 4 are:

i. Does the production-based correlation between vowel duration and Naive Discriminative Learning cue association strength aid in word recognition?

ii. Does the production-based correlation between vowel duration and Naive Discriminative Learning cue association strength aid in morphological recognition?

I addressed these questions using two auditory experiments. The results of this Chapter indicate that variation in processing is dependent both on task (either lexical or morphological decision) and condition (morphological tense). Chapter 4 concludes that relationships between linguistic properties and acoustic details can provide a helpful link between speech production and speech processing, but are not necessary for processing. Instead, the relationships act more as a resource that listeners have the ability to draw upon. The weak production-processing link found in Chapter 4, in conjunction with the results from speech production found in Chapter 3, provides evidence for Chapter 5's theoretical discussion on the mental representation of acoustic detail.

4) What can evidence from production and processing tell us about the representation of acoustic detail? (Chapter 5)

The final Chapter of this dissertation relates the findings from Chapters 2, 3, and 4 to the mental lexicon. I propose a new framework for representing acoustic detail after discussing how current theories on the mental representation of morphological information and acoustic detail apply to the results described in Chapters 2, 3, and 4.

The remainder of the current Chapter provides some of the necessary background for the entire dissertation. I discuss the following topics: 1) the scope of the linguistic data used in this dissertation and how this scope addresses the aforementioned research questions; 2) an overview of empirical evidence from linguistic literature on acoustic detail in spontaneous speech production and processing; and 3) a brief discussion of the relevant literature concerning the relationship between the mental lexicon, morphology, and acoustic detail.

1.2 Scope of Linguistic Data for this Dissertation

To study the research questions outlined above, the current dissertation investigates differences in the production and processing of acoustic detail between morphological forms. This dissertation is limited to a set of irregular monosyllabic English verbs that differ between the past and present tense based on a single vowel phone. This includes words like *sing*/*sang* and *get*/*got*. Morphological pairs that contain a vowel change as well as the addition of an extra phone (such as *weep*/*wept*), and pairs that contain other phonological changes (such as *am*/*was*), are not under investigation. Investigating this specific set of words has several advantages:

1) Though morphologically different, these word pairs are phonologically the same except for a single segment.

Kuperman et al. (2007) call these segments 'pockets of indeterminacy' (or areas of uncertainty) where there lies a specific area, or pocket, that carries the entire weight of the word's morphological meaning. In the current set of irregular English verbs, the vowel segment resides in this pocket. For example, the morphological form of the word /sŋ̲/ is indeterminate without filling the vowel pocket: /si̲ŋ/ or /sæ̲ŋ/.

2) The phonological differences between these word pairs are limited to one segment.

Unlike Kuperman et al. (2007), who studied pockets of indeterminacy that were filled by 1-2 segments, the pocket of indeterminacy in the present set of verbs is filled by only one segment and always by a vowel. This makes the pockets of indeterminacy (i.e., the vowels) in the present word set comparable to one another (when the surrounding phonetic environment is controlled). Thus, it is possible to contrast a vowel in a past tense pocket (e.g., /s<u>æ</u>ŋ/) with the same vowel in a present tense pocket (e.g., /h<u>æ</u>ŋ/). In this way, the acoustic detail in these vowels can be compared across morphological forms.

3) These word pairs allow the influence of morphology and paradigm on the production and processing of acoustic detail to be tested.

Investigating morphologically related word pairs enables me to test directly for how various linguistic properties affect speech production and processing. These include common properties such as lexical frequency and neighbourhood density, as well as properties that are specific to this set of words such as morphology (i.e., past and present tense) and paradigmatic support. I can assess the mental representation of acoustic detail by testing the effect of morphology on speech production and processing and comparing morphological forms.

For these reasons, all three studies contained in this dissertation focus on this set of irregular English verbs. The first study investigates the acoustic detail present in the spontaneous production of these verbs. The second study analyzes the effect of morphology and paradigmatic support on the production of acoustic detail. The final study explores how the acoustic variability found in production can affect listeners' subsequent perceptual processing. In doing so (and as discussed in the previous section), the studies presented here address whether acoustic detail provides a link between speech production and speech processing.

The presence or absence of a production-processing link can provide insight into the role of acoustic detail in lexical representation. Several theories of mental representations have been posited based on studies in both spoken word production and spoken word processing, each discussed in detail below. This dissertation expands upon these studies by contributing new evidence for the relationship between acoustic detail and morphology in speech production and speech processing.

1.3 The Issue of Spontaneous Speech

Spontaneous speech is both interesting and problematic to study because it is produced with massive amounts of variability and reduction (Labov, 1972; Guy, 1991; Greenberg, 1999; Ernestus et al., 2002; Johnson, 2004; Ernestus and Warner, 2011). For example, the duration of a particular word can vary amongst productions of the same word by the same speaker by as much as one full second (Dilts, 2013). Moreover, the acoustic details within segments are also variable, such as the intensity of a consonant (Warner and Tucker, 2007) or the inherent formant structure of vowels (Nearey, 2013).

However, research indicates that this acoustic variability can be systematic in nature. Several studies have found predictive relationships between linguistic properties and the production of acoustic detail. For example, many studies have shown that word frequency modulates word and segmental duration (Jurafsky et al., 1998, 2001; van Son et al., 2004; Aylett and Turk, 2004; Pluymaekers et al., 2005, 2006; Gahl 2008; Dilts et al., 2011; Schuppler et al., 2011). These studies have found that highly frequent words tend to be produced with shorter durations, while words with lower frequencies tend to be produced with longer durations (cf. Kuperman et al., 2008). Aylett and Turk (2006) found a similar relationship between formant frequencies and lexical frequency, where vowels belonging to low frequency syllables are articulated more centrally than those of high frequency syllables.

Like lexical frequency, the phonological neighbourhood density of a word often correlates with acoustic detail. For example, many studies have found that phonological neighbourhood density is predictive of formant frequencies in vowels (Wright, 1997, 2004; Munson and Solomon, 2004; Munson, 2007; Gahl et al., 2012) as well as the produced durations of words and segments (Scarborough, 2004; Wright, 2004; Gahl et al., 2012).

Higher-level linguistic features have also been found to modulate the acoustic productions. For example, word duration can be predicted by the association strength between a word and its surrounding semantic and syntactic context (Bell et al., 2003, 2009). Moreover, relative intensity, voicing, and formant structure have also been found to predictably vary across different discourse conditions (Warner and Tucker, 2011).

In addition to speech production, acoustic detail has also been shown to have an effect on the processing of speech (for a more general overview, see Cutler, 1998). Studies have found that acoustic details can affect processing at both the lexical and segmental levels. This includes the acoustic details of: word duration (; Pollack and Pickett, 1964; Liberman, 1967), coarticulations with the surrounding environment (Scarborough, 2004; Sumner and Samuel, 2005), the inherent spectral properties of vowels (Nearey and Assmann, 1986; Strange et al., 1989), influences of prosodic structure (Mehta and Cutler, 1988), and the reduction or deletion of a segment (Mehta and Cutler, 1988; Van Bergem, 1993; Cutler, 1998; Kemps et al., 2004; Tucker, 2011).

There is strong evidence in the speech processing literature that linguistic properties and acoustic details are correlated. Measures of word frequency (Connine et al., 1990; cf. Ernestus and Baayen, 2007), neighbourhood density (Luce and Pisoni, 1998; Vitevitch and Luce, 1998; Vitevitch et al., 1999; Luce and Large, 2001), paradigmatic support (Bybee and Slobin, 1982; Stemberger, 2004; Kuperman et al., 2007; Hanique et al., 2010; Hanique and Ernestus, 2011; Schuppler et al., 2012; Cohen, 2014), the immediate phonetic and syntactic context (Ernestus et al., 2002), semantic and syntactic associations (van de Ven et al., 2009; van de Ven et al., 2011; van de Ven et al., 2012), and collocational frequency (Hilpert, 2008) have all been found to correlate with the processing of acoustic variation.

Because acoustic details and linguistic properties have been found to correlate in both speech production and processing, it is often thought that speech production and speech processing are linked. They are thought to be two components of a single speech system rather than separate, autonomous processes (for a discussion, see Liberman, 1984, 1996; Dell et al., 1997). The speech signal, then, is assumed to be a by-product of this link. It is encoded during production with acoustic cues relevant to processing and subsequently decoded during processing with the help of the acoustic cues (Lindblom, 1990; van Son and Pols, 2003; Aylett and Turk, 2004; Flemming, 2010; Jaeger, 2010; Gahl et al., 2012; Pate and Goldwater, 2015).

The studies referenced here interpret the role of acoustic detail within the theoretical frameworks of either speech production or speech processing. This dissertation expands upon these studies by interpreting the role of acoustic detail according to both speech production and speech processing.

1.4 Mental Representations of Morphology and Acoustic Detail

The data used in this dissertation allow me to investigate the mental representations of both morphology and acoustic detail. This involves determining whether morphology and acoustic detail reside inside or outside of the lexicon. What follows is a discussion of current theories on the mental representations of acoustic detail and morphology. Spoken word recognition theories provide hypotheses for the mental representations of acoustic detail, and speech processing theories provide hypotheses for the mental representations of morphological information.

1.4.1 Mental Representation of Morphological Information

The current dissertation compares morphological forms of irregular English verbs in order to investigate the mental representation of acoustic detail. Before doing so, it is first necessary to assess the mental representation of morphological forms. I consider three possible approaches for understanding the representation of morphological information as it relates to the lexicon. Each approach is explained here.

The first approach holds that morphological information is not contained in the lexicon. Instead, abstract lexical representations of words (such as lemmas) are stored in the lexicon, and these pass through a separate morphological process in order to derive various morphological word forms. Thus, morphological specification/information is derived via a separate morphological process as one step within the larger speech processing process, not stored explicitly in the lexicon. Proponents of this morphology-process approach include Taft and Forster (1975), Marslen-Wilson et al. (1994), Levelt et al. (1999; Weaver++), and Cohen-Goldberg (2013; Heterogeneity of Processing Hypothesis).

A second approach holds that lexical representations are stored in the lexicon with their morphological information fully specified. Unlike in the morphology-process approach, word forms are not morphologically derived from abstract representations. Proponents of this morphology-storage approach include Manelis and Tharp (1977), Stemberger and MacWhinney (1986; for high frequency morphological forms), Caramazza (1988; the Augmented Addressed Morphology Model which includes a morphology-process component for novel words), and Baayen et al. (1997; the Parallel Dual Route Model which also allows for a parallel morphology-process component.

Finally, a third approach holds that morphological information is captured in learned connections between stored meanings and output of the speech production system (or input of the speech recognition system). Here, individual meanings, rather than individual word forms, are stored within the lexicon. Implicit learning connects these stored meanings to their outputted word forms. In this approach, morphological information resides outside of the lexicon as a generalized statistical pattern of learned associations (or a connection) between an output/input form and a mentally stored meaning. Proponents of this morphology-generalization approach include the Convergence Theory (Seidenberg and Gonnerman, 2000) and Naive Discriminative Learning (Baayen et al., 2011, Baayen et al., in press).

1.4.2 Mental Representation of Acoustic Detail

There are two general accounts for the mental representation of acoustic detail: an acoustic-detail-storage account, and an acoustic-detail-abstraction account. These two accounts are based on how acoustic detail interacts with the lexicon.

The acoustic-detail-storage account holds that every instance of an acoustically variant word form is stored with the word in the lexicon. Here, acoustic detail resides within the lexicon as a property of lexical representations (Hanique and Ernestus, 2012; Hanique et al., 2013). Different theories of speech production specify the extent to which acoustic detail is stored. Exemplar-based theories (Johnson, 2006; Goldinger 1996, 1998; Pierrehumbert 2001, 2003), for example, hold that the storage of acoustic detail is conditioned with experience. The encounter of a new variant form is matched to these exemplars and then incorporated into the lexical representation.

Other researchers (Klatt, 1979, Samuel, 1982; Kuhl, 1991, Thyer et al., 2000) propose that in addition to the storage of variant acoustic forms, mental representations contain an acoustic form that is abstracted over these stored variations (such as prototypes and perceptual magnets). The encounter of a new variant form is then matched to these abstracted prototypes and incorporated into the lexicon representation (with the prototype updated, if need be).

The acoustic-detail-abstraction account holds that a phonological process strips the speech signal of acoustic detail in order to parse the signal into discrete, abstract phonological representations. These phonological representations are then mapped to representations in the lexicon. Acoustic detail is represented as noise in the speech signal, outside of the lexicon. Proponents of this acoustic-detail-abstraction account differ in terms of how acoustic detail is abstracted.

Some models of spoken word recognition or production describe the phonological process in terms of probabilistic relationships between the acoustic detail and abstract phonological representations (such as in Shortlist B, Norris and McQueen, 2008). Other models make use of formal phonological processes to derive abstract forms from the noisy speech signal (such as Weaver++, Levelt et al., 1999). And still, other proponents of the acoustic-detail-abstraction account include a hidden 'phonological interference mechanism' for disambiguating phonologically variant forms (Lahiri and Marslen-Wilson 1991; Gaskell and Marslen-Wilson, 1996, 1998).

These two main approaches towards the mental representation of acoustic detail are similar to the previously discussed mental representations of morphology. In the literature, there is both a storage-based account and a process-based account of how morphology and acoustic detail relate to the lexicon. This dissertation extends the third account of morphological representation, a generalization account, to the mental representation of acoustic detail. Just as morphological variation acts as a tool to directly access stored meanings through learned patterns of statistical association, I propose that acoustic detail can function in the same way. The chapters contained within this dissertation (Chapters 2, 3, and 4) will provide empirical evidence for such an acoustic-detail-generalization account. Chapter 5 returns to this discussion of the mental representation of acoustic detail.

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Chapter 2:
Dynamic Formant Movement in Spontaneous Speech Vowels

2.1 Introduction

Studies of vowel perception have found strong support for the existence of dynamic formant movement in monophthongs, similar to those in diphthongs (Strange et al., 1983; Parker and Diehl, 1984; Nearey and Assmann, 1986; Strange, 1989; Andruski and Nearey, 1992; Zahorian and Jagharghi, 1993; Hillenbrand et al., 1995; Jenkins et al., 1999; Hillenbrand and Nearey, 1999; Assmann and Katz, 2000, 2004; Morrison and Assmann, 2013). Dynamic formant movement may be useful to the listener, as research in vowel perception suggests that listeners are better able to distinguish between and identify vowels with movement compared to their steady-state formants. Listeners use cues such as a vowel's pattern of movement through the vowel space and its F1xF2 location in the vowel space to identify vowels.

The formant trajectories of vowels and existence of dynamic formant movement have also been studied extensively in acoustic production research. Many early studies have measured the acoustic details of vowels in citation speech and found strong support for the existence of dynamic formant movement in vowels (Potter and Steinberg, 1950; Peterson and Barney, 1952; Stevens and

House, 1963), leading to specific theories on inherent vowel movement (Assmann et al., 1982; Nearey and Assmann, 1986; Andruski and Nearey, 1992; Hillenbrand et al., 1995; Assmann and Katz, 2000; Hillenbrand, 2001; Hillenbrand and Houde, 2003; Nearey, 2013; Morrison and Assmann, 2013). This tendency for vowels to display spectral movement throughout their duration, known as Vowel Inherent Spectral Change (VISC; Nearey and Assmann, 1986; Strange, 1989), is systematic and persistent across dialects and speakers (see Nearey, 2013, for a discussion). Studies show that the acoustic cues related to VISC are as informative as other inherent vowel properties, such as pitch and duration (Hillenbrand et al., 2000; Hillenbrand et al., 2001).

The VISC research discussed above has focused on data from carefully produced laboratory speech. Some researchers (namely Strange et al., 1986; Strange and Jenkins, 2013) are wary of investigating VISC in spontaneously produced vowels because of the amount of hypo-articulation and coarticulation present in spontaneous speech (discussed further below). The present study tests this concern by investigating VISC in spontaneous speech. I predict that formant trajectories in spontaneous speech will have patterns similar to those demonstrated in laboratory speech. In order to discuss current theories of VISC and how they apply to the present study, it is necessary to first highlight the challenges faced when analyzing spontaneous speech.

2.1.1 Challenges of Dynamic Formant Movement in Spontaneous Speech

Compared to carefully elicited laboratory speech, spontaneous speech is produced with faster articulations and more gestural overlap (Lindblom, 1963). Spontaneous speech presents two considerable challenges to the analysis of dynamic formant movement. The first challenge concerns articulatory undershoot, or hypo-articulation, while the second challenge concerns coarticulation with the surrounding phonetic environment.

Spontaneous speech is produced more quickly than citation or laboratory speech, often resulting in less movement in the vocal tract and reduced segments/words (for discussion, see Lindblom, 1963; Ernestus and Baayen, 2007;

Tucker, 2011; Warner et al., 2012; Strange and Jenkins, 2013). There is strong evidence for speakers using a smaller vowel space in spontaneous speech compared to more carefully elicited speech (Lindblom, 1963, 1990; Moon and Lindblom, 1994; Aylett and Turk, 2006). This leads to an overall effect of vowel centralization and hypo-articulation in spontaneous speech. Strange and colleagues argue that this centralization effect that is inherent to spontaneous speech is at odds with dynamic formant movement (1989, 2013). They reason that, because vowels in spontaneous speech are already produced with reduced articulations, any dynamic formant movement will also be reduced, perhaps to insignificance. Simply stated, Strange et al. claim that vowels in spontaneous speech are articulated too quickly to exhibit any systematic patterns of movement.

Furthermore, Strange and colleagues predict that coarticulatory effects will be too great to overcome. They contend that the gestures from the surrounding phonetic environment will overlap with the vowel's gesture, perhaps eclipsing the vowel entirely. This poses a second challenge to analyzing spontaneous speech data for formant movement: it is difficult to parse out formant movement that is inherent to the vowel only, and not to coarticulation effects.

However, this coarticulatory challenge is not unique to spontaneous speech; it also poses a challenge for citation speech. In fact, current research on vowel production in citation speech focuses on statistical methods to control for coarticulation from the phonetic environment (for a discussion, see Nearey 2013; Broad and Clermont, 2014). In the past, however, coarticulation was addressed by carefully crafting and controlling the phonetic context surrounding the vowel, e.g., by creating CVC contexts with initial /h, b, d, g, p, t, k/ consonants and final /b, d, g, p, t, k/ consonants (Andruski and Nearey, 1992; Hillenbrand et al., 1995; Assmann and Katz, 2000; Hillenbrand et al., 2001; Hillenbrand and Houde, 2003; Nearey, 2013).

Unlike the carefully controlled conditions of laboratory speech, the phonetic context surrounding a vowel in spontaneous speech is relatively uncontrolled and highly variable. The phones preceding and following a vowel are also produced with variable spectral properties, often due to the reduced nature of spontaneous speech (van Son and Pols, 1999; Johnson, 2004; Tucker and Warner, 2007; Tucker, 2011; Warner and Tucker, 2011; Warner et al., 2012). The variability in a vowel's immediate phonetic context adds to the difficulty in parsing inherent formant trajectory patterns from coarticulatory effects. According to Strange and Jenkins (2013), the variable nature of the phonetic context coupled with its rapid articulation could bury systematic patterns of formant trajectories beneath the effects of coarticulation.

The present study takes a first step towards analyzing vowel patterns in spontaneous speech in the face of these challenges. I use various statistical and observational techniques to control for variability in the phonetic environment, allowing me to distinguish between vowel formant patterns and coarticulation. Further, I analyzed a large sample size of vowel acoustic data in order to maintain statistical power.

However, it is notable that the purpose of this study is more to observe and describe dynamic formant movement patterns in spontaneous speech, than to formally address the inherent nature of spectral change in spontaneously produced vowels. The descriptive observations in the present study are made under current theories of VISC. Theoretical research on VISC aims to characterize two aspects of dynamic formant movement: 1) how to best measure dynamic spectral properties, and 2) how to best describe VISC patterns.

2.1.2 Theories of Vowel Inherent Spectral Change

There are several theories as to which details of formant movement are most relevant for production and perception. Throughout the course of VISC research, three main hypotheses have been proposed to capture the informative nature of formant movement patterns. Morrison (2013; see also Morrison and Nearey 2007) identified these as the: onset+offset hypothesis, onset+slope hypothesis, and onset+direction hypothesis. Each of the three hypotheses acknowledges the importance of the formant trajectories' onset. They differ, however, in what type of information best captures the dynamic spectral movement that follows.

The onset+offset hypothesis predicts that in addition to the onset, a vowel's offset F1 and F2 values (which can be used to calculate a trajectory's change in frequency, ΔF) will be the most informative. The onset+slope hypothesis predicts that formant movement patterns are a function of time (ΔF/Δt), and the velocity of a vowel's trajectory will be the most informative. Lastly, the onset+direction hypothesis predicts that the overall direction of movement in a vowel's trajectories (such as "increasing F1+decreasing F2," "decreasing F1+decreasing F2," etc.) will be the most informative.

In fact, it seems that the best performing hypothesis is one consisting of a vowel trajectory's onset+offset+pitch+duration. In a discriminant analysis, Morrison (2013) found the onset+offset hypothesis to be superior in capturing both the acoustic production detail and the perceptual cues used by listeners (see also Nearey and Assmann, 1986; Hillenbrand et al., 2001; Morrison and Nearey 2007). Other studies on the perception of dynamic formant movement have found vowel duration and pitch to be informative of VISC as well (Hillenbrand et al., 2001). For example, a vowel's intrinsic pitch can help the listener discern between vowels articulated in the upper and lower halves of the vowel space (for discussion, see Ohala and Eukel, 1987). Vowel duration is also informative in discerning between traditionally named 'tense' and 'lax' vowels (for discussion, see Hillenbrand, 2013). A framework that combines these factors as onset+offset+pitch+duration is summarized by Morrison and Assman (2013).

In addition to testing the best means of capturing VISC, there has been substantial research on describing the VISC patterns of movement in carefully produced speech. According to Nearey (2013), there are four different types of VISC movement:

1) upsilon-movement: movement towards the high back corner of the vowel quadrilateral
2) alpha-movement: movement towards the low ventral corner of the vowel quadrilateral
3) iota-movement: movement towards the high front corner of the vowel quadrilateral

4) schwa-movement: centralization, or movement towards the centre of the vowel quadrilateral

The 'inherent' nature of VISC connotes that certain vowels tend to display a characteristic type of movement. For example, /o/ tends to pattern with upsilon-movement and /æ/ tends to pattern with alpha-movement. A predictive theory of VISC is based on observations that these patterns persist across speakers and utterances.

However, current predictions of dynamic formant movement have been entirely based on vowel data from citation speech. Though some studies have investigated vowel production in context (Andruski and Nearey, 1992; Hillenbrand et al., 1995; Assmann and Katz, 2000; Hillenbrand et al., 2001; Hillenbrand and Houde, 2003; Nearey, 2013), all studies of VISC and dynamic formant movement have analyzed vowels produced in carefully controlled, laboratory-based elicitations. There have been no studies that have investigated the nature of dynamic formant movement in a more ecologically valid situation, such as the unbalanced contexts of everyday spontaneous conversations. Since much has been learned about vowels' dynamic spectral properties in citation speech, several VISC researchers (namely, Hillenbrand, 2013; Strange and Jenkins, 2013) are calling for the next step in vowel production analysis: dynamic spectral properties of spontaneous speech.

The present study expands the research of dynamic formant movement and VISC by analyzing vowels produced in everyday, conversational spontaneous speech. The analyses used in this chapter focus on both descriptive and statistical investigations of vowels produced in spontaneous speech. Although the aforementioned challenges prevent me from directly testing one VISC theory over another, my data do allow for general comparisons to be made between the dynamic formant patterns in spontaneous speech versus citation speech. The purpose of the present study is to take an initial step in observing and describing dynamic formant movements in spontaneous speech as they relate to predictions of VISC patterns made on laboratory speech data.

2.2 Method

2.2.1 The Data

The present study limits the measurement of vowel tokens to a subset of monosyllabic irregular English verbs. The subset of monosyllabic irregular English verbs includes 74 verb pairs that differ between their past and present tense forms based on a single vowel. For example, the dataset included irregular verbs like *sing*/*sang*, but excluded irregular verbs that contained the addition of a phoneme, such as *weep*/*wept*, and verbs that contained other phonological changes, such as *is*/*were*. Studying this subset of English verbs allows for subsequent investigation into the role that morphology plays in the production and processing of the vowels' acoustic details (see Chapters 3 and 4 of this dissertation).

Productions of these verbs were extracted from the Buckeye Corpus of Conversational English (henceforth, Buckeye Corpus; Pitt et al., 2007). The Buckeye Corpus contains roughly 300,000 words in 40 hours of recorded spontaneous speech gathered from sociolinguistic-like interview sessions with 40 adult speakers. Speakers are evenly distributed amongst genders and age, and each speaker's recording lasts roughly for an hour. The Buckeye Corpus yields 6,983 verb tokens containing ten different monophthongs: /i/, /ɪ /, /ɛ /, /æ/, /ʌ /, /u/, /ʊ /, /o/, /ɔ /, and /ɑ/.

The contours of the fundamental frequency and first, second, and third formants (henceforth, f0, F1, F2, and F3, respectively) for each vowel were automatically gathered using FormantMeasurer (Morrison and Nearey, 2011) and hand-corrected. For the entire duration of each vowel, pitch and formant measurements were taken approximately every 2ms. Quantile plots of the first and second formant are given in the Appendix (Figure A.1, Figure A.2, Figure A.3, and Figure A.4).

2.2.2 Analyses

The current study contains two analyses of dynamic formant movement: 1) a description of the dynamic formant patterns for each vowel; and 2) a discrimination test of how to best capture the dynamic formant patterns.

The first analysis consists of both descriptive and statistical analyses to test for any dynamic movement in the spontaneously produced vowel formants. For the descriptive analysis, vowel onsets and offsets were plotted and analyzed for visible differences. The statistical analyses consist of both standard tests of difference (t-tests) and Linear Mixed Effects Regression (LMER; Baayen et al., 2008) analyses. These were computed in the R statistical environment using the *lme4* (Bates et al., 2014) and *languageR* (Baayen, 2013) packages.

The second analysis follows the methods of Morrison and Nearey (2007) for determining how to best capture the informative nature of the dynamic formant patterns. A set of linear discriminant analyses were used to determine which of the three hypotheses of VISC movement (onset+offset, onset+slope, or onset+direction) performs best in discriminating vowels from one another, based on the acoustic information each hypothesis provides. These were computed in the R statistical environment using the *MASS* package (Ripley et al., 2014).

Both analyses were iterated five times: once using non-normalized Hertz values and four times using data normalized by one of four techniques for comparison (Lobanov, 1971; Nearey, 1978; bark transform: Traunmüller, 1990; and logarithmic transform). The results of the normalized analyses were similar to each other and to that of the non-normalized analyses. As such, the results of the analyses calculated based on non-normalized Hertz values are discussed here.

2.2.2.1 Standard Tests of Difference (t-tests) Procedure

In the difference tests, a series of t-tests were used to assess significant differences between vowels' F1 and F2 onsets and offsets. These tests were performed separately on males and females. To decrease the effect of the surrounding phonetic environment on the trajectory of formant movement, the analysis was limited to formant values that occured between 20% and 80% of the vowel's total length (i.e., following Nearey, 2013's reanalysis of the Hillenbrand et al., 1995 data).

This method of decreasing the effect of the phonetic context reduces the effect of formant transitions at the tail ends of the vowel but does not control for the interaction between formant trajectories and the phonetic environment. Not all effects of the phonetic environment on formant production can be accounted for by removing the formant transitions; the formants themselves will be produced differently or masked according to the phonetic environment (for a discussion, see Van Summers, 1987; Sussman et al., 1991; Nearey, 2013; Broad and Clermont, 2014).

With the acknowledgement of this possible confound with the phonetic context, each vowel was tested for a significant difference between 1) F1 values at 20% and 80% of the total vowel duration, and 2) F2 values at 20% and 80% of the total vowel duration.

2.2.2.2 Linear Mixed Effects Regression Procedure

To better control for the surrounding phonetic environment, an additional LMER analysis was conducted over the trimmed data (i.e., over 20-80% of the vowels' total durations). The identities of the phones in the surrounding environment (i.e., the phone before the vowel and the phone after the vowel) were included as phonetic controls of context on the formant measures. Though using articulation characteristics of the surrounding phonetic context (such as place, voice, and manner) would make for a simpler, more interpretable model, this was not possible for the data at hand. For some vowels, there was not enough contrast in the articulatory characteristics to allow for LMER modelling. For example, the vowel /æ/ for females was always followed by a voiced consonant, making it impossible to model the contrast between voiced and voiceless phones. For this reason, the identities of the phones in the phonetic environment surrounding the vowel were used to model the contribution of the immediate context, rather than articulatory characteristics.

Ideally, in a regression analysis, the formant values under investigation would be compared to a neutral reference level comprising formant values for the same vowel in a phonetic context-free environment (such as in isolation). However, productions of each vowel in such context-free environments do not exist in the Buckeye Corpus for every speaker. Thus, instead of conducting a regression analysis that compares vowel formants to a reference level of phonetic context (dummy coding), the regression analysis compared vowel formants to the mean of the phonetic context (deviation coding). The mean of all the phonetic environments that occur with a vowel, then, serves as the neutral reference, which will be calculated from the dataset. The phonetic context mean and, consequentially, the VISC mean, may differ between data sets and sets of words. It is important to keep in mind that the current chapter investigates relative VISC values and discerns patterns of change, rather than absolute measures.

To further control for the surrounding phonetic environment, the distribution of both the phone before and the phone after each vowel (across all speakers) was evaluated for any skewing that would affect the mean of the phonetic context. For example, a greater representation of a particular phonetic environment would shift the mean towards that particular environment, producing a skewed mean of the surrounding context instead of a more neutral one. There are several ways of dealing with this skewed mean: 1) some of the items belonging to the skewing environment could randomly be removed so that the distributions are more even; 2) weights could be assigned to each environment so that each environment is weighted equally, though the number of items within each equally weighted environment can vary; or 3) all items from skew-inducing environments can be removed altogether. The third option (removing all skew-inducing items) was chosen for this particular analysis. The first option (random removal, even distribution) proved difficult to control across speakers; often, the skew-inducing environments were produced mostly by a handful of speakers (e.g., a particular environment was used by a few speakers, and those few speakers used the environment often). The second option (assigning weights) proved ineffectual for sparser environments: the weighted contribution from environments with low densities would be calculated based on a few items (low statistical power) and is less informative than the weighted contribution from environments with higher densities. Thus, removing the items belonging to skew-inducing environments altogether seemed the least arbitrary and maintained the most statistical power.

Half of the vowels (namely /i/, /ɪ /, /ɛ /, /æ/, /o/) contained disproportionate skewing in the distribution of the surrounding phonetic context (see the Appendix Table A.1, Table A.2, and Table A.3). For example, /n/ occurred before /o/ three times as often than any other phone (with 50% of that particular environment produced by only 30% of the speakers). These skewed distributions were resolved by excluding formant measures associated with the disproportionate contexts. Figure 2.1 illustrates the linear model's results for /i,/ /ɪ /, /ɛ /, /æ/, /o/ before and after removing the skewed formant measures, compared to the average of the raw data.

With the exception of /æ/, resolving the skewed context distributions resulted in a similar pattern of VISC movement, with a shift in the vowels' location in the F1xF2 vowel space. Thus, removing the skewed measures (n=955, 13% of the original data set) generates estimates that are more representative of the raw data (as seen in Figure 2.1). Post-hoc analyses also show that resolving context skewing improves the statistical models' performance (according to the models' AIC measures). There were 6,028 vowel tokens remaining in the data set after removing those skewed for context. Information about the vowel tokens removed, including the skewed contexts, are given in the Appendix (Table A.4).

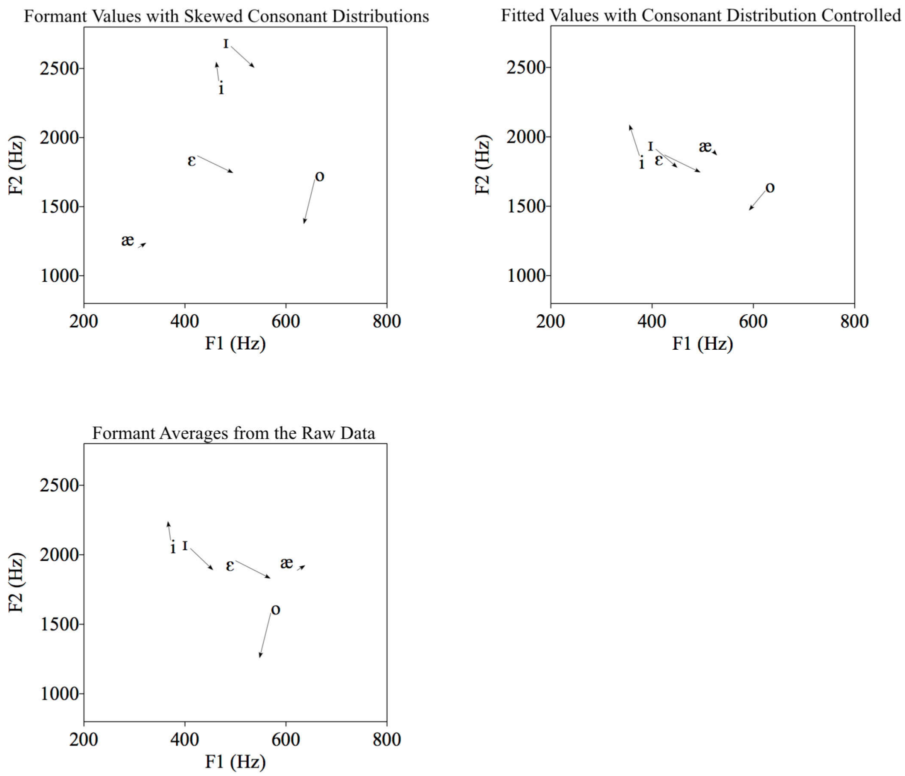

Figure 2.1: Illustration of removing skewed context distributions for the five vowels affected by skewing. The upper-left pane presents the fitted formant values from a linear mixed-effects regression model without controlling for context skewing. The upper-right pane presents the fitted formant values from the linear mixed-effects regression model with context skewing controlled. The lower-left pane presents average formant values from the raw measurements.

F1 and F2 for each vowel were modelled separately in the regression analysis, for a total of 20 linear mixed-effects models (10 vowels, each with F1 as the dependent variable in one model and F2 as the dependent variable in a second model). The duration of each vowel was normalized in terms of percentages of the total vowel duration (i.e., 20% of the total vowel duration, 30%, 40%, 50%, 60%, 70%, and 80%).

These normalized measures of time served as the main independent variable in predicting formant values, with the vowel onset (20%) serving as the reference level. In this way, a vowel’s formant value at the 20% time step was compared to the formant value at each subsequent time step. The LMER results are then relatable to the difference tests (t-tests) by comparing the formant values of the vowel onset (20% time step) to the formant values ofthe vowel offset (80% time step, based on Nearey's reanalysis of the data (2013) from Hillenbrand et al., 1995).

The deviation coding of the phonetic context (the phone before and after the vowel) also served as an independent variable. The vowel's duration, average pitch, and speaker gender served as controls. A simple inspection of the Pearson's correlation coefficients for all possible two-way interactions found no strong correlations and thus low collinearity between the numeric predictors. Random intercepts were allowed for individual speakers. A summary of the predictors for the LMER models is given in Table 2.1.

Table 2.1: Predictors for main effects and random effects in the LMER models.

Predictor	Description	use in LMER models
Formant Value	the F1 and F2 value at a particular time point; given in Hertz; F1 and F2 for each vowel were analyzed in separate LMER models	dependent variable
Time	normalized measure of time; each 10% of the total vowel duration is marked from 20%-80% (i.e. 20, 30, 40, … 80%)	independent variable of interest
Vowel Duration	given in milliseconds	control variable
Previous Segment	deviation coding for the segment preceding the vowel	control variable
Next Segment	deviation coding for the segment following the vowel	control variable
Pitch	the f0 value at a particular Percent time point; given in Hertz	control variable
Gender	the gender of the Speaker as identified in the Buckeye Corpus	control variable
Speaker	the anonymous identity of the Speaker	random intercept

2.2.2.3 Discriminant Analysis Procedure

In addition to investigating the presence of dynamic formant movement, additional linear discriminant analyses tested the ability of Morrison's (2013; Morrison and Nearey, 2007) dynamic formant movement models to distinguish between vowels in spontaneous speech. The analysis is based on a linear stepwise parametric technique trained on all various combinations of F1 and F2 onsets, offsets, slope, direction, pitch, and duration.

Vowel onset and offset measures were again taken at the 20% and 80% points of each vowel. A vowel's slope was calculated as the ratio of the Euclidian distances between the vowel's F1xF2 offset and F1xF2 onset. Onset and offset measurements used for calculating the formant trajectories' slopes were again taken at 20% and 80% of each vowel's total duration. It is possible, and likely, that taking onset/offset measurements at other durational points in the vowel could affect the slope measurement (since a linear slope's function is dependent upon where in the vertical and horizontal planes a sample is taken). However, the 20% and 80% formant measurements were used to maintain consistency throughout the analysis.

A vowel's direction was coded factorially according to the vowel's direction of formant movement (i.e., all possible variations of F1 [no change, increasing, or decreasing] combined with F2 [no change, increasing, or decreasing] for a total of 9 possible combinations). The same iteration of the discriminant analyses was performed two times: once on vowels produced by males only, and once on vowels produced by females only.

2.3 Results

2.3.1 Vowel Properties, Gender, and Dialect

Table 2.2 illustrates three properties of each vowel: average duration, frequency in the Buckeye Corpus, and average formant values for each gender. Overall, the difference in vowel duration is as expected, with tense vowels being produced longer than their lax vowel counterparts (mean duration of tense vowels: 129.14ms, mean duration of lax vowels: 71.44ms; $t = 38.9089$, $p < 0.001$; Klatt, 1976).

Gender differences in the vowel space are also as expected. A discriminant analysis shows that there is a significant difference between speaker genders in the location of vowels in the vowel space. Females tend to articulate vowels with higher F1 and F2 frequencies compared to males ($p < 0.001$ for all vowels).

Additionally, the vowel space measured by the Euclidian distance from the centre of the vowel space to the four corner vowels /i/, /æ/, /u/, and /ɔ / is larger for females than for males ($p < 0.001$ for all vowels).

It is notable that the high back vowels /u/ and /ʊ/ are, in general, fronted in the Columbus, Ohio dialect (Thomas, 1989; Lavob et al., 2005). This dialectal fronting is evident in the F2 measures from /u/ and /ʊ/ in the present subset of irregular English verbs of the Buckeye Corpus. /u/ and /ʊ/ fronting are illustrated in the mean F2 value, as well as in the vowel plots in Figure 2.2.

Table 2.2: Four vowel properties in the subset data of the Buckeye Corpus: average vowel duration; frequency of occurrence in the subsetted Buckeye Corpus; and mean F1 and F2 values for males and females.

Vowel	Average Duration (ms)	Frequency in Buckeye Corpus	Males		Females	
			Mean F1 (Hz)	Mean F2 (Hz)	Mean F1 (Hz)	Mean F2 (Hz)
/i/	117.78	339.80	340.27	1984.67	396.33	2415.93
/ɪ/	66.52	406.33	400.23	1841.77	475.32	2154.48
/ɛ/	82.99	480.09	479.37	1736.81	598.62	2031.21
/æ/	114.35	576.30	576.30	1802.56	699.70	2030.30
/ʌ/	73.68	541.17	541.44	1395.18	686.89	1582.52
/u/	113.82	367.14	370.51	1526.77	461.54	1836.97
/ʊ/	62.45	423.13	426.63	1491.34	507.06	1725.65
/o/	146.62	497.50	497.79	1288.05	641.22	1509.09
/ɔ/	143.14	565.29	572.56	1044.73	676.59	1169.76
/ɑ/	101.97	572.11	571.52	1554.83	748.17	1733.03

2.3.2 Dynamic Formant Movement Patterns

For the descriptive analysis of formant movement, the average F1xF2 values at 20% of the vowel's total duration will serve as the onsets, and average F1xF2 values at 80% of the vowel's total duration will serve as the offsets. The trajectories of the formant movements for each of the 10 vowels are illustrated in Figure 2.2, separated by gender. Labelled arrows indicate formant movement through the vowel space. The blunt end of each arrow marks the average onset of the labelled vowel, while the tip of the arrowhead marks the average offset.

2.3.2.1 The Presence of Dynamic Formant Movement

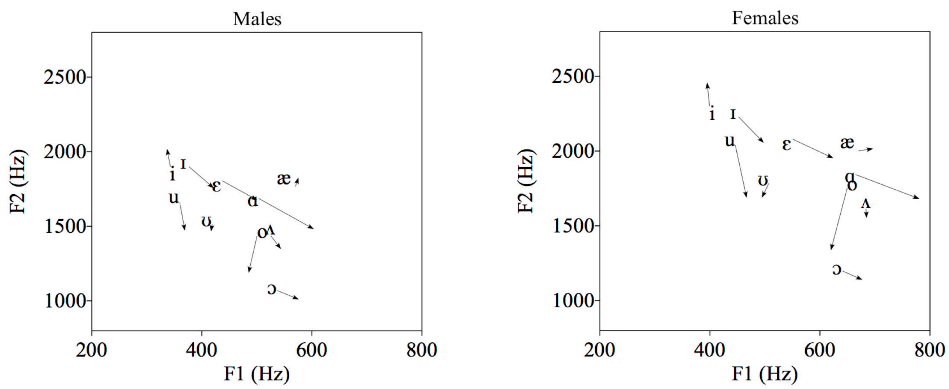

Figure 2.2: Vowel plots for the average onset and offset of each vowel. Data from males are shown in the first panel, data from females in the second. Blunt ends of the arrows indicate 20% of the total vowel duration (onsets) and arrowheads indicate 80% of total vowel duration (offsets).

As seen in Figure 2.2, most of the vowels move dynamically through the vowel space. The dynamic formant movement visually evident in the onsets and offsets is also supported by the statistical analyses. Table 2.3 shows the results for the t-tests and LMER models; all coefficients for the t-tests and LMER models can be found in the Appendix (Table A.5 and Table A.6).

The results of the difference analyses (t-tests) show that, with the exception of /æ/ (which does not exhibit any statistically significant dynamic formant movement in either gender), every vowel exhibits some statistically significant movement in at least one dimension (F1 or F2). This is evident in both the vowel plot (Figure 2.2) and regression coefficients (Table 2.3).

Overall, most of the vowels in the subset of irregular English verbs from the Buckeye Corpus exhibit dynamic formant movement in at least one formant dimension. Nine out of the ten vowels display movement in the F1 vowel space, and seven out of the ten vowels display movement in the F2 vowel space (with 7 vowels exhibiting movement in both formant dimensions). This dynamic formant movement is robust in both the descriptive vowel plot analysis and the statistical analyses (t-tests and linear mixed-effects regression).

Table 2.3: Summary of statistical analyses for differences in F1 and F2 onsets/offsets. The left side shows the significance values from the analysis on significant difference (t-tests on males, females, and combined genders). The right side shows the results from the linear mixed-effects regression analysis (controlled for gender). Shading indicates non-significance.

	significant difference (t-test) (uncontrolled for context)						linear mixed-effects regression (statistically controlled for context)	
	males		females		combined genders		statistically controlled for gender	
Vowel	F1 onset/offset difference	F2 onset/offset difference	F1 onset/offset difference	F2 onset/offset difference	F1 onset/offset difference	F2 onset/offset difference	F1 onset/offset difference	F2 onset/offset difference
/i/	p = 0.13	p < 0.01	p = 0.43	p < 0.01	p = 0.16	p < 0.01	t = -5.30	t = 15.98
/ɪ/	p < 0.01	p < 0.01	p < 0.01	p < 0.01	p < 0.01	p < 0.01	t = 8.53	t = -11.89
/ɛ/	p < 0.01	p < 0.01	p < 0.01	p < 0.01	p < 0.01	p < 0.01	t = 16.04	t = -14.14
/æ/	p = 0.87	p = 0.35	p = 0.29	p = 0.82	p = 0.48	p = 0.45	t = 0.16	t = -0.33
/ʌ/	p = 0.08	p < 0.01	p = 0.93	p < 0.01	p = 0.23	p < 0.01	t = 1.90	t = -7.93
/u/	p = 0.19	p < 0.01	p = 0.16	p < 0.01	p = 0.10	p < 0.01	t = 2.73	t = -14.19
/ʊ/	p = 0.87	p = 0.06	p = 0.52	p < 0.01	p = 0.57	p < 0.01	t = -0.55	t = -5.03
/o/	p < 0.01	p < 0.01	p < 0.01	p < 0.01	p < 0.01	p < 0.01	t = -5.90	t = -11.47
/ɔ/	p < 0.01	p < 0.01	p = 0.18	p = 0.15	p < 0.01	p < 0.01	t = 5.40	t = -6.52
/ɑ/	p < 0.01	p < 0.01	p < 0.01	p < 0.01	p < 0.01	p < 0.01	t = 28.84	t = -28.89

2.3.2.2 The Direction of Dynamic Formant Movement

In addition to the difference between onset and offset, the direction of movement shown in the vowel plots is also of interest. Statistical analysis shows that the amount of movement differs between genders for some vowels (measured as the Euclidian distance between onset and offset for each formant; see Table 2.4), but the patterns of direction are similar (as illustrated in Figure 2.3). Thus, the results that follow are from analyses with the genders combined.

It is also noted that the patterns observed here are particular to the data at hand, specifically regarding the dialect of the speakers. The descriptions below are intended to give an overview of the observational trajectories for this particular set of central Ohioan vowels. How the formant patterns described below compare to the formant patterns observed in other North American dialects (especially the high back vowels) is addressed in the subsequent Discussion section.

Table 2.4: Euclidean distance estimates and coefficients from tests of significant differences (t-tests) in formant movement between males and females; boldface indicates non-significance.

Vowel	F1			F2		
	est. Euclidian distance for males	est. Euclidian distance for females	*p*-value for gender differences in amount of movement	est. Euclidian distance for males	est. Euclidian distance for females	*p* value for gender differences in amount of movement
/i/	118.5406	163.6485	0.63	427.9936	591.1031	< 0.01
/ɪ/	68.7624	99.3933	0.88	294.0575	335.1692	0.01
/ɛ/	69.8361	99.6508	0.13	229.7997	270.1119	0.84
/æ/	149.0723	146.3191	0.52	261.4749	241.8436	0.46
/ʌ/	130.3040	187.1380	0.03	210.9727	301.9798	0.06
/u/	89.6379	125.1657	0.12	237.1169	336.1949	< 0.01
/ʊ/	51.5258	97.4717	0.47	132.2941	185.2130	< 0.01
/o/	94.6212	133.1375	< 0.01	297.0597	363.3115	< 0.01
/ɔ/	116.3860	143.9893	0.85	515.7780	664.9841	0.97
/ɑ/	124.2274	198.1164	0.02	137.1151	160.9024	< 0.01

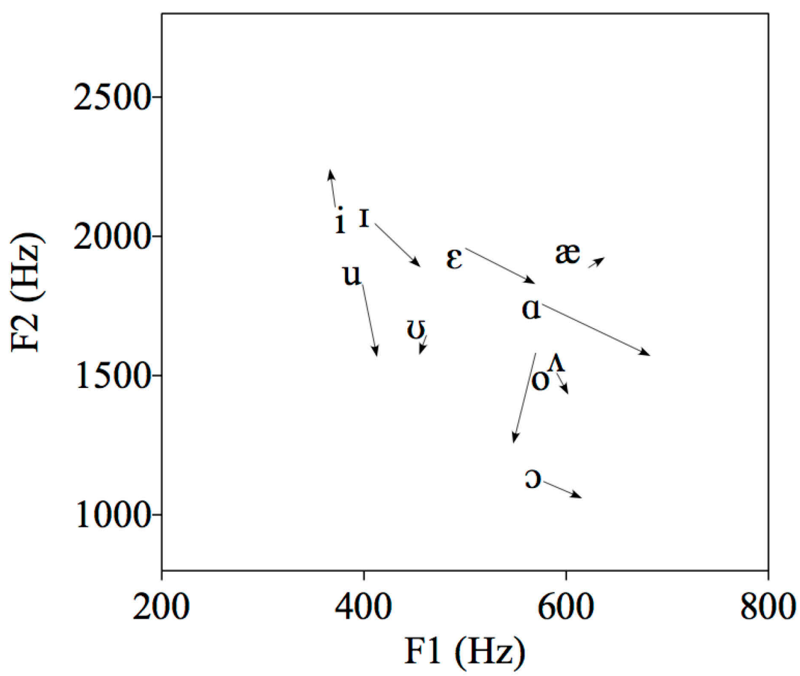

Figure 2.3: Vowel plots for the average onset and offset of each vowel across speakers. Blunt ends of the arrows indicate 20% of the total vowel duration (onsets) and arrowheads indicate 80% of total vowel duration (offsets).

Since /æ/ did not show any statistically significant movement (Table 2.3), it was not analyzed for patterns in directional movement. The remaining nine vowels were analyzed for significant F1 and F2 directional patterns between their onsets and offsets. The vowel plots, t-tests, and LMER models agreed that five of the nine vowels (/ɪ /, /ɛ /, /u/, /ɔ /, /ɑ/) exhibit significant movement towards the lower region of the vowel space (indicating a downwards movement in height), as seen in their higher F1 offset values relative to their lower F1 onset values (with the exception of /u/, which had significant movement according to the LMER model but not the t-test). On the other hand, /i/ and /o/ exhibit F1 movement towards the higher region of the vowel space (indicating the tongue moving upwards in height). /o/'s negative F1 movement is evident both on the vowel plot and in the statistical analyses. Though visually present on the vowel plot, /i/'s decrease in the first formant is significant only when context is statistically controlled for (i.e., in the LMER model, but not in the difference test). The two remaining vowels /ʌ / and /ʊ/ do not exhibit any significant F1 movement in either statistical analysis, though F1 movement is visually present on the vowel plot.

Eight of the nine vowels also showed significant movement towards the back area of the vowel space (indicating a decrease in tongue advancement), as evident in their lower F2 offset values relative to their higher F2 onset values. As with the differences in the onset/offset of the vowels' first formant, arrows in the vowel plot (see Figure 2.3) and statistical analyses illustrate F2 movement to the back of the vowel space. The front vowel /i/, however, exhibits the opposite F2 movement. /i/'s higher F2 offset values relative to its lower F2 onset values indicate more of a movement towards the front vowel space area. A summary of each vowel's F1 and F2 movements is given in Table 2.5 below, and each vowel's VISC-like movement is addressed in the Discussion.

Table 2.5: Summary of vowel F1 and F2 movement. An 'X' indicates the same statistical significance for both the difference tests on data from all genders and linear mixed-effect model.

	F1 movement (tongue height)			F2 movement (tongue advancement)			
Vowel	Positive (lower)	Negative (higher)	No Significant Movement	Positive (more front)	Negative (more back)	No Significant Movement	VISC-like movement
/i/		LMER ONLY		X			Iota
/ɪ/	X				X		Alpha/ Schwa
/ɛ/	X				X		Alpha
/æ/			X			X	none
/ʌ/			X		X		Alpha (trending)
/u/	X				X		Upsilon
/ʊ/			X		X		Upsilon
/o/		X			X		Upsilon
/ɔ/	X				X		Alpha
/ɑ/	X				X		Alpha

2.3.3 Discriminating Dynamic Formant Movement

The outcomes of the linear discriminant analysis are illustrated in Table 2.6. The outcomes are given for two iterations of the same discriminant analyses: once for males only, and once for females only. The baseline model is composed of a single F1 and F2 measurement (in addition to the f0 and duration components). The percentages shown for the baseline models indicate how well the models perform at identifying the vowels. The outcomes for the other three models are displayed in terms of percentages that indicate the contribution of a particular model when compared to the baseline F1 onset+F2 onset model. A positive (+) percentage indicates that a particular model performs better than the baseline model by x%. A negative (-) percentage indicates that a particular model performs worse than the baseline model by x%. All models, including the baseline model, include f0 and duration components as well. Each combination of F1 and F2 onsets, offsets, slope, and direction that are of interest are shown.

Table 2.6: Results of the discriminant analysis: amount of improvement compared to a single F1 and F2 measurement. In addition to the formant measures listed, all models also include f0 and duration components.

Model	Males only	Females only
(baseline model) pitch + duration + F1 onset + F2 onset	50.06%	51.64%
pitch + duration + F1 onset + F2 onset + F1 offset + F2 offset	7.08%	6.39%
pitch + duration + F1 onset + F2 onset + slope	0.05%	-0.05%
pitch + duration + F1 onset + F2 onset + direction	-40.19%	-40.41%

Regardless of gender, a model of dynamic vowel movement consisting of formant onsets and offsets (in addition to f0 and vowel duration) performed the best at discriminating vowels produced in spontaneous speech, with an accuracy ranging from 57.14 to 58.03%. When comparing the models between genders, the addition of slope to the baseline F1 onset + F2 onset model performed equally as well as the baseline model itself, with both models discriminating amongst vowels with accuracies ranging from 50.11 to 51.59%. A model containing direction performed considerably worse than all other models, with accuracy in vowel discrimination ranging from 9.87 to 11.23%. Out of the baseline, offset, slope, and directional models, the offset model performs the best at discriminating between vowels.

2.4 Discussion

Analyzing formant patterns in vowels from spontaneous speech presents specific challenges that arise due to the rapid nature of production and coarticulation with the surrounding phonetic context. The present study attempted to control the surrounding phonetic context in part by removing the vowels' transitional periods and focusing only on the vowel's centre (between 20 and 80% of the vowel's total duration). Additionally, linear regression analyses were used to statistically control for the surrounding phonetic environment by comparing formant values to the arithmetic means of the phonetic context, with possible skewing in the distribution of context removed. However, these steps do not fully remove all effects exerted by the surrounding phonetic context. As such, results in this section are discussed with the acknowledgement that full context control was not achieved, but that there are nevertheless discernible patterns of dynamic formant movement. Notably, Hillenbrand (2013) emphasizes that coarticulation can confound dynamic formant patterns without obscuring them entirely.

2.4.1 Patterns of Formant Movement in Spontaneous Speech

Researchers have hypothesized that dynamic formant movement seen in citation speech will not be present in spontaneous speech due to hypo-articulatory and coarticulatory effects with the surrounding context (Strange et al., 1983; Strange and Jenkins, 2013). However, this study finds that, as seen in citation speech, vowels produced in spontaneous speech do not exhibit steady-states. The dynamic nature of spontaneously produced vowels is evident both in descriptive vowel plots and statistical tests of difference and linear mixed-effects regression modelling. The present analysis finds formant movement that is similar to that of Nearey's (2013) reanalysis of Nearey and Assmann (1986) data on vowels produced in citation speech with carefully controlled phonetic contexts. While the Nearey and Assmann (1986) analysis also used a similar method of controlling for phonetic context by disregarding the 24%-64% tail ends of vowels, the actual production of the vowels were also carefully controlled for context (with all vowels being produced in isolation). Since the production of vowels in spontaneous speech is not as carefully controlled as the citation speech vowels, comparisons between the present data and VISC seen in citation speech are limited.

Nonetheless, there are general similarities and differences between the present spontaneous speech data and citation speech data. The vowels in this study that display significant formant movement can be grouped into three different categories according to their combined F1xF2 movement. Five vowels with positive F1 movement and negative F2 movement, /ɪ /, /ɛ /, /ʌ /, /ɔ /, /ɑ/, can possibly be classified as exhibiting VISC-like patterns that Nearey (2013) has termed Alpha-movement. Alpha-movement is characterized by formant trajectories that move towards the low back corner of the vowel space (i.e., a slope with a negative F2 and positive F1 for high vowels, and a slope with a positive F2 and positive F1 for low vowels). Though the F1 movement in /ʌ / is not significant, the descriptive analysis shows the vowel moving towards the lower area of the vowel space (trending positive F1 movement). Nonetheless, /ɪ /, /ɛ /, /ɔ /, and /ɑ/ best exemplify this type of movement, as seen in the directional tilt of their long trajectory tails, and the directional pointing of their arrowheads. However, it is possible that ɪ/ is instead moving towards the centre rather t han back area of the vowel space, exhibiting Schwa-like-movement rather than Alpha-like-movement. That is, the negative F2 movement of this vowel could be attributed to an effect of centralization rather than an intended back-edge target. An investigation of the vowel plots does not provide any obvious cues for distinguishing any centralization, or Schwa-like-movements from Alpha-like-movements.

However, the high front vowel /i/ can be classified as exhibiting a different type of movement all together. /i/ moves in the opposite direction of Alpha-movement, towards the high front corner of the vowel space, what Nearey (2013) classifies as Iota-movement. The Iota-like-movement in /i/ is evident by the vowel's long trajectory tail and stands out as the only vowel with positive F2 movement.

The remaining three vowels /u/, /ʊ/, /o/ exhibit movement towards the high back corner of the vowel space (though the F1 movement in /ʊ/ is not significant, the vowel plot shows a trend in movement towards the high area of the vowel space). Movement towards this region of the vowel space is termed Upsilon-movement in Nearey (2013).

To summarize, according to Nearey (2013), there are three expected patterns of VISC movement that are relevant here:

1) /u/, /o/ exhibit Upsilon-movement
2) /ɪ/, /ɛ/, /æ/, /ʊ/ exhibit Alpha-movement
3) /i/, /ɑ/, /ʌ/ are not identified as exhibiting any particular movement

Depending on where these vowels are located in the vowel space, Alpha-movement can be also interpreted as Schwa-movement, notably for /ɪ/.

Overall, the patterns of vowel movement found in the present study support the three expected patterns of VISC movement. Of the ten vowels analyzed in the present study, only four display patterns of movement that diverge from what is expected:

1) /i/ exhibits Iota-like-movement in the present study, compared to the expected insignificant movement
2) /æ/ does not exhibit any significant movement in the present study, compared to the expected Alpha-movement
3) /ʊ/ exhibits Upsilon-like-movement in the present study, compared to the expected Alpha-movement
4) /ɑ/ exhibits Alpha-like-movement in the present study, compared to the expectation of no movement

The difference in the movement pattern of /i/ found in the present data is based on the increase in the vowel's F2 from onset to offset. While the expectation for /i/ to exhibit insignificant movement is based on citation speech from Nearey and Assman (1986), many other studies have instead found increasing F2 movement, or Iota-like-movement, in citation speech data (Andruski and Nearey, 1992; Hillenbrand et al., 1995; Assmann and Katz, 2000; Hillenbrand et al., 2001; Nearey, 2013). This discrepancy may be partially attributable to a difference in phonetic context: the observations made by Nearey and Assmann (1986) were based on vowels produced in isolation. All of the studies that instead found an increasing F2 pattern for /i/ (suggesting Iota-movement) focused on vowels produced between two consonants (i.e., in CVC contexts with initial /h, b, d, g, p, t, k/ consonants and final /b, d, g, p, t, k/ consonants). Moreover, research focused on the production aspect of vowel formants has found evidence for the modulation of formants, especially F2, when a vowel is placed in various phonetic environments (Summers, 1987; Sussman et al., 1991). Overall, the present study supports the F2 pattern of movement for /i/ found when the vowel is studied within a phonetic environment. My findings on dynamic formant movement using spontaneous speech data confirm the expectations from citation speech based on these studies.

For /ʊ/, the difference between Alpha-movement in citation speech and Upsilon-movement in the present study could be due to a difference in dialectal variation. As stated, the current data of spontaneous speech was gathered from speakers from Columbus, Ohio, a dialectal region notorious for back vowel fronting. The plot of /ʊ/ in the vowel space is much higher on the F2 axis, then, compared to /ʊ/ in vowel plots of other dialects (see Nearey, 2013, for evidence from Western Canadian, North Texan, and Western Michigan dialects). A decrease in F2 would indicate Upsilon-movement for /ʊ/ in the present study, while in other dialects (such as Western Canadian, North Texan, and Western Michigan) an increase in F2 would indicate Alpha-movement (and confusion with Schwa-movement). The dialectal fronting of /ʊ/ in the present study can account for the difference between the realized Upsilon-movement and expected Alpha-movement. That is, a decrease in F2 movement for /ʊ/ could instead be indicative of resolving vowel fronting, or decreasing the vowel's advancement to make it less dialectally fronted. A similar pattern is also seen with the other fronted vowel, /u/.

The most striking differences in spontaneous and citation speech formant patterns, however, come from the low vowels /æ/ and /ɑ/. It appears that the patterns of these two vowels found in the present study have been reversed given what is expected from citation speech data. /æ/ exhibits no movement in the present study when it is expected to exhibit significant Alpha-movement, and /ɑ/

exhibits significant Alpha-like-movement in the present study when it is expected to exhibit no movement. While the movement is not significant, the overall trajectory of /ɑ/ in studies on citation speech point towards the same low back corner trajectory, also seen in the Alpha-like-movement exhibited in the present study (Nearey and Assman, 1986; Hillenbrand et al., 1995; Assmann and Katz, 2000; Hillenbrand et al., 2001; Nearey, 2013). However, both the trajectory and lack of significant movement for /æ/ in the present study is surprising. It is possible that the confounds of the surrounding phonetic context are overriding any dynamic formant movement for /æ/ in the present study. It is also possible that the data for /æ/ lacks statistical power, since the vowel is by far the least frequently occurring vowel in the data set (with 58 tokens out of 6,028; a table of vowel frequency is listed in the Appendix Table A.7).

Overall, the vowels in the present spontaneous speech study exhibit more centralization (seen in the plotting of the vowels in the vowel space) and Schwa-movement (exhibited by three of ten vowels) compared to vowels in studies on citation speech. Several proposed theories of spontaneous speech account for such instances of vowel centralization, or reduction, such as articulatory undershoot (Lindblom, 1963) and the Dynamic Dispersion Hypothesis (Strange and Jenkins, 2013). These theories would, for example, predict that speakers will use less jaw, lip, and tongue movement, all of which would contribute to lowering/decreasing the height of vowel articulation and articulating vowels in the more central area of tongue advancement. This gradual decrease is the basis for Strange et al. (1983) predicting that spontaneous vowels will not exhibit patterns of movement that are similar to that of citation speech vowels. This hypothesis is partially supported by the current data when considering the overall effect of vowel space centralization. However, even though vowels produced in spontaneous speech use a smaller and more central area of the vowel space, they still, for the most part (with the exception of four vowel patterns, discussed above), mirror the formant patterns and/or trajectories found in citation speech. Spontaneous vowels do not exhibit insignificant minute changes in formant frequencies, but rather move dynamically through the limited vowel space.

2.4.2 Onset+Offset+Pitch+Duration Model of Formant Movement

The present study's models of VISC in spontaneous speech support the findings of perception research and studies on citation speech. There is a slight superiority for a combined onset+offset+pitch+duration model in capturing the dynamic spectral properties of vowels in conversational English compared to a model of a single F1xF2 measurement. These results are in line with both Hillenbrand et al.'s (2001) research on citation vowels and other studies comparing the different approaches to VISC analysis (such as Morrison and Nearey 2007; Morrison, 2013). It appears that as with citation speech, spontaneously produced vowels are best predicted by their onsets and offsets as they move through the vowel space. The general patterns of amount and direction of formant movement (slope and directional models) are no better at statistically discriminating amongst spontaneous vowels than a single formant measure. Where a vowel explicitly begins and ends in the vowel space is more informative of its identity than the vowel's less specific characteristics of slope and direction of movement.

2.4.3 Future Research

In future studies on spontaneous speech data, it will be important to establish a better means of controlling for the phonetic context. Nearey (2010, 2013) has postulated a theoretical basis for controlling for coarticulation effects when analyzing patterns of dynamic formant movement. His application of mitigating context effects in citation speech can further be adapted into a statistical means of controlling for coarticulation in spontaneous speech (such as in Broad and Clermont, 2014). It is also possible to select a subset of contexts from which to glean vowel data, in order to minimize the effects of the surrounding phonetic environment. For instance, more context-neutral occurrences of vowel productions in spontaneous speech can be selected as a means of limiting coarticulatory influence.

The issue of vowel centralization, however, is less problematic than the issue of coarticulatory influence. The results in the present study indicate that vowels produced in a reduced, centralized form exhibit dynamic formant movement. Though vowel space centralization decreases the range of formant movement, it is not hindering the observation of formant trajectories.

A final future direction of research investigating dynamic formant movement in spontaneous speech is to continue to incorporate data from spontaneous speech production and perception into models of VISC. This can be achieved only by investigating the generalizability of VISC in other speech genres, which would require directly addressing the issues of coarticulation and vowel centralization.

2.5 Conclusion

The present study investigated the existence of dynamic formant movement in 10 monophthongal vowels produced in casual everyday conversations. This analysis of dynamic formant movement is unique in that it is performed on data from spontaneous speech. In investigating the acoustic detail of vowels in the highly variably spontaneous speech context, there were challenges of vowel centralization and coarticulatory effects from the surrounding phonetic environment. While vowels were not controlled for the context in which they were produced, disregarding the tail ends of the vowels and statistical methods attempted to control the effect of gestural overlap from the surrounding phonetic environment. Though these means of control are not complete, they nevertheless allowed for a descriptive analysis of dynamic formant movement and a general comparison with VISC data in citation speech.

With regard to the reservations expressed by Strange and colleagues (1989, 2013) on the investigation of dynamic formant movement in spontaneous speech, the present study finds that these concerns are warranted, but not insurmountable. Even though there is vowel reduction and centralization, as well as context skewing and influences from the phonetic environment, patterns of dynamic formant movement may still be discernible in spontaneously produced vowels. Most of the dynamic patterns observed in the present study are reminiscent of the VISC expectations outlined by Nearey (2013). However, not all of the patterns are exhibited, and some of the observed patterns are present to a lesser degree than their VISC counterparts. Nevertheless, this study is a step in the investigation of dynamic spectral properties of vowels in spontaneous speech.

The present study finds a slight superiority of a dual-target model of dynamic formant movement in discerning between spontaneous speech vowels. An onset+offset+duration+pitch model of formant trajectories outperforms comparable models based on formant trajectories' slopes and direction of movement. These results are in line with previous findings from VISC data in citation speech (Nearey and Assmann, 1986; Hillenbrand et al., 2001; Morrison and Nearey, 2007; Morrison, 2013). These findings are promising for future research on dynamic formant movement in spontaneous speech.

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Chapter 3:
Morphological Influence of Vowel Dispersion and Dynamic Formant Movement

3.1 Introduction

One of the most interesting characteristics of spontaneous speech is the amount of variability present in the acoustic signal. Not only are words produced with segmental variation, but the phones themselves are produced with acoustic differences in their acoustic details (see Dilts, 2013, for a discussion). It is assumed that such differences in the acoustic signal are driven by the linguistic input, but the details of this input and its effect on acoustic variation remain unclear.

Studies on spontaneous speech production often focus on acoustic detail, and how it is predictively modulated by linguistic properties (examples of such studies are discussed below). The current chapter defines ‘linguistic property’ as any linguistic parameter that is variable. For example, word frequency is a linguistic parameter that varies by the frequency of individual lexical items. Linguistic properties, while necessarily variable, are not necessarily continuous or highly gradient. For example, word frequency is an example of a linguistic property that varies continuously; morphology is a linguistic property that varies discretely. The morphological possibilities in a language are finite. However, for a given phonological representation, there may be multiple morphological meanings. For example, the phoneme sequence /ɹʌ n/ refers to more than one morphological meaning, such as a 1st person present tense verb (“I/we run”), a 2nd person present tense verb (“you/you all run”), a 3rd person plural present tense verb ("they run"), and a noun (“a run”). There exists, then, differences in the morphological linguistic property of the single word /ɹʌ n/.

This study investigates how linguistic properties affect the production of vowel formants’ acoustic detail in spontaneous speech. In particular, the current chapter investigates the role of morphology in the amount of dispersion a vowel displays from the centre of the vowel space, how far a formant deviates from the vowel onset and offset, and the realization of vowel formant movement. The analyses here focus on monosyllabic irregular English verbs that vary between their past and present tense forms by a single vowel segment (e.g., as in /ɹʌ n/ and /ɹ æn/). This subset of verbs is unique because the morphological linguistic property of the verbs (i.e., whether they are in the past or present tense) is signalled by a change within a single phoneme. Without the vowel, the morphology of a verb in this subset is unknown (e.g., /ɹ _n/ signifies neither the past nor the present tense). The morphological information for this subset of verbs, then, is wholly contained within the vowel (e.g., it is /æ/ that signifies the past tense in /ɹ æn/). However, a vowel (such as /æ/) itself can signify both the past tense (as in the word /ɹ æn/) and the present tense (as in the word /hæŋ/). It may be useful, then, to compare the acoustic detail of a vowel when it alternates between the past and present tenses.

In addition to investigating the role of morphology in the realization of acoustic detail, the current chapter also analyzes the role of the linguistic paradigm (see below for a discussion on evidential support for the linguistic paradigm). ‘Linguistic paradigm’ refers to a set of patterns that a particular group of words follows between different morphological forms. For example, the past tense of irregular English verbs can be signalled by a variety of vowel patterns (or paradigms), such as /u/ (as in 'blew'), /æ/ (as in 'ran'), and /ɪ / (as in 'bit'). The linguistic paradigm for these irregular past tense English verbs is the collection of patterns /u/, /æ/, and /ɪ /. Several words may belong to one paradigm (such as 'flew,' 'blew,' 'grew' and 'threw' for the /u/ pattern), and yet vary in terms of other linguistic properties ('flew,' 'blew,' 'grew' and 'threw', for example, all have different word frequencies). Whereas any word can share a linguistic property (any word, for example, can have a word frequency; or, most verbs can have a past or present tense), linguistic paradigms are defined patterns that are specific to a particular group of words.

What follows is a brief discussion of evidence from previous research about the influence of linguistic properties and linguistic paradigms on the production of acoustic detail. Several theories about the role of linguistic properties and paradigms in acoustic detail production have been formulated based on this evidence. These theories are also discussed below in order to provide the theoretical backdrop for the hypotheses tested by the current chapter.

3.1.1 Evidence from Studies on Linguistic Properties and Acoustic Detail

The hypothesis that linguistic properties influence phonetic detail has strong support in the literature, seen in a range of linguistic properties and dimensions of phonetic detail. For example, many studies have demonstrated an effect of word frequency on word and/or segmental duration (Jurafsky et al., 1998, 2001; van Son et al., 2004; Aylett and Turk, 2004; Pluymaekers et al., 2005, 2006; Gahl 2008; Dilts et al., 2011; Schuppler et al., 2011; Tily and Kuperman, 2012; Pate and Goldwater, 2015; cf. Warner and Tucker, 2011). These studies have found that when a word has a high frequency (i.e., is encountered more often; has a low probabilistic uncertainty), it is produced with a shorter duration; and when a word has a lower frequency (i.e., is encountered less often; has a high probabilistic uncertainty), it is produced with a longer duration. That is, the linguistic property of word frequency relates inversely to the acoustic detail of duration. Aylett and Turk (2006) found that word frequency has an influence on vowel formant structure in addition to vowel duration. Their study showed that at the lower end of the frequency continuum, vowels are produced with formant structures that indicate a more peripheral vowel space; and on the higher end of the frequency continuum, vowels are produced with formant structures that correspond to more vowel centralization.

Studies have demonstrated that other linguistic properties also affect vowel formants. Both Munson and Solomon (2004) and Gahl et al. (2012), for instance, have investigated the influence of phonological neighbourhood density on vowel formant frequencies. For words in isolation, Munson and Solomon found that, overall, denser phonological neighbourhoods (which have a high probabilistic uncertainty) correspond to larger vowel spaces. However, Gahl et al. found the opposite pattern for words produced in spontaneous speech.

The linguistic properties of word frequency and phonological neighbourhood density also jointly affect the probabilistic uncertainty of a word. For example, words that appear frequently and have sparser neighbourhood densities have a low probabilistic uncertainty, and are thus linguistically 'easy' words. Wright (2004) investigated how these factors influence the amount of dispersion that vowels display from the centre of the vowel space in isolated words. He found that high amounts of dispersion (producing vowels more on the periphery of the vowel space) correlate with linguistically 'easy' words compared to 'hard' words. These findings are similar to that of Munson and Solomon (2004) for words produced in isolation but are again the opposite of Gahl et al.'s (2012) findings on words produced in spontaneous speech.

Finally, in a paper on the predictability of reduction in function words, Bell et al. (2003) used discourse factors as linguistic properties (such as disfluencies and contextual probabilities) to analyze the phonetic variation in segmental realization (i.e., whether a segment was fully produced, or whether it was deleted relative to the word's canonical form). This study found that semantic and syntactic context can also influence the phonetic realization of spontaneously produced function words: function words are less segmentally reduced when they occur in more probabilistically uncertain contexts.

Overall, these studies illustrate that more probabilistic uncertainty (as measured by a particular linguistic property) occurs with more enhanced acoustic detail. Though each study focuses on different theoretical motivations for investigating this correlation (to be discussed below), they all nevertheless provide strong support for the relationship between linguistic processes and speech production. The production of acoustic detail does not happen in a vacuum, devoid of meta-phonetic influence. Acoustic variation, instead, is the product of a relationship between linguistic properties and the speech production system.

3.1.2 Evidence from Studies on Linguistic Paradigms and Acoustic Detail

As with linguistic properties, the influence of linguistic paradigms on acoustic detail is also well instantiated in previous research. Though linguistic paradigms may seem similar to linguistic properties (this point is contended later in the Discussion of the present chapter's experimental results), they have historically been treated as separate linguistic influences in the production of speech. Bybee and Slobin (1982) were among the first to recognize the effect of linguistic paradigm on speech production. The researchers termed the paradigmatic patterns 'schemas' to highlight the independence of a word's paradigmatic pattern from its linguistic properties such as word frequency. Schemas are statements that determine how the past tense form of a word is derived from its lemma. For example, words metastasize the final consonant to end in a particular phonetic natural class (e.g., dental) and additionally undergo a vowel alternation, as in *bring*/*brought*.

Subsequent research has expanded upon the idea of a schema to include measurable means of defining linguistic paradigms, often via pattern frequency. There are various means of quantifying pattern frequency: one method is to calculate pattern frequency as a ratio of one form to another (Kuperman et al., 2007; Hanique et al., 2010; Hanique and Ernestus, 2011; Schuppler et al., 2012); another method involves calculating paradigmatic entropy (Cohen, 2014). Regardless of how the pattern frequency was measured, these studies found strong support for the influence of linguistic paradigm on acoustic detail. Words and segments in more frequent paradigmatic patterns tend to be produced with longer durations and less segmental deletion. Stronger linguistic paradigmatic support (low uncertainty) correlates with phonetic enhancement. Because the patterns between linguistic paradigms and acoustic details (low uncertainty, more enhancement) are the opposite of the patterns between linguistic properties and acoustic details (more uncertainty, more enhancement), linguistic paradigms and properties are thought to be separate influences on acoustic detail.

Instead of pattern frequency, Stemberger (2004) used gang size to quantitatively investigate linguistic paradigms. Gang size allows one to differentiate between patterns with high densities and patterns with lower densities (i.e., more words/segments belong to one pattern compared to another). Stemberger found that larger gang sizes correlate with fewer speech errors; or, as with the studies on pattern frequency, stronger linguistic paradigmatic support correlates with phonetic enhancement.

While pattern frequency and gang size are based on linguistic probabilities, a final means of measuring linguistic paradigmatic support is based on Naive Discriminative Learning (NDL; see Baayen et al., 2011). NDL metrics indicate how strongly particular cues (such as the phones in a word) are associated with particular outcomes (such as morphology, or tense). According to Tucker et al. (in preparation), phones that are more strongly associated with one morphological tense over another are better morphological cues, which they refer to as having a strong cue-to-tense activation level. Stronger cue strength is indicated by a stronger NDL measure, which represents more linguistic paradigmatic support.

For example, as described above, in the subset of monosyllabic irregular English verbs, the vowel /æ/ can signify both the past tense (as in the word /ɹ æn/) and the present tense (as in the word /hæŋ/). In NDL terms, /æ/ is a cue to both the past and present tense. To calculate the paradigmatic strength of /æ/, NDL metrics determine how robustly the cue /æ/ signifies one of the tenses. In this small example, /æ/ occurs equally in the past and present tense; thus, it is not a good morphological cue. This cue would receive a low NDL measure to indicate its weak cue-to-tense activation level, and is considered to offer minimal paradigmatic support (though the current example illustrates NDL measures in terms of uniphone cues, Tucker et al., calculate NDL measures in terms of diphone cues).

NDL measures of paradigmatic support are different from more traditional measures of paradigmatic support, such as gang size (Stemberger, 2004) and pattern frequency (Kuperman et al., 2007; Hanique et al., 2010; Hanique and Ernestus, 2011; Schuppler et al., 2012). The main difference is that NDL is a learning network that facilitates associations between form and meaning through the learning of statistical patterns. Rather than dissociate the speaker from the listener, NDL assumes that they are one in the same: a learner of the acoustic nuances in speech. This distinction is important to make because it assumes that productions are made based on prior learning of associations between acoustic form and meaning rather than the ease of perception or production (cf. Lindblom, 1990; Aylett and Turk, 2004). That is, the speaker is not explicitly tailoring their speech productions to suit either their or the listener's needs, but rather guided by a network of implicit associations learned over the course of their life. The variation in acoustic detail, then, is a product of this network of learned associations, rather than a conscious speaker control of acoustic detail.

In the NDL framework, learning cue-to-tense associations can be either positive (activation) or negative (unlearning). "Positive" learning accounts for the frequency of a particular vowel occurring in a particular pattern. "Negative" learning penalizes occurrences of the same vowel occuring in a different pattern. Following the above example of /æ/, the cue-to-past tense activation level of /æ/ would include positive weights for positive learning (such as past tense /ɹ æn/), and negative weights for negative learning (such as present tense /hæŋ/). This penalization for /æ/ occurring in both the past and present tense is unique to the NDL metric of paradigmatic support. The amount of paradigmatic support in NDL cue-to-tense activation levels, then, is more precise in that it evaluates not only the likelihood of a vowel's occurrence with a particular pattern, but also the likelihood of that vowel occurring with a different pattern.

Tucker et al. (in preparation) measured cue-to-tense association strengths and found that stronger NDL tense activation measures correlate with longer vowel durations in monosyllabic irregular English verbs (examples of NDL scores are given in the Appendix Table A.8 and Table A.9). That is, a vowel with a high NDL cue strength (more paradigmatic support) will have a longer duration (phonetic enhancement) than a vowel with a lower NDL cue strength. As with the other paradigms discussed previously, stronger linguistic paradigmatic support in NDL correlates with phonetic enhancement.

While the influence of linguistic paradigms on acoustic detail in spontaneous speech is less studied than the influence of linguistic properties, the results from linguistic paradigm studies are well-established. Regardless of how linguistic paradigm is measured or defined, research shows that paradigmatic support strongly correlates with phonetic detail: more instantiated patterns are often produced with more enhanced phonetic detail.

3.1.3 Hypotheses of Linguistic Properties, Linguistic Paradigms, and Acoustic Detail

Several hypotheses have been put forth to describe the nature of the relationship between linguistic properties, linguistic paradigms, and acoustic variation. Two of the most applicable theories to the current chapter are the Smooth Signal Redundancy Hypothesis, and the Paradigmatic Signal Enhancement Hypothesis.

The Smooth Signal Redundancy Hypothesis put forth by Aylett and Turk (2004, 2006) accounts for the relationship between linguistic properties and acoustic detail. This hypothesis stems from Information Theory (Shannon, 1948; Pierce, 2012), which penalizes signal redundancy. For Aylett and Turk, signal redundancy occurs when the signal (or speech utterance) contains both acoustic redundancy and linguistic redundancy. The Hypothesis holds that speech signals are less likely to contain double-redundancy (i.e., both acoustic redundancy and linguistic redundancy), and instead are more likely to have single-redundancy (i.e., either acoustic redundancy only, or linguistic redundancy only).

Acoustic details and linguistic properties are considered 'redundant' at extreme values. For measures of acoustic detail, extreme measurable values tend to correspond to acoustic salience (e.g., larger durational values, larger formant distances from the centre of the vowel space). For linguistic properties, however, the literature is divided on how the scale is defined (Gahl et al., 2012). This is due to a division in theoretical perspectives of speech production: one hypothesis is that speech production is listener-driven while another holds that it is speaker-driven. If speech production is listener-driven, extreme values on the linguistic property scale would correspond to parameters that make comprehension less confusing for the listener, or what Wright (2004) terms 'easy' words (e.g., are more frequent, have fewer phonological competitors). On the other hand, if production is speaker-driven, extreme values would correspond with parameters that make speech easier to produce for the speaker, or that ease articulation (e.g., are produced frequently and have more phonological neighbours that are similar in their articulations).

Both approaches have support in the literature, for example, by examining neighbourhood density using the Smooth Signal Redundancy Hypothesis. According to the listener-driven model of speech production, redundancy would occur where words are easier to comprehend - in more *sparse* phonological neighbourhoods, as there are fewer lexical competitors. The Smooth Signal Redundancy Hypothesis would predict, then, that sparse phonological neighbourhoods (linguistic redundancy) would correspond to shorter vowels and more centralized dispersions (no acoustic redundancy), which is supported in Munson and Solomon (2004, as described above). However, according to the speaker-driven model of speech production, redundancy would occur where words are easier to articulate - in more *dense* phonological neighbourhoods, as similar articulations are more frequent (i.e., more neighbours). Here the Smooth Signal Redundancy Hypothesis would predict that dense phonological neighbourhoods (linguistic redundancy) would correlate with shorter vowels and more centralized dispersions (no acoustic redundancy), which is supported in Gahl et al. (2012, also described above).

Thus, the speech production literature has yet to define redundancy for linguistic properties, or what extreme values mean. It could be the case (as seen in the present chapter) that the scale is dependent upon whether one takes a listener- or speaker-driven approach.

Research on linguistic paradigms shows that stronger linguistic paradigmatic support correlates with phonetic enhancement; in fact, this relationship is independent of the relationship between linguistic properties and phonetic detail. While the Smooth Signal Redundancy Hypothesis describes the probabilistic relationship between uncertainty in linguistic properties ('redundancy') and acoustic detail, the Paradigmatic Signal Enhancement Hypothesis also includes linguistic paradigms (Kuperman et al., 2007)

The Paradigmatic Signal Enhancement Hypothesis holds that while both linguistic properties and linguistic paradigms influence the production of acoustic detail, paradigmatic enhancement supersedes any influence of linguistic properties. The past tense irregular English verbs best exemplifies this. Recall that /u/ and /æ/ are possible paradigmatic vowel patterns to signal the past tense in irregular verbs, such as in *grew* and *ran*. Under a listener-driven assumption, the Smooth Signal Redundancy Hypothesis would predict that the word with the most redundancy (i.e., least uncertainty, perhaps due to high lexical frequency) would be produced with less acoustic redundancy (i.e., it would be acoustically reduced, perhaps with a shorter vowel duration). *Ran* is more frequent than *grew*, so the Smooth Signal Redundancy Hypothesis would predict /æ/ in *ran* to have a shorter duration than /u/ in *grew* (phonetically inherent vowel durations aside).

However, the Paradigmatic Signal Enhancement Hypothesis predicts that paradigm effects supersede linguistic property effects, and words with more paradigmatic support would be acoustically enhanced (e.g., would have longer vowel durations). If /æ/ has more paradigmatic support than /u/ (i.e., /æ/ is more strongly associated with the past tense than /u/), the Paradigmatic Signal

Enhancement Hypothesis would predict /æ/ in *ran* to have a longer duration than /u/ in *grew*. Thus, under the Paradigmatic Signal Enhancement Hypothesis, it is possible to have a high frequency word (*ran*) produced with a longer vowel duration than a lower frequency word (*grew*), contrary to the predictions of the Smooth Signal Redundancy hypothesis. The current chapter addresses these two hypotheses to explore the implications of paradigmatic strength superseding linguistic properties in the Discussion.

Like the Smooth Signal Redundancy Hypothesis, the Paradigmatic Signal Enhancement Hypothesis could be motivated by either a speaker- or listener-driven approach to speech production. The correlation between strong paradigmatic support an acoustic enhancement could be beneficial for the listener: adding acoustic salience for well-entrenched paradigms. The correlation could also be beneficial for the speaker: more frequent or well-entrenched paradigms make them easier to articulate, resulting in phonetic enhancement. A listener-driven motivation of the Paradigmatic Signal Enhancement Hypothesis is tested in Chapter 4 of this dissertation.

3.1.4 The Current Analyses: Organizing Principles and Preliminary Predictions

The current chapter analyzes linguistic properties and paradigms using four acoustic measures (amount of vowel movement, formant deviance from vowel onset and offset, and amount of vowel dispersion). The linguistic property analyzed here is that of morphological tense: whether an irregular English verb is in the past or present tense. The measure of paradigmatic support analyzed here is the same employed by Tucker et al. (in preparation): NDL cue-to-tense activation strength. A previous study on more traditional measures of paradigmatic support, such as gang size, did not find a significant correlation between acoustic variation and the irregular monosyllabic English verbs at hand (Sims et al., 2010). As such, NDL, a different measure of paradigmatic support, is evaluated here.

Morphological tense and NDL paradigmatic support are analyzed in a series of four statistical analyses. As a series, these four analyses are designed to test the Smooth Signal Redundancy Hypothesis and the Paradigmatic Signal Enhancement Hypothesis on four different, but related, vowel formant measures. The first analysis investigates the effect of tense and NDL on vowel dispersion. The second and third analyses investigate the effects of tense and NDL on the amount of formant deviance from the vowel onset and offset. The final analysis investigates the effects of tense and NDL on the amount of non-linear formant movement.

The analyses in the current study test the following hypotheses: For spontaneous speech data, the acoustic detail measured (amount of vowel dispersion from the centre of the vowel space and amount of formant deviation and movement) will be modulated by linguistic properties (morphology, word frequency and neighbourhood density) and paradigmatic support (NDL cue association strengths) according to both the Smooth Signal Redundancy Hypothesis and the Paradigmatic Signal Enhancement Hypothesis. The Smooth Signal Redundancy Hypothesis predicts there to be more phonetic enhancement (greater amounts of vowel dispersion and formant deviation and movement) when there is uncertainty in linguistic properties, such as in words with low frequencies.

In the current chapter, this hypothesis is extended to morphological tense. The more uncertain morphological form of an English verb is the form marked for tense, which is the past tense form of the verb (Bybee and Slobin, 1982). In the current set of irregular monosyllabic English verbs, the tense of the verb is determined by the vowel. ***Thus, it is predicted that the past tense form of the verb (the more morphologically uncertain form) will correspond to greater amounts of vowel dispersion, formant movement and deviation***

The Paradigmatic Signal Enhancement Hypothesis predicts there to be more phonetic enhancement (greater amounts of vowel dispersion and formant deviation and movement) when a word has stronger paradigmatic support. According to the Paradigmatic Signal Enhancement Hypothesis (Kuperman et al., 2007), paradigmatic support is measured in terms of probability, or, as an example for the current data, the likelihood of a vowel to appear in either the past tense (notably: not the joint probability of a vowel occurring in the past and present tense).

In the current chapter, the Paradigmatic Signal Enhancement Hypothesis is extended to encompass a new measure of paradigmatic support: NDL cue-to-tense activation levels. NDL metrics expand upon the Kuperman et al. measure of paradigmatic support by adding the probability of a vowel also occurring with the other tense (or, the joint probability of a vowel occurring in the past and present tense). ***Thus, it is predicted that stronger NDL cue association strengths will correlate with greater amounts of vowel dispersion, formant movement and deviation.*** These predictions are tentative will serve primarily to organize discussion.

3.2 Methodology

3.2.1 Items

The current analyses focus on 74 monosyllabic irregular English verbs in the Buckeye Corpus of Conversational English (henceforth, Buckeye Corpus; Pitt et al., 2007). This subset of English words consists of irregular verbs that differ between their present and past tense forms on a single vowel alone (for example, *sing*/*sang*). However, verbs that contain the addition of a phonological segment, such as “weep/wept” and verbs that are suppletive, such as “go/went,” were not included in the irregular verbs subset. The vowels from each instance of words in the irregular verbs subset were extracted from the Buckeye Corpus, yielding 6,028 tokens of 10 vowel types: /i/, /ɪ /, /ɛ /, /æ/, /ʌ /, /u/, /ʊ/, /o/, /ɔ /, and /ɑ/. Though acoustic measures were gathered for each of the vowel tokens (as outlined below), the analyses described in this chapter are limited to the 5,718 vowel tokens that contained measures for all the lexical and phonetic predictors under investigation (see the Appendix Table A.7 and Table A.9 for more information about these vowels, including a simple wordlist, the lexical frequency of the words they belong to, vowel frequency, and their frequency of occurrence with the past and present tense).

3.2.2 Acoustic Measurements

Frequency measurements of the first and second formant (henceforth, F1 and F2, respectively) are the acoustic characteristics under investigation in the series of analyses. To gather formant data, spectral F1 and F2 contours were marked and hand-corrected using the FormantMeasurer program (Morrison and Nearey, 2011). The program yielded continuous F1 and F2 Hertz measurements at increments of 2ms over the entire length of the vowel duration.

These formant measurements were limited to those between 20% and 80% of each vowel's total duration. Discarding the first and last 20% of a vowel's duration helps to mitigate the effect of the surrounding phonetic environment on the formant data. For the linear analyses of vowel dispersion and formant movement, a sample measurement was taken at each 10% increment of the vowels' total duration from 20-80%, yielding seven F1 and seven F2 measurements for each vowel token. In the nonlinear models of formant movement, all the time step intervals in the data were included to allow for more precise modelling.

To analyze a vowel's dispersion from the centre of the vowel space, each speaker's vowel space area, perimeter, and centre were first calculated. In accordance with Bradlow et al. (1996) and Wright (2004), the perimeter and area of each speaker's vowel space were determined using the speaker's mean formant values for the peripheral vowels /i/, /ɑ/, and /o/. The centre of each speaker's vowel space was determined by calculating the triangular centre of the three peripheral vowels. The Euclidian distance (taken as an absolute value) of each individual vowel from its speaker's centre was then calculated for each F1 and F2 point, separately, for each of the seven time points. This yielded 14 measures of vowel dispersion for each vowel token (7 time points x 2 formants). It is important to note that amount of vowel dispersion is relative to the vowel space centre, while amount of formant movement is relative to the vowels' F1xF2 onset position in the vowel space. The two measures are related but provide different information about the vowels' acoustics.

3.3 Series of Statistical Models: Analyses and Local Results

What follows is a discussion of four analyses. All four analyses test for significant effects of morphological tense and NDL cue association strengths on vowel formant data. Table 3.1 outlines a summary of the four analyses, each of which first investigates a global effect of morphological tense and NDL cue association strength pooled across all vowels, then separates these effects by vowel. The first analysis (§3.3.1) uses a linear model to test for effects of tense and NDL cue association strength on vowel dispersion from the centre of the vowel space. The second analysis (§3.3.2) uses a linear model to test for effects of tense and NDL cue association strength on formant deviance from vowel onset, while the third analysis (§3.3.3) does the same from vowel offset. The final analysis (§3.3.4) uses a non-linear modelling technique to test for effects of tense and NDL cue association strength on the amount of formant movement in formant trajectories.

These analyses form a hierarchical sequence of quantitative reasoning that supports the final analysis. The first analysis, on vowel dispersion, mirrors the methodologies established in the phonetic literature (such as Wright 2004; discussed above), while the second and third analyses address phonetic issues with the dispersion analysis by investigating a different measure of acoustic detail: formant deviation from vowel onset and offset. Unlike the vowel dispersion analysis, these deviation analyses attempt to capture formant movement while mitigating the effects of the formants assimilation to the surrounding phonetic environment. To do so they take into account the contribution of the context before and after the vowel on the formant's trajectory (Lindblom, 1963; Broad and Clermont, 1987). The final analysis expands upon the previous two by modelling the same formant data, but in a non-linear fashion, to better capture the contours of formant movement.

The four analyses in this series are discussed in succession according to Table 3.1. More detailed and explanatory justification for how each analysis follows from the previous is given in the introduction to each analysis. Following the presentation of each analysis, §3.3.5 summarizes the results of all four analyses, tying in the contributions of each analysis to my prediction.

Table 3.1: Summary outline of the four analyses to be discussed.

Section	
3.3.1	Linear Analysis of Vowel Dispersion
3.3.1.1	Statistical Procedures
3.3.1.2	Predictors
3.3.1.3	Results with All Vowels Combined (global)
3.3.1.3.2	Tense (linguistic property)
3.3.1.3.3	NDL Cue Strength (paradigmatic support)
3.3.1.4	Results by Vowel and by Time Percent
3.3.1.4.2	Tense (linguistic property)
3.3.1.4.2	NDL Cue Strength (paradigmatic support)
3.3.2	Linear Analysis of Formant Deviation from Vowel Onset
3.3.2.1	Statistical Procedures
3.3.2.2	Predictors
3.3.2.3	Results with All Vowels Combined (global)
3.3.2.3.1	Tense (linguistic property)
3.3.2.3.2	NDL Cue Strength (paradigmatic support)
3.3.2.4	Results by Vowel and by Percent
3.3.2.4.1	Tense (linguistic property)
3.3.2.4.2	NDL Cue Strength (paradigmatic support)
3.3.3	Linear Analysis of Formant Deviation from Vowel Offset
3.3.3.1	Statistical Procedures
3.3.3.2	Predictors
3.3.3.3	Results with All Vowels Combined (global)
3.3.3.3.1	Tense (linguistic property)
3.3.3.3.2	NDL Cue Strength (paradigmatic support)
3.3.3.4	Results by Vowel and by Percent
3.3.3.4.1	Tense (linguistic property)
3.3.3.4.2	NDL Cue Strength (paradigmatic support)
3.3.4	Non-Linear Analysis of Formant Movement
3.3.4.1	Statistical Procedures
3.3.4.2	Predictors
3.3.4.3	Results with All Vowels Combined (global)
3.3.4.3.1	Tense (linguistic property)
3.3.4.3.2	NDL Cue Strength (paradigmatic support)
3.3.4.4	Results by Vowel

3.3.4.4.1	Tense (linguistic property)
3.3.4.4.2	NDL Cue Strength (paradigmatic support)
3.3.5	Summary of Results

3.3.1 Linear Analysis of Vowel Dispersion

This first analysis is a traditional analysis of formant values to test the effects of morphological tense (linguistic parameter) and NDL (paradigmatic strength) on the dispersion of vowels from the centre of the vowel space (Wright, 2004; Gahl et al., 2012). To capture a more dynamic, rather than static, effect of vowel dispersion, these effects are tested on formant values at 20%, 30%, 40%, 50%, 60%, 70%, and 80% of the total duration for each vowel. After addressing the statistical modelling technique and predictors employed in this analysis, the results of the tense and NDL main effects on vowel dispersion are discussed.

3.3.1.1 Statistical Procedure

The effects of tense and NDL on the linear distances of the vowels from the centre of the vowel space were tested in a Linear Mixed Effects Regression Analysis (LMER; Baayen et al., 2008). The LMER modelling technique allows me to test for differences in the linear dispersion data according to specified predictors while accounting for factors of random variance for individual speakers. Analyses were computed in the R statistical environment using the *lme4* (Bates et al., 2014) and *languageR* (Baayen, 2013) packages.

Predictors in the LMER model are discussed in the next section, and the LMER call can be found in the Appendix (Table A.10). The LMER analysis proceeded in a backwards-fitting parametric fashion. In order to select a model, I visually compared residuals and fitted estimates between models, as well as the Akaike Information Criteria (AIC) scores. All principled two-way interactions were checked, along with other possible principled predictors (such as neighbourhood density and speaking rate). Only those predictors that achieved significance in the models were kept (see below for predictors' descriptions). A simple inspection of the Pearson's correlation coefficients found no significant pairwise collinearity in all possible two-way interactions between numeric predictors. The random effects structures of the models were also checked in a parametric fashion. Both item and speaker random intercepts were checked, as well as all random slope combinations. Random slopes that were not supported by likelihood ratio tests ($p > 0.05$) were excluded. For ease of computation, F1 and F2 data were modelled separately.

3.3.1.2 Predictors

A summary of the predictors for the LMER analysis at hand is given in Table 3.2. The LMER call can be found in the Appendix (Table A.10). The acoustic measure of Vowel Dispersion serves as the dependent variable for the current LMER analysis. As discussed previously, seven samples of dispersion for F1 and F2 were gathered for each of the 5,718 vowel tokens: one at every 10% time point from 20%-80% of the total vowel duration. These time points are referred to as Percent, with 20% serving as the reference level in the model.

Table 3.2: Predictors for main effects, interactions, and random effects in the Linear Mixed Effects Regression analysis of NDL and Tense on vowel dispersion.

Predictor	Description	use in current analysis
Vowel Dispersion	absolute value of the Euclidean Distance of the vowels from the centre of the vowel space	dependent variable
NDL Cue Strength	diphone Naive Discriminative Learning cue association strengths with the past tense, aggregated over the word	independent predictor of interest x Percent
Tense	morphological past or present tense reference level: present	independent predictor of interest x Percent
Percent	seven normalized 10% time steps (from 20%-80% of the total vowel duration) reference level: 20%	x NDL Cue Strength x Tense
Frequency	log value of the local Buckeye lexical frequency	x Vowel Duration random intercepts for Speaker slopes
Vowel Duration	log value	x Frequency random intercepts for Speaker slopes
Vowel Identity	the identy of the vowel reference level: /ʌ/	main effect
Previous Voicing	deviation coding for the segment preceding the vowel reference level: means of all factors	main effect
Previous Place	deviation coding for the segment preceding the vowel reference level: means of all factors	main effect
Previous Manner	deviation coding for the segment preceding the vowel reference level: means of all factors	main effect
Following Voicing	deviation coding for the segment preceding the vowel reference level: means of all factors	main effect
Following Place	deviation coding for the segment preceding the vowel reference level: means of all factors	main effect
Following Manner	deviation coding for the segment preceding the vowel reference level: means of all factors	main effect
Speaker	unique speaker identifier	random intercepts

There are two independent predictors of interest in the current LMER model and for all subsequent models in this series of statistical analyses. The first, Tense, is a binary factor predictor that indicates whether a vowel belongs to a verb in the past or present tense (e.g., an instance of /æ/ from ‘hang’ would be marked as *present* while /æ/ from ‘ran’ would be marked as *past*). Tense is included in the LMER model in an interaction with Percent to capture differences in amount of dispersion between the past and present tenses at the various Percent time points. As stated in the Introduction, the past tense verb forms are the marked, or more linguistically uncertain verb forms, and are predicted to correlate with phonetic enhancement (more formant movement). For this reason, the present tense serves as the reference level, to which the past tense is compared.

The other predictor of interest concerns the paradigmatic nature of the vowels: NDL Cue Strength. The current chapter uses the measures of NDL cue-to-tense activation from Tucker et al. (in preparation) that is calculated for all verbs in the Buckeye Corpus (including the subset of verbs at hand) on the basis of diphone cues activating either the past or present tense. NDL cue strength is calculated based on a two-layer connectionist model (Baayen et al., 2011). The basic schema of an NDL network is that produced forms (first level, input) cue meanings (second level, output; see Figure 3.1). In the NDL network, association strengths between forms and meanings are calculated according to Danks (2003) adaptations of the Rescorla-Wagner equations (1972). The Rescorla-Wagner equations compute weights, which correspond to learning an association between a particular form and a particular meaning. These equations do so by calculating the probability of that form/meaning pair, and penalizing for unlearning (when a particular form occurs with another meaning, and vice versa). These equations are employed iteratively: weights, or learning association strengths, are adjusted/recalculated for each new form-meaning pairing.

Tucker et al. calculated NDL Cue Strength using morphological tense (past/present) as cued meanings (second level) and diphone pairs as produced forms (first layer). The NDL Cue Strength of a verb is the aggregate sum of all its diphone cue-to-tense activation levels. Diphones that were strongly associated with a particular tense (i.e., and not both tenses equally) were weighted with a higher cue-to-tense activation strength. Figure 3.1 illustrates this in a pair of verbs used in the current study, *blow* and *blew* (all the verbs in the current study are taken from the set of verbs studied by Tucker et al.). Diphones in the first layer are mapped to tenses in the second layer, with arrow thickness corresponding to strength of association. In the illustration below, it is clear that the morphologically informative diphone pairs are those that contain the vowel (shown in Figure 3.1 with blue lines), as these distinguish the verb's morphological tense. The diphone pairs that contain only consonants are less informative, since those diphones cue both the past and present tense equally (shown in Figure 3.1 with red lines). Thus, it is the diphone pairs containing the vowel that are the most informative for calculating the NDL strength of the verb's diphone cues in activating tense.

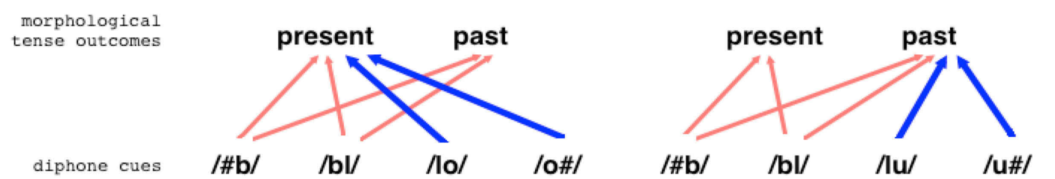

Figure 3.1: Illustration of an NDL network for the words *blow* and *blew*, comprising two layers: morphological tense and diphone cues. Arrows indicate associations between the two layers, with thickness indicating activation strength.

The cue-to-tense activation levels are calculated for each diphone in each verb. The NDL Cue Strength of a verb is the aggregate sum of all its diphone cue-to-tense activation levels. Since the diphones containing consonants only are not informative of morphological tense (as they occur equally in the past and present tense), it is the diphone pairs containing the vowel that are responsible for differences in the aggregated NDL Cue Strength for a particular verb.

NDL Cue Strength allows me to represent how strongly a particular vowel (in its diphone pairs) is associated with tense on a continuous, numerical scale. It differs from classic measures of gang size (e.g., Stemberger, 2004) in that the vowel alternation pattern in the morphological paradigm is not considered. For example, when determining the paradigmatic strength of /u/ (e.g., as in *blow*/*blew*), NDL Cue Strength is not determined by how many verbs follow the present-tense-/o/ → past-tense-/u/ morphological paradigm (a classic measure of gang size). Instead, NDL Cue Strength represents how indicative the diphones containing /u/ are for one morphological tense. In the NDL paradigm, vowels that serve as greater cues for one tense over the other are assigned a more positive NDL Cue Strength pattern. A negative NDL Cue Strength indicates that the vowel diphones of the particular word are not strongly associated with either tense. Taking NDL Cue Strength as a means of measuring paradigmatic support, it follows that a higher NDL Cue Strength for a particular word indicates strong paradigmatic support for the vowel diphone patterns in signalling tense. A table of each irregular verb and its average NDL Cue Strength is provided in the Appendix (Table A.9).

Recall that Tucker et al. found that these NDL cue-to-tense activation strengths modulate fine phonetic detail: higher levels of NDL cue strength correlate with phonetic enhancement (longer vowel durations). Their findings support the predictions of the Paradigmatic Signal Enhancement Hypothesis (Kuperman et al., 2007): stronger paradigm support is correlated with phonetic enhancement.

The remaining predictors in the models serve as lexical and phonetic controls. Frequency is a local measure of word frequency: it represents a token count of how often a particular verb appears in the Buckeye Corpus. Frequency is included in the model as the logged value of the raw frequency counts. A table of each irregular verb and its local Frequency is provided in the Appendix (Table A.8). Several studies have found a high correlation between segment duration and frequency in speech production. In work most related to the current study, Tucker et al. found that duration decreases for vowels in irregular verbs with a higher word frequency. Thus, Vowel Duration (measured in milliseconds) was included in the current model as a phonetic predictor in an interaction with the lexical predictor, Frequency.

The final predictors in the LMER model are an attempt to control for the phonetic environment surrounding the vowel: the Voice, Place, and Manner of the Previous and Following Segment. Several studies have illustrated that the articulations both before and after a vowel (phonetic context) can greatly influence the vowel's production, evident in its formant trajectories (for a discussion, see Broad and Clermont, 2014). However, there is currently no systematic means for disentangling the influence of the surrounding phonetic environment from a vowel's inherent formant trajectory when using unbalanced data in spontaneous speech corpora. It is not yet possible to parse a formant trajectory into its discrete components comprising context trajectory patterns and trajectory patterns that are inherent to the vowel. Thus, any generalizations or analyses on formant data may be confounded by articulations before and after the vowels.

Our attempt to control for phonetic context by including an interaction between each vowel and the Previous and Following Voice, Place, and Manner of articulation for the phones surrounding the vowel is derived from work by Nearey (2013; see also Broad and Clermont 1987). Nearey identifies three contributing factors to a vowel's formant trajectory: 1) the trajectory from the locus of previous consonant to the vowel target (C_1V), 2) the vowel target (V), and 3) the trajectory from the vowel target to the locus of the following consonant (VC_2). Instead of calculating the exact trajectories of C_1V and VC_2, I included the articulatory characteristics of the C_1, and C_2 in the model as they interact with the vowel (coded as the identity of the vowel; reference level: /ʌ/), which approximates the assimilation of the vowel trajectories' with the surrounding context. I chose to code the C_1 and C_2 by articulatory characteristics (Place, Voicing, and Manner) because doing so resulted in less data sparsity than coding by phone identity. Where as coding by phone identity splits the C_1 and C_2 into 28 sparsely populated factors (or 28 phone identities), coding by articulatory characteristics splits the C_1 and C_2 into fewer factors (7 for Place; 2 for Voicing; and 6 for Manner), gaining more members for each factor. The Appendix (Table A.1, Table A.2, Table A.3, Figure A.5, and Figure A.6) contains the distributional plots and tables of the C_1 and C_2 phone identities, and place/voice/manner factors.

In order to include consonant articulation characteristics (which are categorical variables) in my linear model, I had to normalize the predictors differently. The nature of these regression models assumes a reference level for each articulation predictor. In the phonetic reality, though, there does not exist a neutral, or referent, level of articulation. For example, bilabial is no more a neutral/referent place of articulation than velar. Thus, instead of comparing each of these phonetic control predictors to an arbitrary reference level within the models (as in dummy coding), the predictors are compared to the mean of the articulation group (as in deviation coding). For example, when assessing the influence of place of articulation on the formant data, the models compare the bilabial place of articulation to the mean of all the places of articulation (the mean acts as the neutral/referent level), instead of to only a velar place of articulation (where the velar place of articulation would act as the neutral/referent level). Though this statistical method of categorical variable coding does not wholly control for the influence of the surrounding phonetic environment, it is nevertheless a step towards disentangling vowel formant values from their surrounding articulation environment.

3.3.1.3 Results with All Vowels Combined (global)

This first analysis focuses on the general centralization of all speakers' vowels simultaneously. Individual vowel identity is dealt with in the next analysis. Figure 3.2 illustrates the results from the LMER models of the interactions between dispersion and the independent predictors of interest, Tense and NDL, at various time points during vowel production. Table 3.3 shows the coefficients of these interactions. All coefficients for the F1 and F2 LMER models are in the Appendix (Table A.11).

In Figure 3.2, the top panels illustrate the effect of Tense for F1 (left panel) and F2 (right panel). The effects of Tense are shown in an interaction with Percent time step, as indicated by line type and colour. A line with a positive slope in these panels indicates that the past tense is correlated with greater amounts of vowel dispersion than the present tense (reference level). A positive slope would reflect my prediction: the more morphologically uncertain tense (past) will correlate with phonetic enhancement (more vowel dispersion). The bottom panels illustrate the effect of NDL Cue Strength for F1 (bottom left panel) and F2 (bottom right panel). As with Tense, the effects of NDL Cue Strength are shown in an interaction with Percent time step, as indicated by line type and colour. A line with a positive slope in these panels indicates that higher NDL Cue Strengths correlate with greater amounts of vowel dispersion. A positive slope would reflect my prediction: more paradigmatic support (greater NDL Cue Strengths) will correlate with phonetic enhancement (more vowel dispersion).

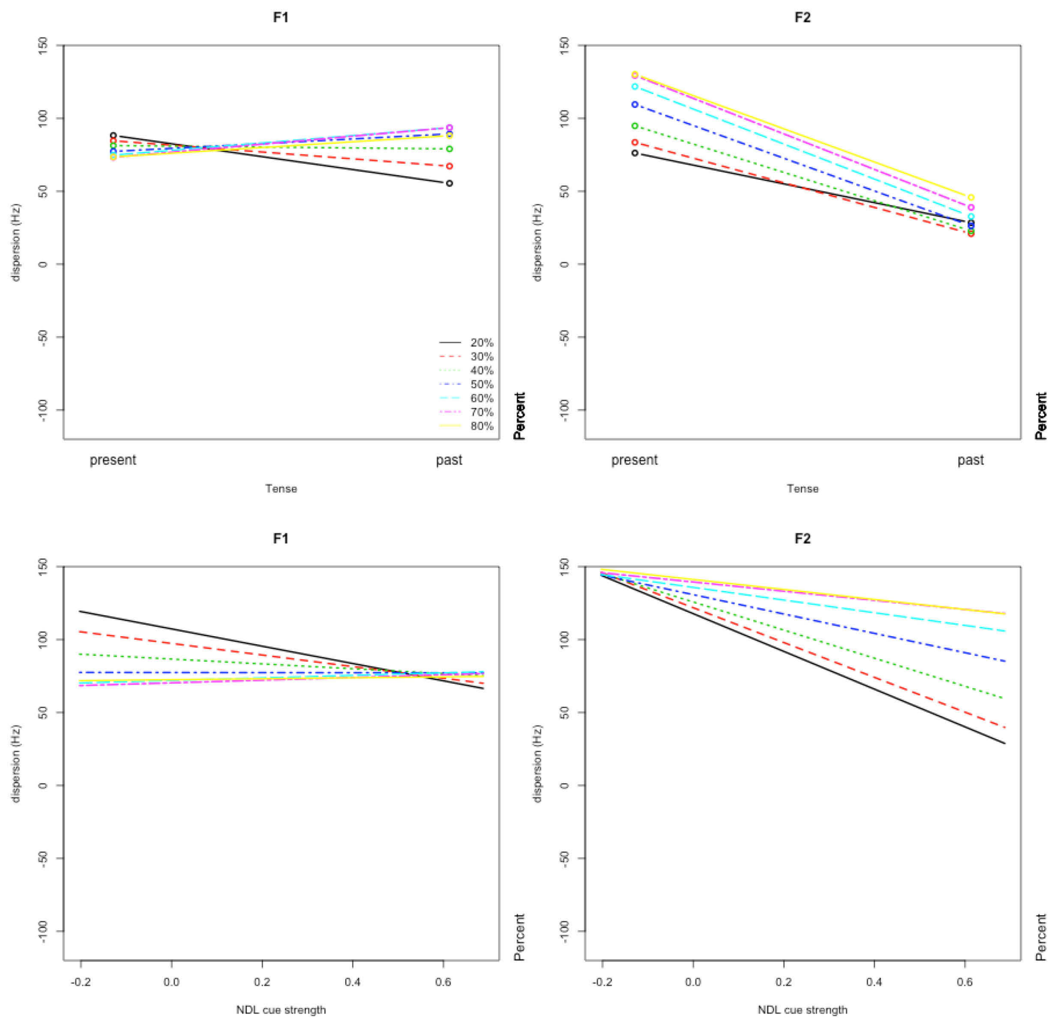

Figure 3.2: Partial effects of the LMER model results for the two predictors of interest. Top row: interactions between dispersion and tense (reference level: present tense and 20% time step) for F1 and F2 at 20-80% total vowel duration. Bottom row: interactions between dispersion and NDL Cue Strength for F1 and F2 at 20-80% total vowel duration (reference level: 20% time step).

Table 3.3 Dispersion LMER model coefficients for the two predictors of interest: Tense and NDL Cue Strength (reference level: present tense and 20% time step).

F1			
Predictor	Estimate	std Error	t value
(Intercept)	-58.3827	29.2753	-1.9943
Tense: past	-32.8123	2.6066	-12.5882
Percent: 30	-9.9599	2.1830	-4.5626
Percent: 40	-20.6675	2.1830	-9.4676
Percent: 50	-29.8967	2.1830	-13.6955
Percent: 60	-35.3127	2.1830	-16.1765
Percent: 70	-36.9782	2.1830	-16.9395
Percent: 80	-34.8091	2.1830	-15.9458
NDL Cue Strength	-59.3505	5.9354	-9.9993
Tense: past x Percent: 30	15.4293	3.0640	5.0357
Tense: past x Percent: 40	30.5306	3.0640	9.9644
Tense: past x Percent: 50	44.8250	3.0640	14.6298
Tense: past x Percent: 60	51.6519	3.0640	16.8579
Tense: past x Percent: 70	53.1408	3.0640	17.3439
Tense: past x Percent: 80	47.3845	3.0640	15.4651
Percent: 30 x NDL Cue Strength	19.6106	6.3897	3.0691
Percent: 40 x NDL Cue Strength	42.7670	6.3897	6.6931
Percent: 50 x NDL Cue Strength	59.0337	6.3897	9.2388
Percent: 60 x NDL Cue Strength	67.9969	6.3897	10.6416
Percent: 70 x NDL Cue Strength	68.5464	6.3897	10.7276
Percent: 80 x NDL Cue Strength	62.5850	6.3897	9.7946
F2			
Predictor	Estimate	std Error	t value
(Intercept)	-498.4431	74.2501	-6.7130
Tense: past	-47.7638	6.9191	-6.9031
Percent: 30	4.0708	5.7966	0.7023
Percent: 40	8.0062	5.7966	1.3812
Percent: 50	13.0229	5.7966	2.2466
Percent: 60	17.9984	5.7966	3.1050
Percent: 70	21.6940	5.7966	3.7425
Percent: 80	23.4357	5.7966	4.0430
NDL Cue Strength	-129.4344	15.7576	-8.2141
Tense: past x Percent: 30	-14.8310	8.1360	-1.8229
Tense: past x Percent: 40	-24.2537	8.1360	-2.9810
Tense: past x Percent: 50	-35.4567	8.1360	-4.3580
Tense: past x Percent: 60	-41.3241	8.1360	-5.0792
Tense: past x Percent: 70	-42.6435	8.1360	-5.2413
Tense: past x Percent: 80	-36.6429	8.1360	-4.5038
Percent: 30 x NDL Cue Strength	10.0258	16.9673	0.5909
Percent: 40 x NDL Cue Strength	33.0379	16.9673	1.9472
Percent: 50 x NDL Cue Strength	63.0881	16.9673	3.7182
Percent: 60 x NDL Cue Strength	85.9819	16.9673	5.0675
Percent: 70 x NDL Cue Strength	97.9981	16.9673	5.7757
Percent: 80 x NDL Cue Strength	95.1271	16.9673	5.6065

The general trend shown in Figure 3.2 and Table 3.3 is that, as the formants move farther in time, the correlation between dispersion and both Tense and NDL Cue Strength increases.

3.3.1.3.1 Tense (linguistic property)

Overall, there is a large effect of morphological tense. Tense was significant in both F1 and F2 dispersion as seen in Table 3.3. The slopes of the lines in the upper panels of Figure 3.2 indicate the direction of Tense's effects on vowel dispersion at each Percent time point. Compared to the reference level (20% present tense), F1 in the past tense displayed significantly greater dispersion from the centre of the vowel space at all the 40%-80% time steps (seen in the upwards slanting slopes), however the opposite is true for the 20%-30% time steps (seen in the downward slanting slope). The effect of Tense on F2 dispersion were more uniform. Compared to the reference level (20% present tense), F2 in the past tense displayed significantly less dispersion from the centre of the vowel space (all Percent lines are sloping downwards). This effect was significant at the 40-80% time steps (insignificant at the 30% time step).

The results of the models are split for the predicted directions. It was predicted that phonetic enhancement (more dispersion) would correlate with the more morphologically uncertain verb form (the past tense). I find support for this prediction at the 40%-80% time steps in the F1 dimension only. In the F2 dimension, I find evidence of the opposite effect: the more morphologically uncertain verb form correlates with less dispersion compared to the unmarked verb form (the present tense).

3.3.1.3.2 NDL Cue Strength (paradigmatic support)

There is also an effect of NDL Cue Strength. When comparing the Percent time steps from 30%-80% to the 20% reference level, F2 displayed significantly less dispersion from the centre of the vowel space as NDL Cue Strength increased, seen in the negative slopes in Figure 3.2. In the F1 dimension, the interaction between NDL Cue Strength and Percent compared to the 20% reference level was significant for only the time steps between 50%-80%. An inspection of the LMER model results in Figure 3.2 indicates that the direction of the correlation between NDL Cue Strength and vowel dispersion for F1 is in the opposite direction as F2: there is slightly more dispersion (slight upward slanting slopes) as NDL Cue Strength increases.

As with the Tense predictor, the results of the model are split for the predicted directions of the NDL Cue Strength effects. It was predicted that phonetic enhancement (more dispersion) would correlate with the stronger morphological support (greater NDL Cue Strengths). For those interactions between NDL Cue Strength and Percent that were significant, I again find support for this prediction in the F1 dimension only. The effects in the F2 dimension are in the opposite direction than was predicted.

However, it is not advisable to interpret the fitted predictions of this global model because this model assumes that the dispersion slope for each vowel is the same. The last panel of Figure 3.3 (below) illustrates how vowel dispersion is carried by vowel. Though Tense and NDL Cue Strength have an effect on vowel dispersion as a whole, their effects on each individual vowel are not directly interpretable. Various studies have shown that vowels are produced with inherent properties that are unique and independent of the spectral properties of other vowels (see Morrison and Assmann, 2013, for a discussion). A model that assumes all vowels are produced with similar inherent spectral tendencies, then, opposes phonetic research. Thus, though this global model shows there to be an overall effect of morphological tense and NDL metrics in the predicted directions, it does not capture any inherent phonetic properties of the vowels. As such, a subsequent LMER analysis by vowel and by time percent was constructed to better capture the inherent differences in the vowels' spectral properties.

3.3.1.4 Results by Vowel and by Time Percent

To mitigate inherent spectral effects, each pairing of a vowel and percent time point were fitted in their own LMER model. For example, the dispersion of /i/ at its 20% time point was a separate LMER model from /i/ at its 30% time point and from /o/ at its 20% time point. This produces 140 models of vowel dispersion (one for each formant of each vowel at each time step; 2 formants x 10 vowels x 7 time points). The models' calls are listed in the Appendix (Table A.10).

Modelling the data in this way tests for the point(s) in time at which the linguistic predictors and/or paradigmatic support significantly affect the amount of vowel dispersion. This method allows one to find effects of the predictors on the dispersion variance for each vowel formant at each time point. It is not intended to compare dispersion amongst vowels at one particular time point nor amongst all the time points for one particular vowel (as a single LMER model with vowels and/or time steps as main effects would do).

Figure 3.3 illustrates averages of the (raw) vowel dispersion values for each of the time steps between 20 and 80% of the total vowel durations, grouped by tense. Figure 3.3 is based on vowel space area, perimeter, and vowel dispersion averages across all speakers; however, the LMER analysis uses the vowel space area, perimeter, and vowel dispersion from individual speakers and vowel tokens. The line colour on the plots illustrate morphological tense with past in blue and present in red. The differences between the past tense and the present tense can be seen in a comparison of the differently coloured lines for each vowel label. The length and direction of the line illustrates the average dispersion from the (averaged) centre of the vowel space. The vowel each line belongs to is illustrated with the vowel label. The last panel of the figure illustrates average vowel dispersion across all speakers and tenses. In this panel, vowel label illustrates the dispersion point in the F1xF2 vowel space, while the colour of the label illustrates the Percent time step.

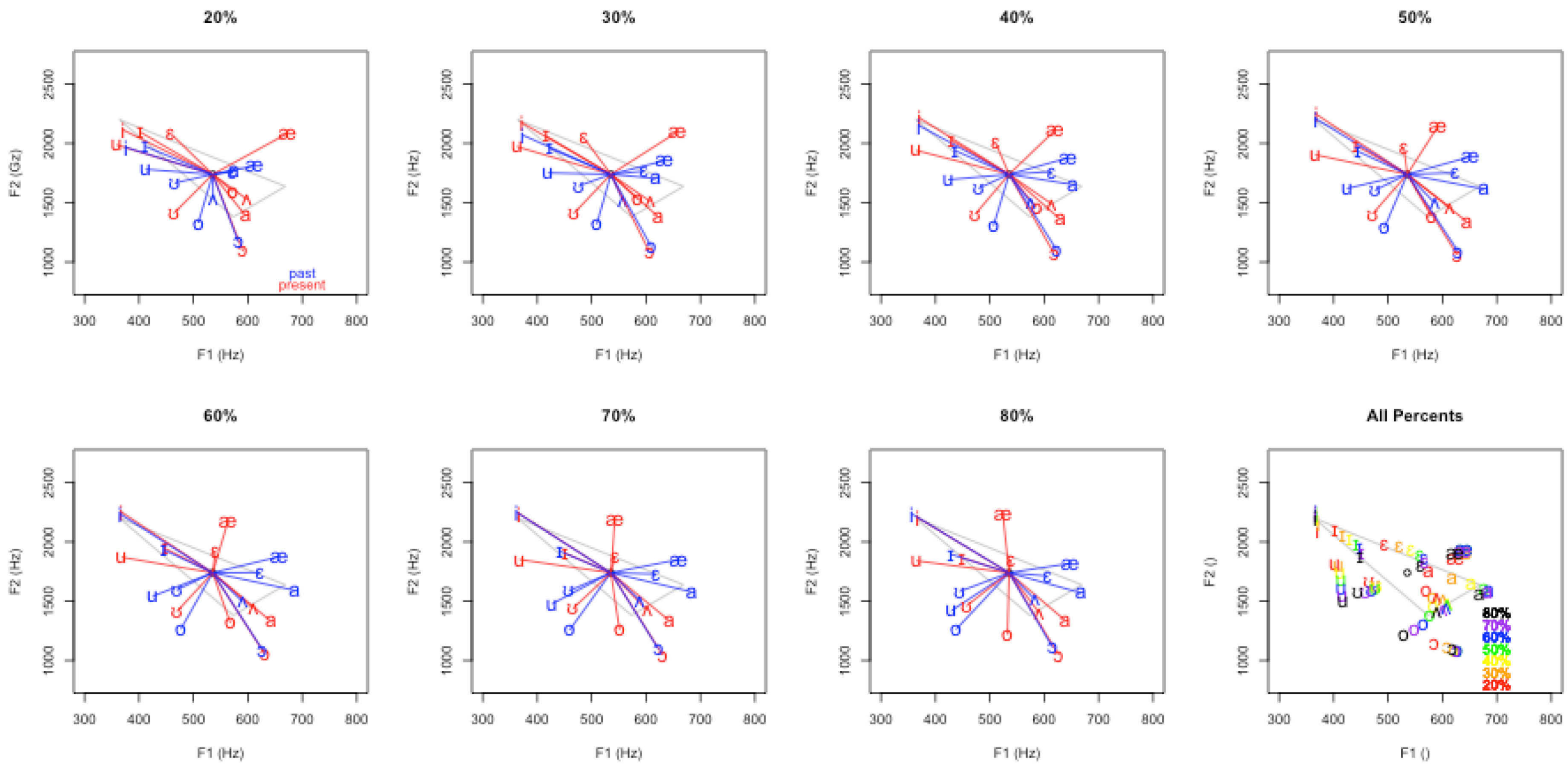

Figure 3.3: Raw averages across all speakers of the observed vowel dispersions from the centre of the vowel space, grouped by tense. Morphological tense is illustrated by line colour, and vowel identity is illustrated by line label.

Table 3.4 gives the *t*-values for the independent predictors of interest - Tense and NDL Cue Strength - in each of the 140 LMER analyses of the observed data (all coefficients for each LMER model are provided in the Appendix Table A.12). The table is colour coded according to the direction of the trend: green indicates a positive direction, yellow indicates a negative direction, and boldface (black font) indicates a significant value. A positive direction for Tense indicates that the past tense correlates with more vowel dispersion compared to the present tense (reference level). For example, the effect of Tense for the F1 of /i/ at the 20% time step is in a positive direction, indicating that the past tense correlates with more vowel dispersion when compared to the present tense, though this effect is statistically insignificant. However, the effect of Tense for the F1 of /ʌ/ at the 20% is statistically significant, but in the opposite direction: the past tense correlates with less vowel dispersion when compared to the present tense. A positive direction for NDL Cue Strength indicates that greater NDL cue strengths correlate with more vowel dispersion. For example, the effect of NDL Cue Strength for the F2 of /i/ at the 50% time step is in a statistically significant positive direction, indicating that greater NDL cue strengths correlate with more vowel dispersion. However, the effect of NDL Cue Strength for the F2 of /u/ at the 50% time step is in a statistically insignificant negative direction, indicating that greater NDL cue strengths correlate with less vowel dispersion.

Recall that I predicted (§3.1.4) the past tense would correlate with more vowel dispersion (a positive trend, green shading) and greater NDL cue strengths would also correlate with more vowel dispersion (a positive trend, green shading).

Table 3.4: *t*-values for the main effects of Tense (reference level: present tense) and NDL for each of the 140 individual LMER models of vowel dispersion modelled on each Vowel Identity and Percent pair. Green shading indicates a positive trend. Yellow shading indicates a negative trend. Boldface (in black) indicates significance.

Tense														
	F1							F2						
Vowel	20%	30%	40%	50%	60%	70%	80%	20%	30%	40%	50%	60%	70%	80%
i	0.6126	0.4831	0.6384	0.5397	0.3444	0.2272	0.6132	-1.1018	-0.5538	0.2291	0.8800	0.9374	1.2213	1.5896
ɪ	-1.0984	-0.9824	-1.3239	-1.6357	-1.5715	-1.5054	-0.7091	0.5749	0.3843	0.1665	0.1383	0.6275	0.8453	0.4774
ɛ	-1.7766	-1.0645	-1.1349	-0.6570	-0.2572	0.1100	-0.1060	**-3.3573**	**-2.6061**	**-2.0378**	-1.3988	-0.5151	0.3337	0.4553
æ	0.0876	1.3621	1.9252	**2.2845**	1.9472	1.7137	1.0140	-1.8889	-1.7301	**-2.0767**	**-2.1162**	-1.8792	-1.7078	-1.6794
ʌ	**-2.7286**	**-2.6705**	**-2.1502**	-1.3538	-1.0499	-0.9779	-0.9776	-1.4662	-1.3865	-1.2139	-1.1092	-1.0112	-0.7570	-0.4750
u	0.0016	0.0237	0.2590	0.3244	0.2819	0.1983	-0.0776	0.4024	-0.1330	-0.3091	-0.0478	-0.0602	-0.3913	-0.8713
ʊ	0.8667	0.4270	-0.0240	-0.0070	0.2520	0.3409	0.8697	0.1336	0.0706	-0.3360	-0.4603	-0.5045	-0.6535	-0.2795
o	0.6959	0.2488	0.1904	0.8488	1.3118	**2.1675**	**3.2227**	-1.8943	**-2.2493**	**-2.6170**	**-2.2130**	-1.6121	-1.0340	-0.8787
ɔ	0.8716	1.1617	1.6783	1.0927	0.6161	0.8903	1.0708	-0.1684	-0.2148	-0.1226	-0.3509	-0.4856	-1.3630	-1.6275
a	-0.9587	-1.2283	-0.2321	0.5583	1.0487	0.9713	-0.1834	**-2.4319**	**-2.4000**	**-2.0788**	-1.4249	-1.1143	-0.7741	0.0193
NDL Cue Strength														
	F1							F2						
Vowel	20%	30%	40%	50%	60%	70%	80%	20%	30%	40%	50%	60%	70%	80%
i	0.4525	1.1669	1.5258	1.7366	1.5904	1.4771	1.5350	0.1872	0.8281	1.5365	**2.1443**	**2.7859**	**2.8876**	**3.0531**
ɪ	1.7166	1.9725	**2.2440**	**2.3621**	**2.0874**	1.4477	0.9572	0.7646	0.9479	0.8372	1.0362	0.5781	-0.0792	-0.3619
ɛ	**-2.0036**	-1.5069	0.2281	1.1682	1.5446	1.1653	0.7522	**-2.5497**	**-3.3743**	**-3.8546**	**-3.9215**	**-3.9638**	**-3.5074**	**-2.4329**
æ	0.2949	-0.4782	-1.0446	-1.3370	-1.1802	-1.0984	-0.7761	1.0319	0.9685	1.1765	1.3573	1.4584	1.9676	**2.3075**
ʌ	1.4465	1.3541	0.8503	0.4009	0.1824	0.3876	0.6074	1.4997	1.3394	0.9793	0.3891	-0.1810	-0.5643	-0.9533
u	-0.2737	-0.1808	-0.0759	-0.0839	-0.3166	-0.7478	-0.8451	1.2306	0.5430	0.0593	-0.0702	0.0376	0.2140	0.4883
ʊ	-0.5473	-0.1466	0.1153	0.0563	-0.1784	-0.2284	-0.5982	-0.4884	-0.6035	-0.1160	0.0272	0.0768	0.2736	0.0395
o	-1.0877	-0.7884	-0.4276	-0.3158	-0.7513	-0.5372	-0.1045	1.3444	0.6641	0.0701	-0.0479	0.0226	0.5809	1.0112
ɔ	-0.2976	-0.3837	0.0894	0.4839	0.5550	0.6057	0.7666	**-2.5044**	**-2.7037**	**-3.1633**	**-2.8419**	**-4.1377**	**-4.8737**	**-4.9189**
a	-0.4757	-0.0823	0.2556	1.1891	1.3434	1.4155	1.2886	1.8445	1.5876	1.0897	0.7771	1.4146	1.2666	0.6613

3.3.1.4.1 Tense (linguistic property)

Tense is significant in 17 of the 140 LMER models (0.05 x 140 models = 7 models are expected to be significant by chance). As seen in Table 3.4 in black boldface, half of the ten vowels - /ɛ /, /æ/, /ʌ /, /o/, and /ɑ/ - display a significant difference in the variance of vowel dispersion from the centre of the vowel space in at least one formant dimension when predicted by Tense (reference level: present). Four of the five vowels (/ɛ /, /æ/, /ʌ /, and /o/) show a significant effect of Tense in both formant dimensions. Figure 3.3 illustrates the dispersion lines gathered from a raw average across all speakers. The dispersion lines for /ɛ /, /æ/, /ʌ /, /o/, and /ɑ/ are visibly different in Figure 3.3.

The direction of the correlation between Tense and amount of dispersion varies amongst the five vowels that had a significant correlation. Most of the significant (boldface) effects seen on Table 3.4 (in yellow shading) are in a negative direction, meaning the past tense is correlated with less vowel dispersion compared to the present tense in these models. However, there are significant positive effects (in green shading) for the F1 of two vowels, /æ/ and /o/, meaning the past tense is correlated with more vowel dispersion compared to the present tense in these models. When viewing the trends for Tense in Table 3.4 as a whole, regardless of significance (black boldface), about half of the trends (44% or 61/140 models) are also in a positive direction.

Whereas I predicted that the more morphologically uncertain past tense would correlate with significantly more vowel dispersion, I do not find strong support for my prediction in the current analysis. There is an overall lack of statistically significant support for the past tense displaying more vowel dispersion compared to the present tense. Moreover, the trends in the data are split between positive and negative effects. There is no clear direction in the models' results for the predictability of Tense; the direction of Tense's effects on vowel dispersion is varied.

It is possible that this variation in the direction of correlation between Tense and Vowel seen both in the by vowel models and in the global models (with all vowels pooled together) is due to the surrounding phonetic environment's places of articulation. While the influence of place of articulation on the formant data is not specifically tested, the effects are illustrated in vowel plots for each place of articulation that precedes and follows each vowel (plots are located in the Appendix Figure A.7 and Figure A.8). The surrounding phonetic environment's place of articulation inherently effect vowel trajectories (shown with arrows in the vowel plots), which could alter the patterns of dispersion seen here. The current analysis of vowel dispersion was not designed to account for these context assimilation effects. Instead, context assimilation effects are better addressed in the two analyses of formant deviation (§3.3.2 and 3.3.3).

3.3.1.4.2 NDL Cue Strength (paradigmatic support)

NDL Cue Strength is significant in 23 of the 140 LMER models (0.05 x 140 models = 7 models are expected to be significant by chance). As seen in Table 3.4, half of the ten vowels - /i/, /ɪ /, /ɛ /, /æ/, and /ɔ / - display a significant difference in the variance of vowel dispersion from the centre of the vowel space when predicted by NDL Cue Strength. All five vowels show a significant effect of NDL Cue Strength for at least one formant and at least one time step, though none of the vowels show a significant effect of NDL Cue Strength for both formants.

The direction of the correlation between NDL Cue Strength and amount of dispersion varies amongst the five vowels that had a significant correlation. The significant effects seen on Table 3.4 (in yellow shading and black boldface) for two vowels, /ɛ / and /ɔ /, are in a negative direction, meaning higher NDL Cue Strengths are correlated with less vowel dispersion compared to lower NDL Cue Strengths. However, the F2 of three of the vowels, /i/, /ɪ /, and /æ/, are trending in a positive direction (in green shading and black boldface), meaning higher NDL Cue Strengths are correlated with more vowel dispersion compared to lower NDL Cue Strengths. When viewing the trends for Tense in Table 3.4 as a whole, regardless of significance (black boldface), slightly more than half of the trends (61% or 85/140 models) are also in a positive direction.

Our prediction was that greater NDL Cue strengths would pattern with phonetic enhancement (more vowel dispersion). Here I find slightly more support for my NDL Cue Strength prediction compared to my Tense prediction. Support for my NDL Cue Strength prediction is seen in the number of vowels showing a significant positive trend between NDL Cue Strength and vowel dispersion, as well as the proportion of positive trends in all of the models. Whereas the global models of the same vowel dispersion data were split on the direction of the NDL cue strength, the current by vowel models illustrate how this directional split is dependent on vowel (rather than across all vowels). For example, the global model found a significant negative correlation between NDL Cue Strength and F2 dispersion, overall. The results of the by vowel analysis here find that the F2 of only two vowels, /ɛ / and /ɔ /, exhibit this significant negative correlation. In fact the F2 dispersion of two other vowels, /i/ and /æ/, show the opposite effect: a significant positive correlation with Tense. It is possible, then, that /ɛ / and /ɔ / provide the most contribution for the negative trend seen in the global model (though this was not explicitly tested). Thus, in addition to lending more support for the predictive hypothesis (higher NDL cue strengths correlate with more vowel dispersion), the by vowel formant dispersion models offer more interpretative explanations of the global formant dispersion models.

However, the support for my NDL Cue Strength prediction is not very strong as there is a lot of variation in the directional trends. As discussed in the previous section, it is possible that this variation in the direction of correlation between NDL Cue Strength and Vowel is due to the influence of the surrounding phonetic environment, namely the place of articulation. Though vowel plots by place of articulation (in the Appendix Figure A.7 and Figure A.8) do indicate that there is an effect of the surrounding phonetic environment, this was not directly addressed in the vowel dispersion analysis. The following two analyses of formant deviation from vowel onset and offset, however, better address context effects, as explained below.

3.3.2 Linear Analysis of Formant Deviation from Vowel Onset

The second LMER analysis builds upon the previous analysis by testing for effects of NDL Cue Strength and Tense on a different acoustic parameter: formant deviance from vowel onset (time step = 0). The previous analysis investigated the location of the vowels in the F1xF2 vowel space relative to the centre of the vowel space. The current analysis investigates not the location relative to the centre the vowel space, but the location relative to the onset of the vowel.

This deviance from vowel onset analysis, coupled with the following deviance from vowel offset analysis, is an attempt to capture the formant assimilation to the consonants at the temporal edges of the vowels. As Lindblom (1963, 1990) explained, in fast speech (such as the spontaneous speech from the Buckeye Corpus), speakers have less time to reach a vowel’s target formant frequencies, resulting in more coarticulation at the vowel's edges and hypo-articulation of the vowel target (or "undershoot": falling short of the target vowel formant values). Linblom notes that the edges of vowel productions are the result of articulators smoothly transitioning between the consonant and the vowel. This is evident in the smooth formant transitions at the edges of vowels, or "context assimilation" transitions. Broad and Clermont (1987; Model IVb, henceforth referred to as the Broad and Clermont context assimilation model) explore these context assimilations by investigating the time domain of the vowel's edges. They find that context assimilation is exponential: formant measurements taken at time slices closer to the edges of the vowels exhibit exponentially greater effects of context assimilation compared to measurements taken at time slices further from the edges of the vowels. In Lindblom terms, coarticulation is a function of time, with coarticulation effects increasing as the speaker's gestures move from a consonant place of articulation to the intended vowel target, and from the intended vowel target to the next consonant place of articulation. The least amount of context assimilation, then, is predicted to be at the point in time when the speaker reaches the maximum distance from the edges of the vowel (or, when the speaker has reached their closest approximation to their intended vowel target, though with articulatory undershoot). A Broad and Clermont context assimilation model predicts that the amount of dispersion from a vowel's onset/offset (its context assimilation) is expected to grow until it reaches an asymptotic state. This asymptotic state is akin to Lindblom's intended vowel target.

It is this exponential decay of context assimilation to an asymptote state (the vowel target) that the current and the following analyses indirectly address. This method of analysis addresses the issues of place of articulate effects discussed in the vowel dispersion analysis. Following from the phonetic research discussed above, it is predicted that the formant deviation from vowel onset will increase until the vowel has reached an asymptotic state. Moreover, it is predicted that linguistic predictors will modulate the formant deviance. The Smooth Signal Redundancy Hypothesis (Aylett and Turk, 2004, 2006) predicts that there will be greater deviance from the edges (less target vowel undershoot) for the morphologically uncertain tense: the past tense. The Paradigmatic Signal Enhancement Hypothesis (Kuperman, 2007) predicts that there will be greater deviance from the edges (less target vowel undershoot) for vowels with strong paradigmatic support (higher NDL cue strengths). These predictions are based on the assumption that more formant deviation from the edges better distinguishes the vowel production, and the intended vowel target is reached with less hypo-articulation (i.e. more deviation towards the vowel's so-called steady state).

3.3.2.1 Statistical Procedures

Predictors in the LMER analysis are discussed in the next section and the LMER call can be found in the Appendix (Table A.10). The overall LMER procedure for the current analysis proceeded in the same way as the previous dispersion analysis, with the exception of the dependent variable of interest. The previous analysis investigated the formants' dispersion from the centre of the vowel space. The current analysis investigates the formants' deviation from the onset of the vowel (time step = 0). For ease of computation, F1 and F2 data were modelled separately.

3.3.2.2 Predictors

A summary of the predictors for the LMER analysis at hand is given in Table 3.5; predictors that have been changed or added to the previous model are highlighted in boldface. The main difference between the LMER analysis at hand and the previous is the dependent variable. While the previous analysis examined vowel dispersion, the current model tests the effects of Tense and NDL Cue Strength on formant deviation from vowel onset.

Table 3.5: Predictors for main effects, interactions, and random effects in the Linear Mixed Effects Regression analysis of NDL and Tense on formants' deviance from vowel onset.

Predictor	Description	use in current analysis
Vowel Deviance	**absolue value of the Euclidean Distance of the vowels from the onset of the vowel (time step = 0)**	**dependent variable**
NDL Cue Strength	diphone Naive Discriminative Learning cue association strengths with the past tense, aggregated over the word	independent predictor of interest x Percent
Tense	morphological past or present tense reference level: present	independent predictor of interest x Percent
Percent	seven normalized 10% time steps (from 20%-80% of the total vowel duration) reference level: 20%	x NDL Cue Strength x Tense **x Vowel Duration**
Frequency	log value of the local Buckeye lexical frequency	x Vowel Duration random intercepts for Speaker slopes
Vowel Duration	log value	x Frequency **x Percent** random intercepts for Speaker slopes
Vowel Identity	the identy of the vowel reference level: /ʌ/	main effect
Previous Voicing	deviation coding for the segment preceding the vowel reference level: means of all factors	main effect
Previous Place	deviation coding for the segment preceding the vowel reference level: means of all factors	main effect
Previous Manner	deviation coding for the segment preceding the vowel reference level: means of all factors	main effect
Following Voicing	deviation coding for the segment preceding the vowel reference level: means of all factors	main effect
Following Place	deviation coding for the segment preceding the vowel reference level: means of all factors	main effect
Following Manner	deviation coding for the segment preceding the vowel reference level: means of all factors	main effect
Speaker	unique speaker identifier	random intercepts

The acoustic measure of Vowel Deviance serves as the dependent variable for the current LMER analysis. Vowel Deviance was calculated via the same method as dispersion. Euclidian distances were calculated by subtracting the formant values at each Percent from the formant values at the vowel onset (time step = 0). The absolute values of these distances were predicted in the LMER models.

In addition to the Voicing, Place, and Manner of the phone before and after the vowel, an interaction between Vowel Duration and Percent was added to the model to control for formant assimilation to context. Recall that the 10% Percent time steps were calculated for each vowel in order to normalize vowel duration. However, a formant's distance from vowel onset at the 50% time step may be further (in terms of duration) than another vowel; the distances between each Percent time step and each vowel onset are not the same for all vowels. The distance from onset, though, influences a formant's deviation from the onset of a vowel (see equations (38) and (39) in Broad and Clermont, 1987). A vowel with a shorter duration will travel a shorter distance, so its deviance from onset will be less than a longer vowel that travels a longer distance. For this reason, Vowel Duration was placed in an interaction with Percent to capture how far a particular vowel has traveled at a given Percent time step. The results of this interaction between absolute duration and normalized time are phonetically interesting, though secondary to the primary focus on morphological effects. More discussion of the phonetically informative results is given in the Appendix (Discussion A.1 and Discussion A.2).

3.3.2.3 Results with All Vowels Combined (global)

The coefficients for the current LMER analysis are given in Table 3.6. Figure 3.4 illustrates the main effects of Tense and NDL Cue Strength and their interaction with Formant. All coefficients for the models are given in the Appendix (Table A.13).

The plots in Figure 3.4 are similar to those from the dispersion analysis. The top panels illustrate the effect of Tense for F1 (left panel) and F2 (right panel), shown in an interaction with Percent time step (line type and colour). A line with a positive slope in these panels indicates that the past tense is correlated with greater amounts of formant deviance from vowel onset than the present tense (reference level). A positive slope would be in line with my prediction: the more morphologically uncertain tense (past) will correlate with phonetic enhancement (more deviance). The bottom panels illustrate the effect of NDL Cue Strength for F1 (left panel) and F2 (right panel), shown in an interaction with Percent time step (line type and colour). A line with a positive slope in these panels indicates that higher NDL Cue Strengths correlate with greater amounts of formant deviance. A positive slope would be in line with my prediction: more paradigmatic support (greater NDL Cue Strengths) will correlate with phonetic enhancement (more deviance).

A Broad and Clermont (1987) context assimilation model would predict that formant deviance will decrease at an exponential rate (irrespective of Tense and NDL Cue Strengths), until the trajectory reaches an asymptote state, roughly half-way through the vowel duration (roughly at the 50% vowel time step).

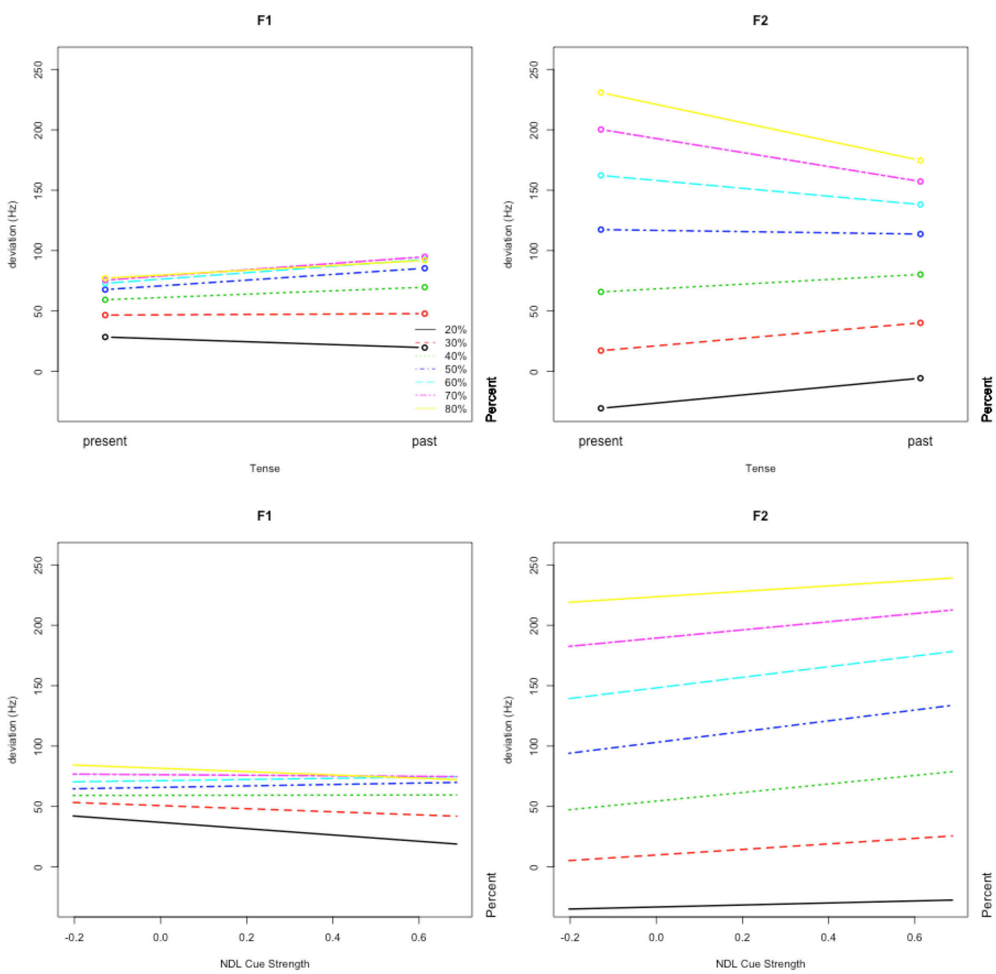

Figure 3.4: Partial effects of the LMER model results for the two predictors of interest: Tense is shown on the top row (for F1 and F2; reference level: present tense and 20% time step), and NDL Cue Strength is shown on the bottom row (for F1 and F2). The coloured lines show the interaction between Percent and the predictors (Tense and NDL Cue Strength).

Table 3.6: Deviance from onset LMER model coefficients for the two predictors of interest: Tense and NDL Cue Strength (reference level: present tense and 20% time step).

F1			
Predictor	Estimate	std Error	t value
(Intercept)	-60.3277	27.1073	-2.2255
Tense: past	-8.7889	2.4983	-3.5180
Percent: 30	-9.5582	10.0868	-0.9476
Percent: 40	8.7738	10.0868	0.8698
Percent: 50	36.6516	10.0868	3.6336
Percent: 60	61.9945	10.0868	6.1461
Percent: 70	86.2746	10.0868	8.5532
Percent: 80	108.1120	10.0868	10.7182
NDL Cue Strength	-26.0884	5.7085	-4.5701
Tense: past x Percent: 30	9.9964	2.9405	3.3996
Tense: past x Percent: 40	19.1579	2.9405	6.5152
Tense: past x Percent: 50	26.4371	2.9405	8.9907
Tense: past x Percent: 60	28.6169	2.9405	9.7320
Tense: past x Percent: 70	28.0819	2.9405	9.5500
Tense: past x Percent: 80	23.5311	2.9405	8.0024
Percent: 30 x NDL Cue Strength	13.3262	6.1728	2.1589
Percent: 40 x NDL Cue Strength	26.5509	6.1728	4.3013
Percent: 50 x NDL Cue Strength	32.0063	6.1728	5.1851
Percent: 60 x NDL Cue Strength	30.8832	6.1728	5.0031
Percent: 70 x NDL Cue Strength	23.8186	6.1728	3.8587
Percent: 80 x NDL Cue Strength	12.4952	6.1728	2.0242
F2			
Predictor	Estimate	std Error	t value
(Intercept)	183.8443	60.7904	3.0242
Tense: past	24.9237	5.4280	4.5917
Percent: 30	-95.3896	21.8949	-4.3567
Percent: 40	-164.3852	21.8949	-7.5079
Percent: 50	-211.0620	21.8949	-9.6398
Percent: 60	-246.8289	21.8949	-11.2734
Percent: 70	-255.1690	21.8949	-11.6543
Percent: 80	-207.1662	21.8949	-9.4619
NDL Cue Strength	8.3677	12.3979	0.6749
Tense: past x Percent: 30	-1.9290	6.3828	-0.3022
Tense: past x Percent: 40	-10.4789	6.3828	-1.6417
Tense: past x Percent: 50	-28.6004	6.3828	-4.4808
Tense: past x Percent: 60	-49.0144	6.3828	-7.6791
Tense: past x Percent: 70	-67.9520	6.3828	-10.6461
Tense: past x Percent: 80	-81.1054	6.3828	-12.7068
Percent: 30 x NDL Cue Strength	14.5606	13.3989	1.0867
Percent: 40 x NDL Cue Strength	27.0531	13.3989	2.0191
Percent: 50 x NDL Cue Strength	36.2152	13.3989	2.7028
Percent: 60 x NDL Cue Strength	35.4277	13.3989	2.6441
Percent: 70 x NDL Cue Strength	25.4561	13.3989	1.8999
Percent: 80 x NDL Cue Strength	14.1628	13.3989	1.0570

The general trend shown in Figure 3.4 and Table 3.6 is that, as the formants move farther in time, the correlation between onset deviance and both Tense and NDL Cue Strength increases, with both effects peaking around 50-60% of the total vowel duration.

3.3.2.3.1 Tense (linguistic parameter)

As seen in Table 3.6, the amount of F1 deviation from vowel onset in the past tense was significantly different than the reference level (20% present tense) for all Percent time steps. The direction of these effects are split in Figure 3.4. F1 in the past tense displayed significantly less deviation from vowel onset at the 20%-30% time steps (seen in the downwards slopes). However this effect is reversed at the 40%-80% time steps where the past tense is correlated with more deviance than the present tense (seen in the upwards slopes).

The amount of F2 deviation from vowel onset in the past tense was significantly different than the reference level (20% present tense) for only the 50%-80% time steps, as seen in Table 3.6. At the the 50% time step, the past tense is correlated with slightly less F2 deviance than the present tense (though the slope is almost horizontal). For the 60%-80% time steps, however, there is a clear downward slant in the slopes, indicating that the past tense is correlated with considerably less F2 deviation compared to the present tense.

It is possible to explain these split patterns of Tense's effects in terms of Broad and Clermont's (1987) model of context assimilation. It appears in Figure 3.4 that formant deviance from offset begins to asymptote around the 50% time step. In the top two panels for Tense, this is evident in the convergence of the Percent lines between 50%-80% (as compared to the more divergent 20%-40% lines). This 50% asymptote boundary is approximately where the effects of Tense change direction. In the F1 model (upper left panel), this is at the 40% time step (green line), and in the F2 model (upper right panel), this is at the 50% time step (blue line). One explanation for the split in Tense's effects is that the morphological predictor's effects become more apparent once the vowel reaches its asymptote state. Prior to reaching the asymptote state (at roughly the 20%-40% time steps), the exponential decay of the context assimilation could be overshadowing the effects of linguistic predictors. Coarticulation is too strong here.

Under this interpretation of the Broad and Clermont model of context assimilation, the effects of Tense are more clear. After the formant trajectory has reached it's asymptotic state, Tense is positively correlated with F1 trajectories (more deviation for the more uncertain verb form - past tense) and negatively correlated with F2 trajectories (less deviation for the more uncertain verb form - past tense).

With this explanation, the results of the models are again split for the predicted directions. It was predicted that phonetic enhancement (more dispersion) would correlate with the more morphologically uncertain verb form (the past tense). As in the analysis of vowel dispersion, I find support for this prediction in the F1 dimension only. In the F2 dimension, I find evidence of the opposite effect: the more morphologically uncertain verb form correlates with less deviation compared to the unmarked verb form (the present tense).

3.3.2.3.2 NDL Cue Strength (paradigmatic support)

NDL Cue Strength was significant for F1 deviation at all Percent time steps according to Table 3.6. The patterns of deviation for NDL Cue Strength in the F1 dimension are similar to the patterns of Tense. At the Percent time steps from 20%-30%, F1 displayed less deviation from vowel onset as NDL Cue Strength increased (seen in the downward slopes of the bottom left panel of Figure 3.4). The opposite is true for the 40%-80% time steps where F1 displayed slightly more deviation from vowel onset. One explanation based on a Broad and Clermont context assimilation model is again that as the vowel reaches its asymptotic state (around the 40% time step), effects of the NDL Cue Strength predictor begin to converge. This could explain the split between the negative and positive slopes. The interpretation is that once the vowel approaches its asymptote state, there is a positive effect of NDL Cue Strength (greater strengths correlate with more deviance). This positive effect is in the predicted direction.

It is also possible that the split between the negative and positive slopes is instead due to effects of the context following the vowel. After the vowel has approached its asymptotic state (i.e. in the last 60%-80% of the vowel duration), the effects of the C_1V decrease, but the effects of the VC_2 increase. Thus, under the current analysis, it is not possible to absolutely distinguish the following phonetic environment's coarticulation effects from the effects of the NDL Cue Strength.

In the F2 dimension, the effects of NDL Cue Strength are only significant at the 40%-60% time steps, according to Table 3.6. Figure 3.4 (bottom right panel) shows clear positive slopes for these time steps: greater NDL Cue Strengths correlate with more formant deviation. According to a Broad and Clermont context assimilation model, the 40%-60% time steps (the time steps where the correlation between NDL Cue Strength and F2 are significant) should be where the F2 trajectory begins to asymptotes. However there is no clear evidence of an F2 trajectory asymptote in the plot of NDL Cue Strength. Regardless, the positive trends in the F2 data are in the predicted directions: more paradigmatic strength correlates with greater amounts of deviance.

3.3.2.4 Results by Vowel and by Time Percent

As with the dispersion analysis, 140 by vowel and by time percent models of formant deviance were computed to check for significant effects of Tense and NDL Cue Strength for each vowel. The same model structure for formant deviance was run over each of the 10 vowels at each of the 7 time percentages for both formants (7 x 10 x 2 = 140 models). The models' calls are listed in the Appendix (Table A.10).

Figure 3.5 illustrates averages of the (raw) vowel deviances from onset for each of the time steps between 20 and 80% of the total vowel durations, grouped by the past and present tenses. This figure is similar to the by vowel/by percent dispersion plots (Figure 3.3). Vowel label illustrates the average onset of each vowel at the 0% time step. Line colour illustrates morphological tense while line length and direction indicates the average formant distance and direction from vowel onset (terminal end marked with a point). Differences in a vowel's deviation with regards to tense can be seen by comparing the two coloured lines for each vowel.

The last panel of the figure illustrates average vowel deviation across all speakers and tenses with line colour indicating Percent time step. This plot illustrates that vowels deviate further from the vowel onset as they progress through time. The exponential decay of vowel deviance predicted by a Broad and Clermont context assimilation model is evident in this plot. /ɛ / best exemplifies this: there is a big jump in formant deviations from 20%-50% (red-green lines), and a levelling off of the deviations as the vowel approaches an asymptote state at 50%-80% time steps (green-black lines).

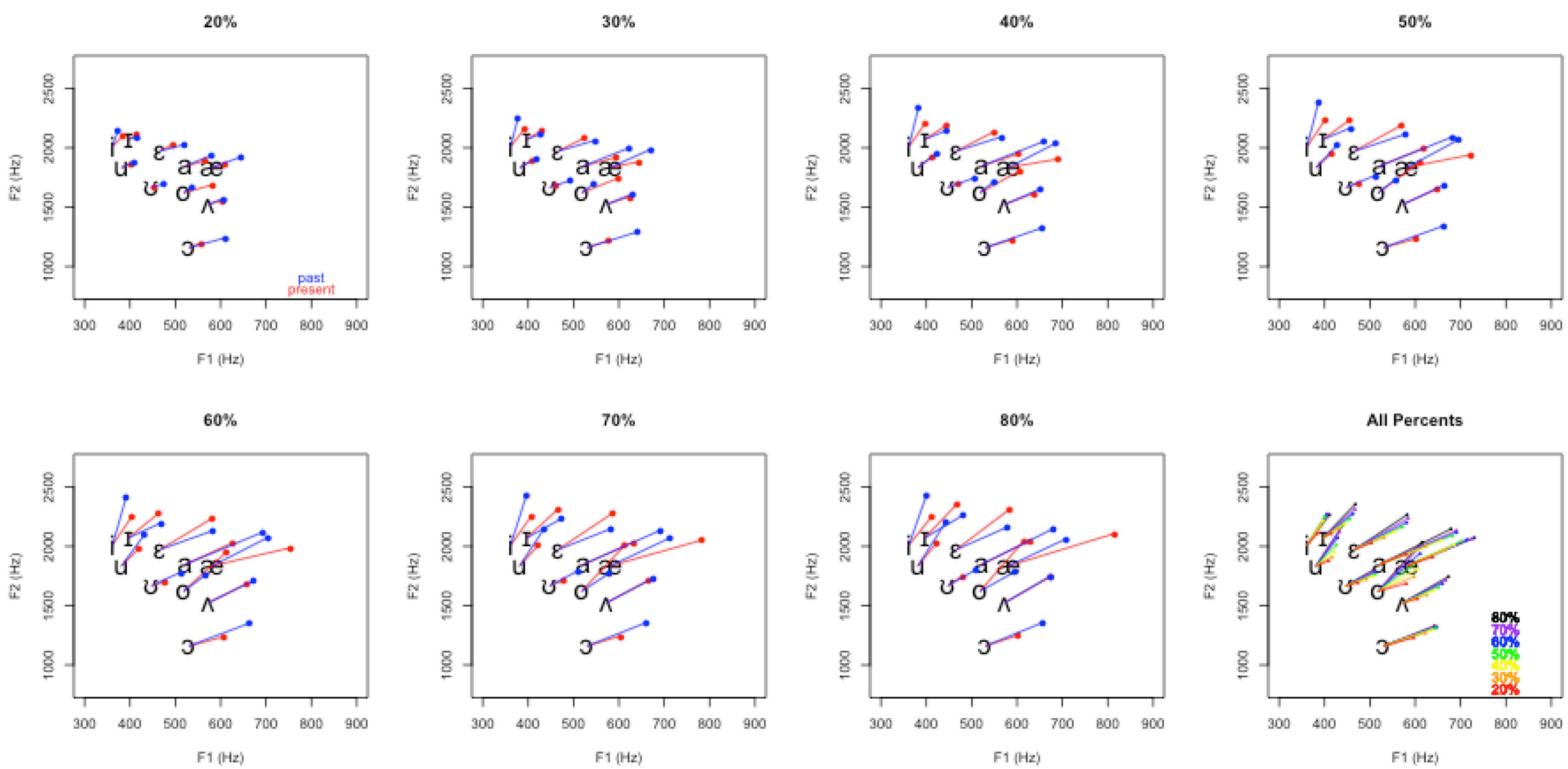

Figure 3.5: Raw averages across all speakers of the observed vowel deviations from the onset of the vowel, grouped by tense. Morphological tense is illustrated by line colour, and vowel onset is illustrated by vowel label.

The *t*-values for the LMER models of formant movement deviance from onset, by vowel, are given in Table 3.7 (all coefficients for each LMER model are provided in the Appendix Table A.14). This table is similar to the by vowel by percent dispersion table (Table 3.4). Positive trends are shaded in green, negative trends are shaded in yellow, and significant trends are indicated with black boldface. A positive trend for Tense indicates that the past tense correlates with more formant deviation than the present tense (reference level). A positive trend for NDL Cue Strength indicates that greater NDL cue strengths correlate with more formant deviation. As with vowel dispersions, my predictions are for all positive (green) trends: the more morphological uncertain tense (past) and stronger paradigmatic support (greater NDL cue strengths) correlate with more formant deviation from vowel onset.

Table 3.7: *t*-values for the main effects of Tense (reference level: present tense) and NDL for each of the 140 individual LMER models of vowel onset deviance modelled on each Vowel Identity and Percent pair. Green shading indicates a positive trend. Yellow shading indicates a negative trend. Boldface (in black) indicates significance.

Tense														
	F1							F2						
Vowel	20%	30%	40%	50%	60%	70%	80%	20%	30%	40%	50%	60%	70%	80%
i	-0.4690	-0.9587	-1.6432	-1.8912	-1.7769	-1.9008	-1.4799	-0.8459	-0.9117	-1.0553	-0.7129	-0.8864	-0.9641	-0.8169
ɪ	0.5872	-0.0370	-0.1156	0.2534	0.7413	0.9069	1.5043	-1.1965	-1.0476	-1.0203	-1.5983	**-2.1348**	**-2.0956**	**-2.0858**
ɛ	1.5170	1.5087	1.5341	1.3423	1.0325	0.0568	-1.6371	**-2.6274**	**-3.7106**	**-4.1036**	**-4.4948**	**-5.0307**	**-4.9812**	**-4.4811**
æ	-0.6478	-0.5506	0.3774	0.6274	0.4987	-0.0074	-0.7549	**-2.0377**	**-2.0614**	-1.7070	-1.8614	-1.9012	**-2.4176**	**-2.9386**
ʌ	-0.1411	0.4618	0.8648	0.9322	0.7613	0.6152	0.2711	-0.2254	-0.4944	-0.4231	-0.2914	-0.7024	-0.9781	-1.2098
u	0.6029	0.7341	0.3410	0.2385	0.4043	0.6394	0.8831	-0.7855	0.3025	0.1506	0.5048	0.6976	0.4877	0.6007
ʊ	-0.0554	0.2041	0.3419	0.1801	-0.0451	-0.1621	-0.1649	0.0021	-0.2996	0.1469	0.0823	0.4191	0.4789	0.2415
o	-0.7773	-0.4355	-0.3710	-0.2800	-0.0623	0.4375	0.9923	0.0798	-0.3474	-0.3018	0.1234	0.2573	0.5003	0.7827
ɔ	0.9446	0.3515	0.0674	0.4293	0.8294	0.7717	0.4827	0.3755	0.1392	0.2619	0.4172	0.5687	0.7139	0.1763
a	0.3133	0.6192	0.7431	0.8654	1.0069	0.8970	0.5386	-1.1751	-0.8961	-0.9850	-1.0290	-1.2706	-0.8254	-0.5995
NDL Cue Strength														
	F1							F2						
Vowel	20%	30%	40%	50%	60%	70%	80%	20%	30%	40%	50%	60%	70%	80%
i	0.6845	1.0235	0.3571	0.1272	0.3277	0.4745	0.3699	**2.1724**	**2.0159**	1.9031	1.9379	**2.2117**	1.8802	1.4033
ɪ	-0.1080	0.2279	0.3137	0.0611	0.0585	0.0288	0.0666	0.4859	0.5023	0.6078	0.1493	0.4771	0.4629	0.5037
ɛ	-0.3714	-0.5093	-0.4320	-0.7697	-1.0741	-0.6427	0.6246	**2.0159**	**2.5985**	**2.8492**	**2.8550**	**2.8908**	**2.4861**	1.7757
æ	0.7391	0.4009	-0.4881	-0.7413	-0.7959	-0.4895	0.0023	1.1141	1.2089	1.0817	1.3321	1.3518	1.6727	**2.2021**
ʌ	0.4184	-0.2263	-0.3227	-0.5348	-0.5694	-0.6529	-0.3491	1.0018	0.5363	0.2857	-0.0935	0.1588	0.2609	0.3707
u	1.8678	1.7947	1.7368	1.7463	1.9079	**2.0909**	1.9027	-1.2196	-0.1736	0.2837	0.7061	1.1567	1.4494	1.8296
ʊ	0.2480	0.0867	-0.1429	-0.0134	0.2302	0.3582	0.3764	-0.0166	0.3019	-0.1567	-0.1092	-0.4923	-0.5970	-0.4396
o	0.4048	-0.0145	-0.2611	-0.2430	-0.0652	0.5140	0.8188	-1.3777	-1.5064	-1.9223	-1.8623	-1.6088	-0.9624	-0.3857
ɔ	-0.1475	-0.5391	-0.6768	-0.8312	-0.8248	-0.7997	-0.7588	-1.3562	-1.2760	0.4209	1.1635	1.8254	1.9192	**3.1095**
a	0.1047	-0.3252	0.1734	0.1564	0.2055	-0.2399	0.1431	0.7711	0.2373	0.3094	0.0719	0.4686	0.1451	-0.5666

3.3.2.4.1 Tense (linguistic parameter)

Tense is significant in 14 of the 140 LMER models (0.05 x 140 models = 7 models are expected to be significant by chance). As seen in Table 3.7, three of the ten vowels - /ɪ /, /ɛ /, and /æ/ - display a significant difference in the variance of deviation from vowel onset when predicted by Tense (reference level: present). The significant differences occur after the vowel has reached an asymptote state for /ɪ /, throughout all the time steps for /ɛ /, and both at the initial time steps (where coarticulation is the strongest) and final timesteps (where coarticulation is weakest) for /æ/. Figure 3.5 illustrates the average formant deviations for each vowel. The three vowels with significantly different deviations between the past and present tense have visually different lines. Of all the models showing significant differences in deviation, 64% (9/14 models) are between the 50%-80% time steps, when the formant trajectory has approximated an asymptote state of context assimilation (Broad and Clermont, 1987).

The direction of the correlation between Tense and deviance from vowel onset is consistent across the three vowels that had a significant correlation. All of the significant effects seen on Table 3.4 (in yellow shading and black boldface) are in a negative direction, meaning the past tense is correlated with less vowel dispersion than the present tense. As with the global analysis of formant deviation from vowel onset, the significant effects of Tense in the by vowel models are not in the predicted direction.

A count of the trends regardless of significance indicates that the F1 and F2 deviation models together are evenly split between positive and negative trends (50%, or 70/140 models, are positive trending, green shading). However, there is a visually clear difference between the F1 and F2 deviance models. In the F1 models, 66% of the trends (46/70 models) are in the positive direction (green shading; higher NDL cue strengths correlate with more deviation). In the F2 models, the proportion of positive trends is reduced to 34% (24/70 models).

As with the global models, support for the predicted results is split. I predicted that the more morphologically uncertain verb form (past tense) would correlate with more vowel deviation. The significant trends and proportion of negative trends in F2 deviation do not support this prediction, but the proportion of trending positive effects in F1 deviation does.

3.3.2.4.2 NDL Cue Strength (paradigmatic support)

NDL Cue Strength is significant in 12 of the 140 LMER models (0.05 x 140 models = 7 models are expected to be significant by chance). As seen in Table 3.7, half of the ten vowels - /i/, /ɛ /, /æ/, /u/, and /ɔ / - display a significant difference in the variance of deviation from vowel onset when predicted by NDL Cue Strength. All five vowels show a significant effect of NDL Cue Strength for at least one formant and at least one time step, though none of the vowels show a significant effect of NDL Cue Strength for both formants and for all of the time steps. Of all the models showing significant differences in deviation, 58% (7/12 models) are between the 50%-80% time steps, when the formant trajectory approximates an asymptote state of context assimilation (Broad and Clermont, 1987).

The direction of the correlation between NDL Cue Strength and deviance from vowel onset is consistent amongst the three vowels that had a significant correlation. All of the significant effects seen in Table 3.7 (in green shading and black boldface) are in a positive direction, meaning higher NDL Cue Strengths are correlated with more deviation than lower NDL Cue Strengths. The results of these models are in the predicted directions: more paradigmatic support correlates with greater amounts of deviation from vowel onset, or phonetic enhancement, overall.

Support for the predicted direction also comes from a count of the positive trends. The proportion of models in Table 3.7 that have a positive trend (green shading) is at 66% (88/140 models). Considering both the significant effects and proportion of trending positive effects, the results for the by vowel models here mirror that of the global analysis (when the global analysis is interpreted under a Broad and Clermont context assimilation model). Both of these analyses show that more paradigmatic support correlates with greater amounts of formant deviation.

3.3.3 Linear Analysis of Formant Deviation from Vowel Offset

The third LMER analysis builds upon the previous by testing for effects of NDL Cue Strength and Tense on formant deviance from vowel offset. This is the second analysis to test the effects of formant deviation under a Broad and Clermont context assimilation model. The predictions and predictors are the same in this deviance from offset analysis. The difference is the direction of deviation. The previous analysis investigated the formants' amount of deviance from the beginning of the vowel (progressive deviation); the current analysis investigates the amount of deviance from the end of the vowel (regressive deviation).

3.3.3.1 Statistical Procedures

Predictors in the LMER model are discussed in the next section and the LMER call can be found in the Appendix (Table A.10). The overall LMER procedure for the current analysis proceeded in the same way as the previous formant deviation analysis, with the exception of the dependent variable of interest. The previous analysis investigated the formants' deviation from vowel onset. The current analysis investigates the formants' deviation from vowel offset (maximum time step). As such, the reference level for the time measurement in the LMER models was set to the end of the vowels (80%). For ease of computation, F1 and F2 data were modelled separately.

3.3.3.2 Predictors

A summary of the predictors for the LMER analysis at hand is given in Table 3.8; predictors that have been changed or added to the previous model are highlighted in boldface. The main difference between the LMER analysis at hand and the previous is the dependent variable. While the previous analysis examined formants' deviance from vowel onset, the current model tests the effects of Tense and NDL Cue Strength on formants' deviance from vowel offset.

Table 3.8: Predictors for main effects, interactions, and random effects in the Linear Mixed Effects Regression analysis of NDL and Tense on formants' deviance from vowel offset.

Predictor	**Description**	**use in current analysis**
Vowel Deviance	**absolue value of the Euclidean Distance of the vowels from the offset of the vowel (maximum time step)**	**dependent variable**
NDL Cue Strength	diphone Naive Discriminative Learning cue association strengths with the past tense, aggregated over the word	independent predictor of interest x Percent
Tense	morphological past or present tense reference level: present	independent predictor of interest x Percent
Percent	seven normalized 10% time steps (from 20%-80% of the total vowel duration) **reference level: 80%**	x NDL Cue Strength x Tense x Vowel Duration
Frequency	log value of the local Buckeye lexical frequency	x Vowel Duration random intercepts for Speaker slopes
Vowel Duration	log value	x Frequency x Percent random intercepts for Speaker slopes
Vowel Identity	the identy of the vowel reference level: /ʌ/	main effect
Previous Voicing	deviation coding for the segment preceding the vowel reference level: means of all factors	main effect
Previous Place	deviation coding for the segment preceding the vowel reference level: means of all factors	main effect
Previous Manner	deviation coding for the segment preceding the vowel reference level: means of all factors	main effect
Following Voicing	deviation coding for the segment preceding the vowel reference level: means of all factors	main effect
Following Place	deviation coding for the segment preceding the vowel reference level: means of all factors	main effect
Following Manner	deviation coding for the segment preceding the vowel reference level: means of all factors	main effect
Speaker	unique speaker identifier	random intercepts

The acoustic measure of Vowel Deviance serves as the dependent variables for the current LMER analysis. Vowel Deviance from offset was calculated in the same way as deviance from onset. Euclidian distances were calculated by subtracting the formant values at the vowel offset (maximum time step) from the formant values at each Percent. The absolute values of these distances were predicted in the LMER models.

The other difference between the current analysis and the previous concerns the Percent predictor. Since vowel deviance from offset is the acoustic measure under investigation, the reference level for Percent was set to 80%, towards the vowel offset.

3.3.3.3 Results with All Vowels Combined (global)

The coefficients for the current LMER analysis are given in Table 3.9. Figure 3.6 illustrates the main effects of Tense and NDL Cue Strength and their interaction with Formant. All coefficients for the models are given in the Appendix (Table A.15).

The plots in Figure 3.6 are similar to those from the dispersion and deviation from onset analyses. The main difference between the plots of the previous two analyses and the current one is that the Percent reference level for the current analysis is set to 80%, closer to the vowel offset. The top panels illustrate the effect of Tense for F1 (left panel) and F2 (right panel), shown in an interaction with Percent time step (line type and colour). A line with a positive slope in these panels indicates that the past tense is correlated with greater amounts of formant deviance from vowel offset than the present tense (reference level). A positive slope would be in line with my prediction: the more morphologically uncertain tense (past) will correlate with phonetic enhancement (more deviance). The bottom panels illustrate the effect of NDL Cue Strength for F1 (left panel) and F2 (right panel), shown in an interaction with Percent time step (line type and colour). A line with a positive slope in these panels indicates that higher NDL Cue Strengths correlate with greater amounts of formant deviance. A positive slope would be in line with my prediction: more paradigmatic support (greater NDL Cue Strengths) will correlate with phonetic enhancement (more deviance).

Similarly to the previous analysis of deviation from vowel onset, a Broad and Clermont (1987) context assimilation model would predict that formant deviance will decrease at an exponential rate (irrespective of Tense and NDL Cue Strengths), until the trajectory reaches an asymptote state, roughly half-way through the vowel duration (roughly at the 50% vowel time step).

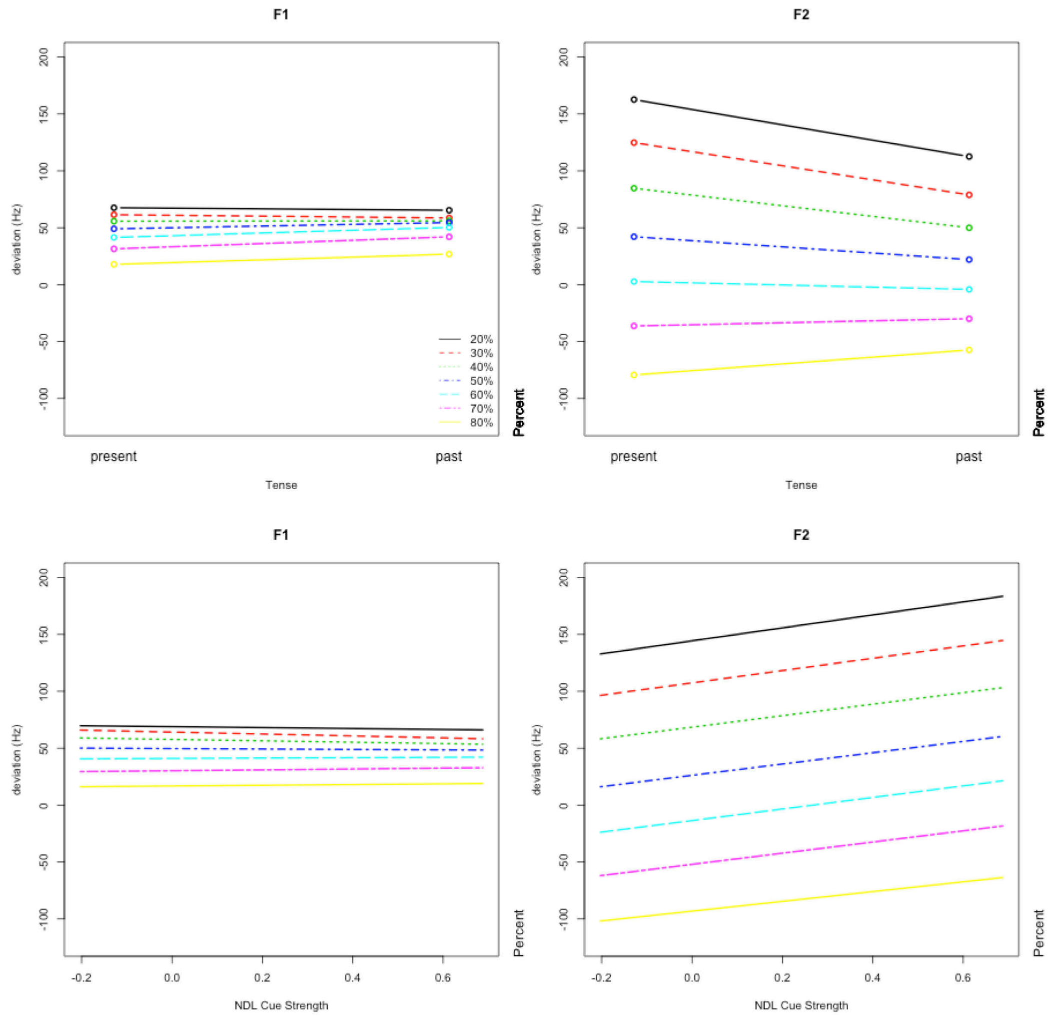

Figure 3.6: Partial effects of the LMER model results for the two predictors of interest: Tense is shown on the top row (for F1 and F2; reference level: present tense and 20% time step), and NDL Cue Strength is shown on the bottom row (for F1 and F2). The coloured lines show the interaction between Percent and the predictors (Tense and NDL cue strength).

Table 3.9: Deviance from offset LMER model coefficients for the two predictors of interest: Tense and NDL Cue Strength (reference level: present tense and 20% time step).

F1			
Predictor	Estimate	std Error	t value
(Intercept)	66.3801	25.7837	2.5745
Tense: past	8.9709	2.3693	3.7863
Percent: 70	-19.2364	9.5612	-2.0119
Percent: 60	-31.8003	9.5612	-3.3260
Percent: 50	-33.6481	9.5612	-3.5192
Percent: 40	-19.7632	9.5612	-2.0670
Percent: 30	7.5149	9.5612	0.7860
Percent: 20	43.2560	9.5612	4.5241
NDL Cue Strength	3.1865	5.4124	0.5887
Tense: past x Percent: 70	1.6025	2.7873	0.5749
Tense: past x Percent: 60	-0.1844	2.7873	-0.0662
Tense: past x Percent: 50	-3.5021	2.7873	-1.2565
Tense: past x Percent: 40	-8.6475	2.7873	-3.1025
Tense: past x Percent: 30	-11.8572	2.7873	-4.2540
Tense: past x Percent: 20	-11.2110	2.7873	-4.0222
Percent: 70 x NDL Cue Strength	0.6944	5.8511	0.1187
Percent: 60 x NDL Cue Strength	-1.5174	5.8511	-0.2593
Percent: 50 x NDL Cue Strength	-5.1803	5.8511	-0.8853
Percent: 40 x NDL Cue Strength	-9.4204	5.8511	-1.6100
Percent: 30 x NDL Cue Strength	-11.7397	5.8511	-2.0064
Percent: 20 x NDL Cue Strength	-7.3538	5.8511	-1.2568
F2			
Predictor	Estimate	std Error	t value
(Intercept)	-323.3378	53.9555	-5.9927
Tense: past	21.9640	5.6273	3.9031
Percent: 70	-9.3547	22.9678	-0.4073
Percent: 60	6.5882	22.9678	0.2868
Percent: 50	24.1125	22.9678	1.0498
Percent: 40	32.5551	22.9678	1.4174
Percent: 30	15.8201	22.9678	0.6888
Percent: 20	-34.0596	22.9678	-1.4829
NDL Cue Strength	42.9038	12.8821	3.3305
Tense: past x Percent: 70	-15.6407	6.6956	-2.3360
Tense: past x Percent: 60	-28.8128	6.6956	-4.3032
Tense: past x Percent: 50	-42.0690	6.6956	-6.2831
Tense: past x Percent: 40	-56.6778	6.6956	-8.4649
Tense: past x Percent: 30	-67.8654	6.6956	-10.1358
Tense: past x Percent: 20	-72.0284	6.6956	-10.7576
Percent: 70 x NDL Cue Strength	6.1474	14.0555	0.4374
Percent: 60 x NDL Cue Strength	7.8729	14.0555	0.5601
Percent: 50 x NDL Cue Strength	6.7728	14.0555	0.4819
Percent: 40 x NDL Cue Strength	7.5815	14.0555	0.5394
Percent: 30 x NDL Cue Strength	11.2217	14.0555	0.7984
Percent: 20 x NDL Cue Strength	14.0322	14.0555	0.9983

The general trend shown in Figure 3.6 and Table 3.9 is that, as the formants move farther in time, the correlation between offset deviance and both Tense and NDL Cue Strength increases, with both effects peaking (regressively) around 50-30% of the total vowel duration. These predictions are in line with a Broad and Clermont (1987) model of context assimilation.

3.3.3.3.1 Tense (linguistic parameter)

To interpret the effects of both Tense and NDL Cue Strength in the offset deviance models, it is important to first point out that the Percent time steps are discussed as they regress backwards. Rather than interpreting formant trajectories as they move forward through time, as with the dispersion and deviance from onset analyses, the deviance from offset analysis interprets the effects of the linguistic predictors as the formant trajectories regress in time, away from vowel offset (maximum time step). For this reason, the reference level in the offset deviance models is set to the 80% time step.

According to Table 3.9 for F1 offset deviance, the past tense was significantly different than the present tense (reference level) at the 40%-20% time steps. The effect of Tense on F1 deviation from vowel offset is similar to its effect on F1 deviation from vowel onset and can also be interpreted in terms of a Broad and Clermont context assimilation model: once the F1 trajectory reaches its 40%-20% asymptote state, the past tense correlates with slightly more deviation (seen in the slight rise of the slope in Figure 3.6). The size of this effect is less than with onset deviance (seen in slope comparisons), but the interpretation of the results is the same. The more morphologically uncertain past tense correlates with more F1 deviation compared to the present tense.

F2 deviance from vowel offset is significant in the past tense for all 70%-20% time steps compared to the present tense 80% reference level. Moreover, Table 3.9 shows that the strength of this effect gradually grows until the vowel reaches an asymptote state roughly around the 40% time step. The directions of Tense's effect on F2 deviance from vowel offset are the same as in F2 deviance from vowel onset. Prior to reaching the asymptote state around the 50%-40% time step, Figure 3.6 shows that the past tense correlates with more F2 deviance (upwards sloping lines for the 80%-70% time steps). Once the F2 trajectory approaches an asymptote state, however, the past tense correlates with less F2 deviance (downwards sloping lines for the 60%-20% time steps). Again, a Broad and Clermont context assimilation model could explain this split in the F2 deviance patterns. The effects of Tense on F2 deviance at the 80%-60% tail end of the vowel could be confounded with the exponential formant trajectories from the surrounding vowel environment. Coarticulation is strong here.

The results of the models are once again split for the predicted directions. My prediction for offset deviation is the same as it was for onset deviation: the more morphologically uncertain verb form (past tense) is expected to correlate with phonetic enhancement (more deviation). As with the analyses of vowel dispersion and formant deviation from onset, I find support for my prediction in the F1 dimension only: as the vowel reaches an asymptote state, the morphologically uncertain past tense correlates with more deviation. The opposite is true in the F2 dimension under a similar context assimilation explanation: as the vowel reaches an asymptote state, the morphologically uncertain past tense correlates with less deviation.

3.3.3.3.2 NDL Cue Strength (paradigmatic support)

However, there is less of an effect of NDL Cue Strength. NDL Cue Strength was significant for only F1 deviation, and only when comparing the 30% time step to the 80% reference level. Here, F1 displayed slightly less deviation from vowel offset as NDL Cue Strength increased.

Unlike with dispersion and deviation from vowel onset, there is not a strong global effect of NDL Cue Strength for deviation from vowel offset. For the single significant effect, the results of this model are in the predicted directions: more paradigmatic support correlates with greater amounts of vowel dispersion, or phonetic enhancement, overall.

3.3.3.4 Results by Vowel and by Time Percent

As with the analyses of dispersion and deviance from onset, 140 by vowel and by time percent models of formant deviance from vowel offset were computed to check for significant effects of Tense and NDL Cue Strength for each vowel. The same model structure for formant deviance from vowel offset was run over each of the 10 vowels at each of the 7 time percents for both formants (7 x 10 x 2 = 140 models). The models' calls are listed in the Appendix (Table A.10).

The results for by vowel offset deviation analysis are reported in the same way as the results from by vowel onset deviation analysis. Figure 3.7 illustrates averages of the raw vowel deviances from offset for each of the time steps between 20 and 80% of the total vowel durations, grouped by tense. Vowel label indicates the average offset of each vowel (maximum time step), line colour indicates morphological tense, and line direction and length indicates formant distance from vowel offset. The last panel of the figure illustrates average vowel deviation across all speakers and tenses with line colour indicating Percent time step. This plot illustrates that vowels deviate further from the vowel onset as they progress backwards through time.

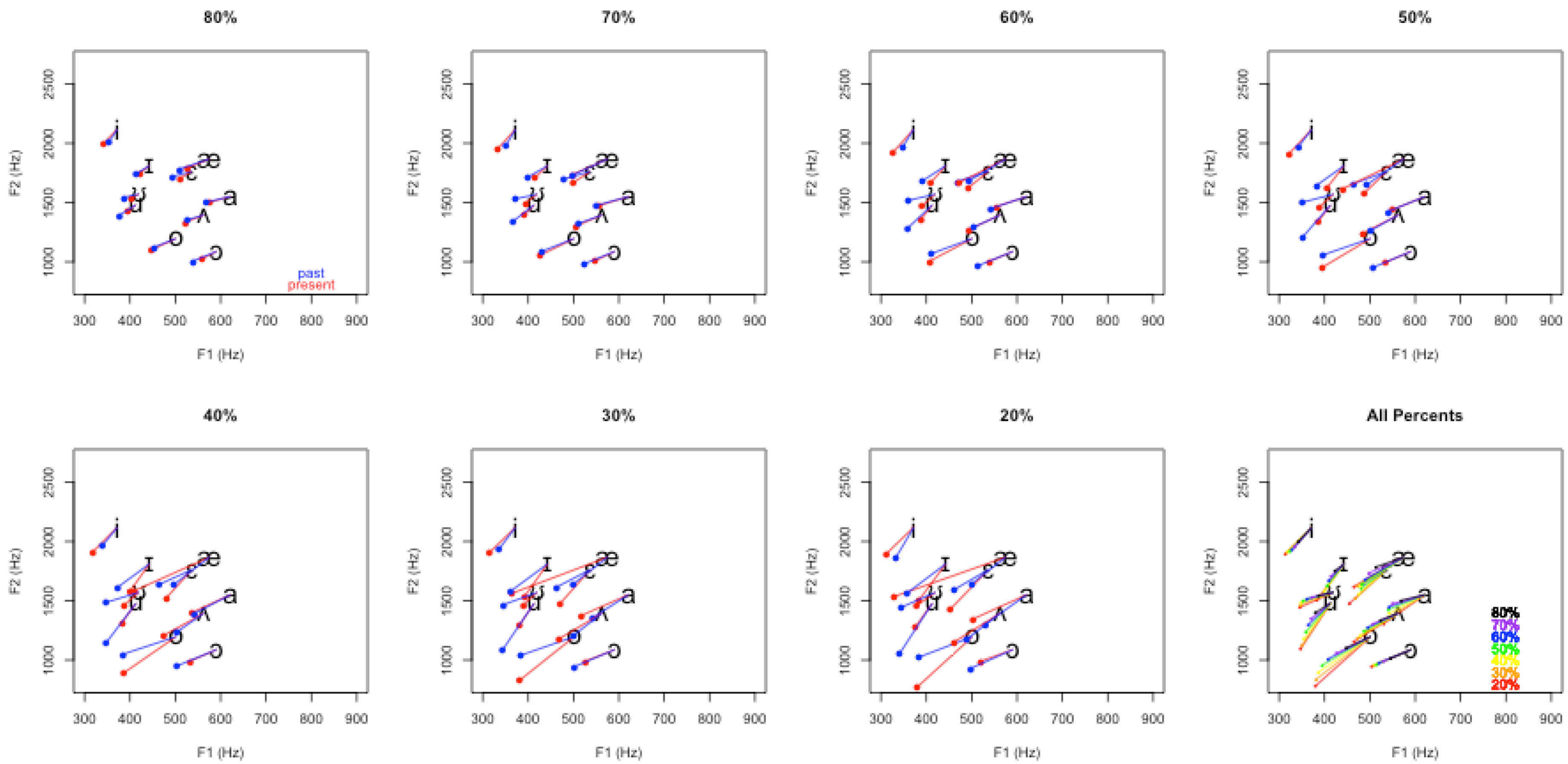

Figure 3.7: Raw averages across all speakers of the observed vowel deviations from the offset of the vowel, grouped by tense. Morphological tense is illustrated by line colour, and vowel offset is illustrated by vowel label.

The *t*-values for the LMER models of formant movement deviance from offset, by vowel, are given in Table 3.10 (all coefficients for each LMER model are provided in the Appendix Table A.16). The colour coding of the effects in Table 3.10 is the same as the previous analysis on formant deviation from vowel onset: green indicates a positive trend, yellow a negative trend, and black boldface significance. For Tense, a positive trend indicates that the past tense correlates with more deviation than the present tense reference level, while for NDL Cue Strength, a positive trend indicates that greater NDL cue strengths correlate with more deviation. The predicted directions are again that the past tense (more morphologically uncertain) and greater NDL cue strengths (stronger paradigmatic support) will correlate with more formant deviation from vowel offset (positive, green trends).

Table 3.10: *t*-values for the main effects of Tense (reference level: present tense) and NDL for each of the 140 individual LMER models of vowel offset deviance modelled on each Vowel Identity and Percent pair. Green shading indicates a positive trend. Yellow shading indicates a negative trend. Boldface (in black) indicates significance.

	Tense													
	F1							F2						
Vowel	80%	70%	60%	50%	40%	30%	20%	80%	70%	60%	50%	40%	30%	20%
i	0.3835	0.4880	0.3288	0.2339	0.1730	0.0654	-0.3092	-1.2874	-1.9562	**-2.3873**	**-2.3763**	-1.8746	-1.5098	-1.0902
ɪ	0.7149	1.4429	1.4934	1.8086	**2.0270**	**2.2280**	1.8827	0.3420	-0.3916	-0.6218	-1.0053	-1.1520	-1.0709	-1.2518
ɛ	-0.0347	-0.3410	-0.4499	-0.9808	-1.9978	**-3.2981**	**-4.0120**	-0.3488	-0.4528	-0.7894	-1.3058	-1.8390	**-2.6360**	**-3.3734**
æ	-1.1290	-1.3569	-1.1660	-0.9558	-1.3479	**-2.1305**	**-2.1226**	-1.4435	**-2.4256**	**-3.5326**	**-3.6620**	**-3.6581**	**-2.9751**	**-3.2009**
ʌ	-1.3226	-1.4103	-1.5173	-1.8260	-1.6688	-1.4971	-1.1131	-0.0780	-0.0556	0.0418	-0.3278	-0.3832	-0.5638	-0.7296
u	0.9214	1.2422	1.3097	1.3189	1.2771	1.2153	1.4035	0.6576	-0.0426	-0.6556	-0.1360	0.3022	0.2323	0.4254
ʊ	0.1407	0.4010	0.5030	0.1209	-0.2454	-0.0488	0.3040	0.0266	-0.0129	-0.4488	-0.0786	0.0427	0.5761	0.2980
o	**-2.2705**	**-2.5770**	**-2.1483**	-1.6303	-1.4894	-1.5878	-1.1308	0.9513	0.9493	0.7196	0.9827	1.2820	1.2999	0.9983
ɔ	-0.7027	-0.3501	-0.2720	-0.5811	-0.3226	-0.6326	-0.4741	0.1972	0.0505	0.8890	0.8573	0.6178	0.2240	0.0638
a	1.2449	**2.2001**	**2.1189**	1.6667	0.6472	-0.4713	-0.1057	1.0504	0.6985	1.0202	0.8613	0.5321	0.2981	0.4727
	NDL Cue Strength													
	F1							F2						
Vowel	80%	70%	60%	50%	40%	30%	20%	80%	70%	60%	50%	40%	30%	20%
i	0.5695	0.9157	0.9535	0.8172	0.8742	0.8227	0.8335	-0.9878	**-2.0628**	**-2.4771**	**-2.5275**	**-2.2339**	-1.9249	-1.2743
ɪ	-0.9567	-1.8487	-1.8293	-1.4789	-1.1133	-0.8927	-0.6583	0.9402	0.9016	0.7893	1.1547	0.8689	0.7935	0.6087
ɛ	-0.1280	-0.1309	-0.1655	0.1215	0.6133	1.2891	1.7536	-1.6320	**-2.1386**	**-2.0012**	-1.8040	-1.2861	-0.3297	0.4066
æ	0.7890	1.0737	0.8075	0.6193	0.8885	1.4110	0.9733	1.3989	1.9870	**2.4395**	**2.5254**	**2.6629**	**2.2653**	**2.5089**
ʌ	-0.0021	0.4238	0.5461	0.7919	0.6988	0.3828	0.0697	-0.0888	-0.1281	-0.3307	-0.3291	-0.5005	-0.3823	-0.1933
u	1.2738	1.0581	0.8993	0.8625	0.8823	0.7802	1.2641	1.0502	0.8622	0.9578	1.5974	**2.1121**	**2.1488**	**2.3983**
ʊ	-0.0435	-0.2691	-0.2161	0.3164	0.7029	0.4174	0.0178	-0.0753	-0.3249	0.1187	-0.1803	-0.2539	-0.7509	-0.4833
o	-0.9721	-1.0958	-0.8652	-0.3995	-0.3101	-0.4274	-0.5814	-0.7452	-1.0611	-0.6831	-0.1428	0.1027	-0.1557	-0.2310
ɔ	-0.1524	-0.5632	-0.5625	-0.7202	-0.9132	-1.2086	-1.0427	1.1934	**2.9041**	**3.0825**	**3.6654**	**3.8155**	**3.6849**	**3.3566**
a	0.1910	-0.2194	0.1752	0.4125	-0.0751	0.0695	-0.1270	-1.0880	-1.0816	-1.5117	-1.6209	-1.8739	-1.7601	**-2.0796**

3.3.3.4.1 Tense (linguistic parameter)

Tense is significant in 21 of the 140 LMER models (0.05 x 140 models = 7 models are expected to be significant by chance). As seen in Table 3.10, six of the ten vowels - /i/, /ɪ /, /ɛ /, /æ/, /o/, and /ɑ/ - display a significant difference in the variance of deviation from vowel offset when predicted by Tense (reference level: present). All six vowels show a significant effect of Tense for at least one formant and at least one time step. In the offset deviation plots (Figure 3.7), the differences in formant deviation between the past and present tense are visually present for these six vowels. Of all the models showing significant differences in deviation, 62% (13/21 models) are between the 50%-20% time steps, when the formant trajectory has reached an asymptote state of context assimilation (Broad and Clermont, 1987).

The direction of the correlation between Tense and deviance from vowel offset varies amongst the six vowels that had a significant correlation. Most of the significant effects seen on Table 3.10 (in yellow shading and black boldface) are in a negative direction, meaning the past tense is correlated with more vowel dispersion compared to the present tense. The results of these models are not in the predicted directions: the more uncertain past tense correlates with less formant deviation. However, the F1 of two vowels, /ɪ / and /ɑ/, are trending in a positive direction (in green shading and black boldface), meaning the past tense is correlated with more deviance from vowel offset compared to the present tense.

A count of the trends regardless of significance indicates that the F1 and F2 deviation models together are split between positive and negative trends (43%, or 61/140 models, are positive trending, green shading). This split in the positive and negative trends is present in both the F1 and F2 deviance models.

As with the global models, the by vowel analysis does not find strong support for my prediction. I predicted that the more morphologically uncertain verb form (past tense) would correlate with more vowel deviation. The significant trends and proportion of positive trends in by vowel formant deviation models do not support this prediction.

3.3.3.4.2 NDL Cue Strength (paradigmatic support)

NDL Cue Strength is significant in 21 of the 140 LMER models (0.05 x 140 models = 7 models are expected to be significant by chance). As seen in Table 3.10, six of the ten vowels - /i/, /ɛ /, /æ/, /u/, /ɔ /, and /ɑ/ - display a significant difference in the variance of deviation from vowel offset when predicted by NDL Cue Strength. All six vowels show a significant effect of NDL Cue Strength for F2 only and at least one time step, though none of the vowels show a significant effect for all of the time steps. Of all the models showing significant differences in deviation, 67% (14/21 models) are between the 50%-20% time steps, when the formant trajectory has reached an asymptote state of context assimilation (Broad and Clermont, 1987).

The direction of the correlation between Tense and deviance from vowel offset varies amongst the six vowels that had a significant correlation. Most of the significant effects seen on Table 3.10 (in green shading) are in a positive direction, meaning higher NDL Cue Strengths are correlated with more deviation than lower NDL Cue Strengths. The results of these models are in the predicted directions: more paradigmatic support correlates with greater amounts of deviation from vowel offset, or phonetic enhancement, overall. However, the F2 of three vowels, /i/, /ɛ / and /ɑ/, are trending in the negative directi on (in yellow shading), meaning higher NDL Cue Strengths are correlated with less deviation than lower NDL Cue Strengths.

Irrespective of significance (black boldface), the trends in Table 3.7 are evenly split with 50% (70/140 models) showing a positive trend (green shading). Considering both the significant effects and proportion of trending positive effects, the results for the by vowel models do not strongly support my prediction. I predicted that stronger NLD Cue Strengths would correlate with more formant deviation from vowel offset, but I do not find conclusive support for this directional prediction. This mirrors the results of the global models. Both the by vowel and global analyses do not find strong evidence for a directional prediction made on the modulation of formant deviance from vowel offset by NDL Cue Strength.

3.3.4 Non-linear Analysis of Overall Formant Movement

The fourth and final step in this series of analyses models the formant trajectories for each vowel non-linearly. In this analysis, the effects of Tense and NDL Cue Strength on the non-linear vowel formant trajectories were tested using Generalized Additive Modelling (GAM; Hastie & Tibshrani, 1998; Wood, 2006). That is, the current GAM models test the effects of Tense and NDL Cue Strength on the non-linear formant trajectories. GAMs have been used in various linguistic domains to analyze non-linear data, such as event-related potentials (Kryuchkova et al., 2012; Tremblay & Newman, 2015), eye tracking (Porretta, 2015; Van Rij et al., in press), and electromagnetic articulography (Tomaschek et al., 2013).

Applying the GAM technique allows one to test for differences in the dynamic formant trajectories across different conditions. Whereas linear models can test for differences in formant movement from onset to offset, they do not capture time-dependent non-linear movement between those two points.

3.3.4.1 GAM Statistical Procedure for Overall Formant Movement

In addition to accounting for factors of random variance for individual speakers (as in the pervious LMER analyses), the random effects structures in GAMs are clustered between groups, items, and speaker by including additional items in the random effects structure. Since the current data is gathered over ten vowels and forty speakers, clustering the formant data in the random effects structure is useful for ensuring a more accurate model fit. Analyses were computed in the R statistical environment using the *mgcv* (Wood, 2016) and *itsadug* (van Rij et al., 2015) packages for the GAM analysis.

Predictors in the GAM model are discussed in the next section, and the GAM call can be found in the Appendix (Table A.10). The GAM analysis proceeded in a stepwise fashion, similar to the LMER analyses (an backwards stepwise fitting of the model). Predictors and random effects structure were selected as with the LMER analyses (again, predictors' descriptions are given below). In order to select the most appropriate GAM, I visually inspected the residuals and estimates, as well as comparisons of the Maximum Likelihood (ML) scores (via the *itsadug* R package; van Rij et al., 2015). For ease of computation, F1 and F2 data were analyzed in separate models.

Since a formant measurement at any point after the onset of the vowel is dependent upon the formant's previous measurement (i.e., a vowel's F1 value at 30% of the vowel's total duration follows from its F1 value at 20%), it is necessary to include time-based autocorrelation within the model. The GAM model, then, is fitted with an autocorrelation parameter (*rho* ≈ 0.8) that is gathered from the first residual time lag using the *itsadug* R package (subsequent model comparisons and visualization of the residuals also confirm the *rho* value is the best-fit for the data). In addition to specifying the autocorrelation parameter, the GAMs are fitted such that each vowel token contains its own time sequence in the model (i.e., each 20%-80% chunk of the data for an individual vowel token was taken as its own unique time series). That is, instead of the model proceeding as if all of the data points belong to one long, continuous time series, the models proceed across 5,718 smaller time series - one for each vowel token.

3.3.4.2 Predictors

A summary for the predictors of the GAM analysis at hand is given in Table 3.11; predictors that have been changed or added to the previous model are highlighted in boldface. Tensor product smooths - te( ) and ti( ) - are used in GAMs to investigate the covariation of a predictor (such as NDL) and a continuous smooth term (such as Time). te( ) is used as a tensor product smooth when there is no main effect for the predictor (such as Vowel), whereas ti( ) is used when there is a main effect for the predictor (such as NDL).

Table 3.11: Predictors for main effects, interactions, and random effects in the General Additive Model analysis of NDL and Tense on vowel formant trajectories.

Predictor	Description	use in current analysis
Formant Frequency	**log transformed**	**dependent variable**
NDL Cue Strength	diphone Naive Discriminative Learning cue association strengths with the past tense, aggregated over the word	independent predictor of interest ti(Time) x NDL Cue Strength + fixed effect
Tense	morphological past or present tense	independent predictor of interest ti(Time) x Tense + fixed effect
Time	**normalized time steps**	s(Time) ti(Time) x NDL Cue Strength ti(Time) x Tense **random effect: s(Time) x Speaker x Vowel**
Vowel Identity	identity of the 10 vowels in the current data	te(Time) x Vowel + fixed effect **(Previous Voicing + Previous Place + Previous Manner) x Vowel** **Vowel x (Following Voicing + Following Place + Following Manner)** **random effect:** **s(Time) x Speaker x Vowel**
Previous Voicing	deviation coding for the voicing of the segment preceding the vowel	**(Previous Voicing + Previous Place + Previous Manner) x Vowel**
Previous Place	deviation coding for the place of the segment preceding the vowel	**(Previous Voicing + Previous Place + Previous Manner) x Vowel**
Previous Manner	deviation coding for the manner of the segment preceding the vowel	**(Previous Voicing + Previous Place + Previous Manner) x Vowel**
Following Voicing	deviation coding for the voicing of the segment following the vowel	**Vowel x (Following Voicing + Following Place + Following Manner)**
Following Place	deviation coding for the place of the segment following the vowel	**Vowel x (Following Voicing + Following Place + Following Manner)**
Following Manner	deviation coding for the manner of the segment following the vowel	**Vowel x (Following Voicing + Following Place + Following Manner)**
Vowel Duration	log transformed	te(Vowel Duration) x Frequency
Frequency	log value of the local Buckeye lexical frequency	te(Vowel Duration) x Frequency
Speaker	unique identifier of the speaker	**random effect: s(Time) x Speaker x Vowel**

The model contains the same two independent predictors of interest as the previous LMER models: Tense and NDL Cue Strength. Both of these predictors were included as fixed effects and in an interaction with Time. Recall that formant measurements were taken for each vowel every 2ms, yielding a continuous time step sequence. Unlike the previous LMER models where the time domain was limited to percents, the time domain in the GAM model included all time steps between 20 and 80% of each vowel's total time sequence.

Another difference between the structure of the predictors in the GAM model and the previous LMER models concerns the treatment of the surrounding phonetic environment. As discussed in the LMER analyses, there are three contributions to a vowel's formant trajectories: 1) the previous context (C_1V), 2) the vowel (V), and 3) the following context (VC_2). In the current model, six fixed effects were created to capture the two-way interactions between the Vowel and the Voicing, Place, and Manner of the phones surrounding the vowel (3 articulations x 2 contexts before/after = 6 interactions with the Vowel). An additional two-way interaction was created for Vowel x Time.

This method of modelling the surrounding phonetic environment is at odds with phonetic theory. The contributions of the C_1V and the VC_2 are time-dependent (Lindblom, 1963), with an exponential rate of decay (Broad and Clermont, 1987, 2014; Nearey, 2013). An ideal phonetic model would include the calculated trajectories of each C_1V, V, and VC_2. However, there is currently no systematic means of parsing out all three components from the formant contours of spontaneously produced speech.

The next best phonetic model would include the interactions of the (factorized) consonants with the (factorized) vowels as they progress through time (as in: C_1V x Time + V x Time + VC_2 x Time). There are two issues with this next best model. The first issue concerns the calculation of NDL cue strengths. Recall that the NDL cue strengths were calculated based on diphone cues (C_1V and VC_2) signalling the morphological tense outcomes. In this way, the surrounding phonetic context is inherently incorporated in the calculation of NDL cue strengths. An aggregate sum of the NDL diphone cue strengths serves as one of the dependent predictors of interest in the current analyses (i.e.: NDL Cue Strength x Time as a predictor of F1 and F2 movement). Adding in an interaction between Time, C_1V and VC_2 diphone pairs (C_1V x Time + VC_2 x Time), then, essentially produces factorial contrasts of the NDL cue strengths

The second issue concerns model convergence. The next best model failed to reach convergence, likely as a result of data sparsity. The nature of spontaneous speech data entails an uneven distribution of the phonetic context surrounding the vowel. This means that some levels of the (factorized) consonant articulations are underrepresented in the dataset as a whole, or are disproportionally amongst all vowels. Chapter 2 of this dissertation also highlights the sparse nature of the contextual data by giving an example of the phonetic context immediately following /æ/: 98% of the consonants following /æ/ are voiced (when the speaker is female, the proportion jumps to 100%). The sparsity of the phonetic context is also illustrated when comparing the distributions of the C_1V and VC_2 diphone pairs. There are 254 unique C_1V and 253 unique VC_2 diphone pairs in the Buckeye Corpus, compared to the 94 unique C_1V and 159 unique VC_2 diphone pairs in the subset of irregular verbs. Distributional plots of the surrounding phonetic context for the entire Buckeye Corpus and for the subset of the irregular verbs are given in the Appendix (Figure A.5, Figure A.6, and Figure A.9).

In an attempt to resolve this issue with the next best model, three statistical methods were employed to alleviate data sparsity: 1) modelling the articulation features (voice, place, manner) of the C_1 and C_2 separately, 2) reducing the number of factor levels for the place of articulation feature by grouping individual places of articulation together according to locus equations predictions (Lindblom, 1963), and 3) modelling data from robust vowels only (i.e. those vowels that are produced in the context of every place of articulation, as re-factorized in (2)). While methods (1) and (2) did alleviate some of the data scarcity issues, there was still enough sparsity in the data to result in non-convergence. Method (3) was the only method where the models converged, however this is a challenge for analysis comparison within the current Chapter. For this reason, Method 3 is not included in the current analysis, though it and Methods 1 and 2 are discussed further in the Appendix (Discussion A.3).

Because of the confounding issues with data scarcity and NDL cue strengths, the next best model of context assimilation (C_1V x Time + V x Time + VC_2 x Time) was further simplified by leaving time out the three-way interactions (i.e. leaving out the interaction with Time for the surrounding context: C_1V x + V x Time + VC_2). Doing so resolves the convergence issue and does not factorize NDL Cue Strengths. This is not an ideal phonetic model as it does not include the informative interaction of time with the surrounding phonetic context (i.e. dynamic contours) and instead models the assimilation to the surrounding phonetic context statically (i.e. shifting the formant contours up and down as a whole, instead of up and down dynamically through time). Phonetic research on modelling formant contours is clear about the dynamic nature of context assimilation, however the current model is a balance between attempting to control for the surrounding phonetic environment, and the abilities of the GAM technique. Though adding these fixed-effect interactions do not fully control for the vowels' environment assimilation, they are a step towards mitigating the effects of the environment (the Discussion section returns to this point).

The remaining predictors in the model carried over from the previous model: Frequency and Vowel Duration are included in a tensor interaction and in the random effects structure as random slopes by speaker. As discussed in the previous analysis of vowel dispersion, Tucker et al. (in preparation) found that the duration of the same set of irregular English vowels is mitigated by word frequency, with random effects (individual differences) for speakers. I include their findings in the model here.

The random effect structure included an interaction between Speaker, Time, and Vowel Identity. This structure accounts for the speaker variation in the dynamic production of vowels.

3.3.4.3 Results with All Vowels Combined (global)

The partial effects of NDL Cue Strength across Time are illustrated in Figure 3.8. Time (normalized in time steps) is plotted on the x-axis. NDL Cue Strength is plotted on the y-axis. High NDL Cue Strengths correspond to the top portion of the plots while low NDL Cue Strengths correspond to the bottom portion of the plots. Formant values are plotted on the z-axis (in colours). The formant value z-axis is read like a topographic map where more warm colours (in the progression of: yellow, orange, white) correspond to higher F1/F2 values and more cool colours (in the progression of: green, aqua, blue) correspond to lower F1/F2 values. A change in colour from blue-green-yellow indicates a positive slope upwards in the formant value. An example of this is seen in the bottom of the F2 plot over the 0-250 time steps. A change in colour from yellow-green-blue indicates a negative slope downwards in the formant value. An example of this is seen in the bottom of the F1 plot over the 0-50 time steps. Contour lines illustrate deviations in colour/direction, labelled for direction (positive or negative) and effect size.

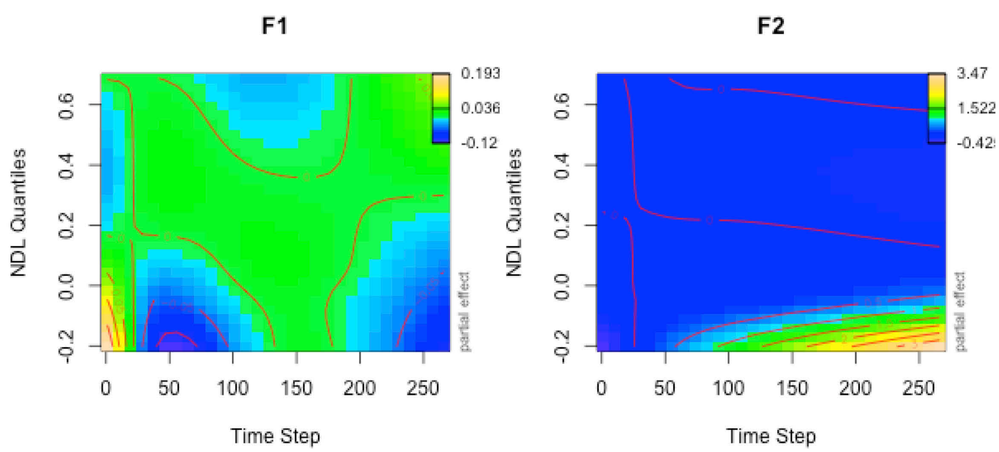

Figure 3.8: F1 and F2 GAM models' partial effects of NDL Cue Strength through Time. Time is shown on the x-axis. NDL Cue Strength is shown on the y-axis. Formant value is shown on the z-axis (in colours).

The results of interest for the current GAM analysis are illustrated in Table 3.12. The Appendix (Table A.10) contains the model calls as well as the full listing of parametric coefficients and smooth terms for the current models (Table A.17).

Table 3.12: Smooth terms of interest from the F1 and F2 GAM models on the effect of Tense and NDL Cue Strength on overall formant values across all vowels.

F1				
Predictor	*edf*	Ref.edf	*F*	*p*
ti(Time Step) x Tense: past	1.3796	1.9124	3.8190	0.0241
ti(Time Step) x Tense: present	1.0158	1.0214	1.4789	0.2232
ti(Time Step,NDL Cue Strength)	7.8264	9.0248	41.1962	< 0.0001
F2				
Predictor	*edf*	Ref.edf	*F*	*p*
ti(Time Step) x Tense: past	1.0040	1.0050	0.5010	0.4796
ti(Time Step) x Tense: present	2.1664	2.4716	8.7526	0.0001
ti(Time Step) x NDL Cue Strength	11.2998	12.4096	58.9209	< 0.0001

Note that the results of these models are to be interpreted cautiously. As discussed in the above section, the statistical method employed here models the interaction between the vowels and the surrounding context as fixed, or static effects, rather than more phonetically valid dynamic effects. This point is of importance when interpreting the magnitude and direction of movement of F2, in particular, as the place of the surrounding context's articulations greatly affects F2 movement (and especially so for reduced speech; Lindblom, 1963). This point is returned in the discussion of the results pertaining to NDL Cue Strength.

3.3.4.3.1 Tense (linguistic parameter)

The GAM technique does not readily allow for interpretations of significant differences within a group of items for a bi-factorial predictor like Tense. Instead, the model tests for significant movement for both morphological tenses. That is, the models tests whether the movement within the F1 or F2 trajectories in both the past and present tense is significantly different than zero (i.e., different than no movement). According to Table 3.12, F1 in the past tense and F2 in the present tense display movement that is significantly different than zero (no movement). This indicates that there is a weak overall effect of Tense on formant movement.

3.3.4.3.2 NDL Cue Strength (paradigmatic support)

Unlike Tense, NDL Cue Strength does strongly and significantly affect overall formant movement for both F1 and F2, as illustrated in Figure 3.8 and Table 3.12. Note that formant movement here refers to an overall, global amount of movement over and above the individual VISC-like patterns (i.e. those discussed in Chapter 2 of this dissertation) and context assimilation trajectories for each vowel.

For F1, vowels associated with low NDL Cue Strengths start off with comparatively high formant values and have sharp formant slopes over time that dip down, rise, and dip down again. Vowels with high NDL Cue Strengths, however, start with lower formant values that decrease and increase in movement more gradually, without decreasing at the end of the vowel duration. For F1, the initial formant values and formant slopes pattern differently according to a vowel's NDL Cue Strength. Formant movement for vowels with high NDL Cue Strengths is different than for vowels with low NDL Cue Strengths.

For F2, however, dynamic formant movement is only seen for vowels with low NDL Cue Strengths. The pattern of formant slopes for low NDL Cue Strengths is the different for F2 than for F1: F2 values start low, instead of high, and steadily rise throughout the vowel's duration, instead of rising and falling (as seen in F1 patterns).

Here, the issue of representing the dynamic effects of the surrounding phonetic environment is important. It is expected that the F2 show dynamic movement, regardless of direction and NDL Cue Strength (see Chapter 2 of the current dissertation). However, Figure 3.8 shows, unexpectedly, little movement overall. This unexpected lack of formant movement is likely to be attributed to the effects of the surrounding phonetic environment (as with the dispersion analysis, previously). The current model does not capture the dynamic effects the place of the surrounding environment has on these formant trajectories. Thus, it is likely that coarticulation is masking any effect of NDL. This coarticulation masking was predicted by Strange and colleagues (1983, 2013).

Coarticulation issues aside, the overall trend in Figure 3.8 is that greater NDL Cue Strengths correlate with less formant movement. Greater formant movement is seen at the bottom edges of the plots, at levels of low NDL Cue Strength. This direction does not support my prediction. Whereas I predicted that greater NDL Cue Strengths would correlate with more formant movement (§3.1.4), I find the opposite effect here.

3.3.4.4 Results by Vowel

As with the LMER analyses, two additional models of formant movement were computed to check for significant effects of Tense and NDL Cue Strength for each vowel. The basic GAM model structure for formant movement was run over both formants (2 models); however, both NDL Cue Strength and Tense were placed in a three-way smooth interaction with Time and Vowel Identity to investigate the effects of the predictors by vowel. The models' calls are listed in the Appendix (Table A.10).

Figure 3.9 illustrates averages of the raw formant trajectories for each vowel in the past and present tense. Here the difference between vowels' trajectories in the past versus present tense is shown by line type (solid line indicates present, dotted line indicates past).

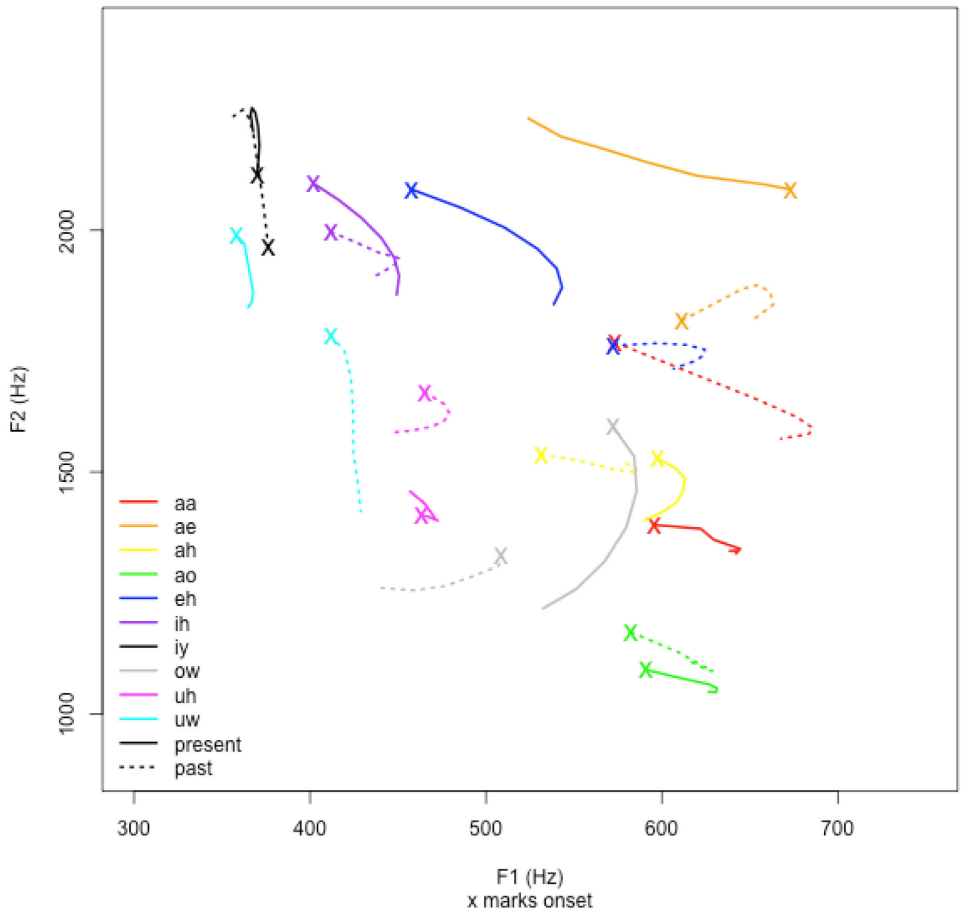

Figure 3.9: Averages of the observed formant trajectories across all speakers; 'x' marks the onset of the trajectory. Morphological tense (past or present) is illustrated by a solid or dashed line, respectively. Vowel identity is illustrated by line colour.

Figure 3.10a illustrates the GAM models' partial effects of the NDL Cue Strength for the F1 of each vowel, and Figure 3.10b illustrates the same for the F2 of each vowel. These figures are read like a topographic map where more warm colours (in the progression of: yellow, orange, white) correspond to higher values and more cool colours (in the progression of: green, aqua, blue) correspond to lower values.

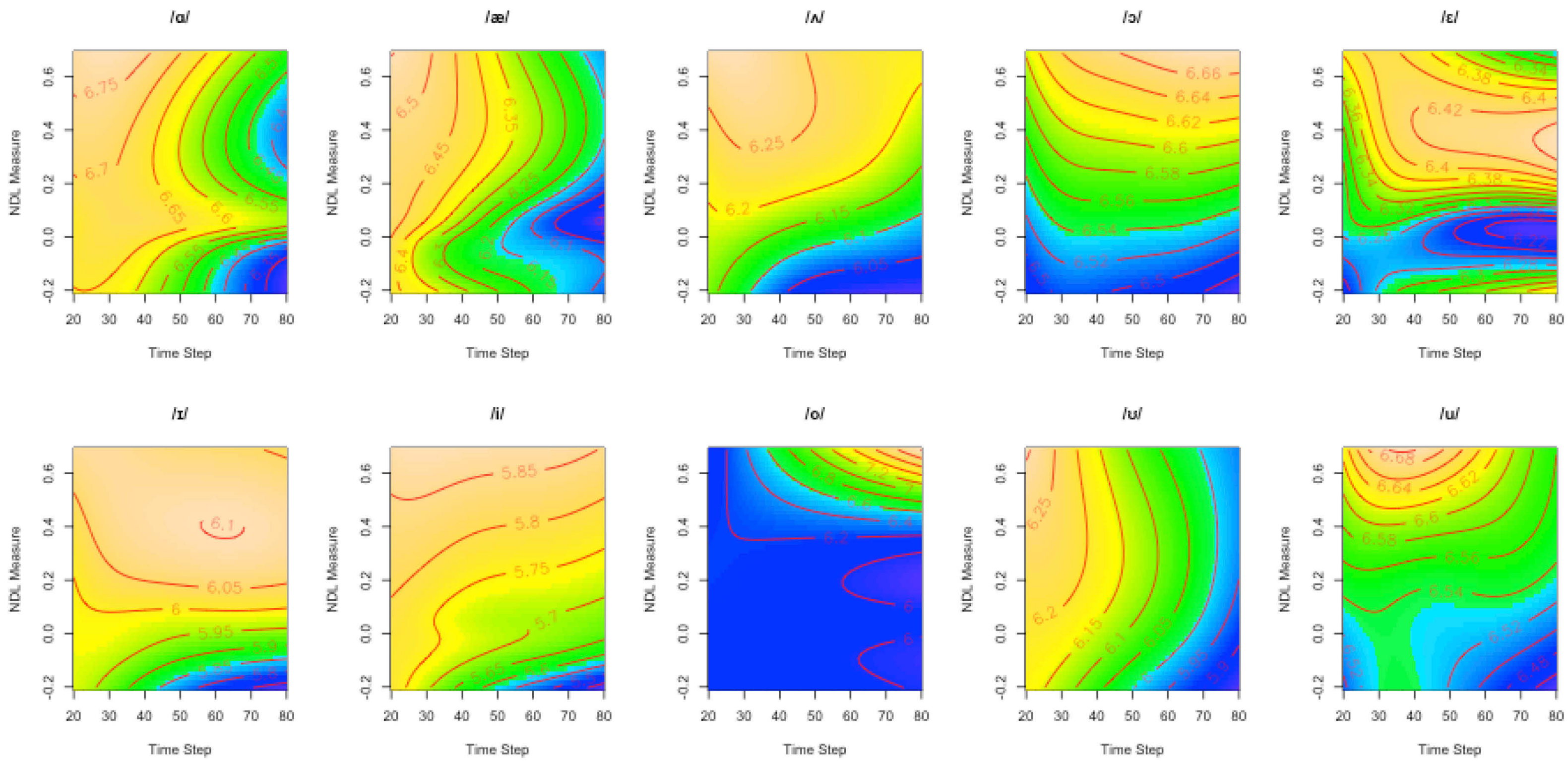

Figure 3.10a: F1 GAM model partial effects of NDL Cue Strength paired with Time for each vowel. Percent of vowel duration is shown on the x-axis. NDL Cue Strength is shown on the y-axis. F1 Measure (in Hertz) is shown on the z-axis (in colours). Effects for /ɔ / and /ʊ/ are not significant. All other effects shown are significant.

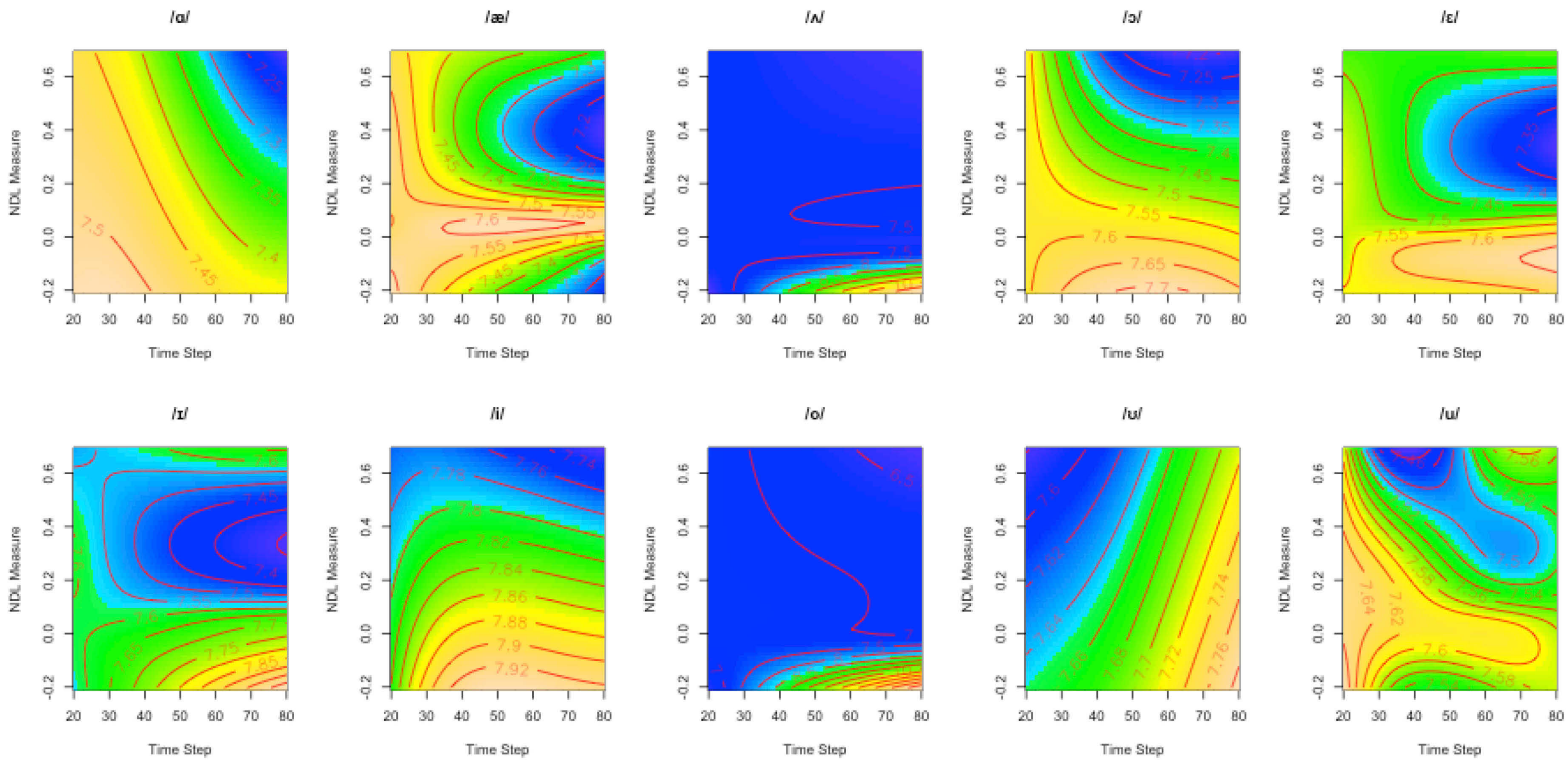

Figure 3.10b: F2 GAM model partial effects of NDL Cue Strength paired with Time for each vowel. Percent of vowel duration is shown on the x-axis. NDL Cue Strength is shown on the y-axis. F1 Measure (in Hertz) is shown on the z-axis (in colours). Effects for /ʊ/ are not significant. All other effects shown are significant.

Table 3.13 gives the smooth terms by vowel for Tense and NDL Cue Strength. The Appendix contains the full listing of parametric coefficients and smoothness terms (Table A.18).

Table 3.13: Coefficients for the approximate significance of smoothness terms of interest in the F1 and F2 GAM models of formant trajectories.

F1				
Predictor	*edf*	Ref.edf	*F*	*p*
ti(Time Step) x interaction(Tense, Vowel) past : a	1.0002	1.0002	17.5761	< 0.0001
ti(Time Step) x interaction(Tense, Vowel) present : a	0.0000	0.0001	0.0287	0.9987
ti(Time Step) x interaction(Tense, Vowel) past : æ	0.0002	0.0003	0.0088	0.9988
ti(Time Step) x interaction(Tense, Vowel) present : æ	1.0000	1.0000	16.7389	< 0.0001
ti(Time Step) x interaction(Tense, Vowel) past : ʌ	1.0001	1.0001	21.5859	< 0.0001
ti(Time Step) x interaction(Tense, Vowel) present : ʌ	0.0000	0.0001	0.3941	0.9953
ti(Time Step) x interaction(Tense, Vowel) past : ɔ	0.0000	0.0001	0.4390	0.9956
ti(Time Step) x interaction(Tense, Vowel) present : ɔ	1.0000	1.0001	0.0023	0.9618
ti(Time Step) x interaction(Tense, Vowel) past : ɛ	1.0001	1.0001	2.9852	0.0840
ti(Time Step) x interaction(Tense, Vowel) present : ɛ	0.0001	0.0001	0.0595	0.9981
ti(Time Step) x interaction(Tense, Vowel) past : ɪ	1.0000	1.0000	10.0147	0.0016
ti(Time Step) x interaction(Tense, Vowel) present : ɪ	1.0002	1.0004	14.6597	0.0001
ti(Time Step) x interaction(Tense, Vowel) past : i	1.0001	1.0001	11.4516	0.0007
ti(Time Step) x interaction(Tense, Vowel) present : i	1.0000	1.0000	12.3661	0.0004
ti(Time Step) x interaction(Tense, Vowel) past : o	0.0002	0.0004	0.4475	0.9900
ti(Time Step) x interaction(Tense, Vowel) present : o	1.0003	1.0005	15.9000	0.0001
ti(Time Step) x interaction(Tense, Vowel) past : ʊ	1.0000	1.0001	1.3605	0.2435
ti(Time Step) x interaction(Tense, Vowel) present : ʊ	1.0000	1.0000	0.1058	0.7450
ti(Time Step) x interaction(Tense, Vowel) past : u	0.0001	0.0001	0.1686	0.9960
ti(Time Step) x interaction(Tense, Vowel) present : u	1.0008	1.0014	0.0477	0.8275
ti(Time Step) x NDL Cue Strength x a	5.0660	6.2648	2.4533	0.0210
ti(Time Step) x NDL Cue Strength x æ	4.6062	5.8020	4.8858	0.0001
ti(Time Step) x NDL Cue Strength x ʌ	7.8282	9.1501	23.7997	< 0.0001
ti(Time Step) x NDL Cue Strength x ɔ	1.0005	1.0010	0.2531	0.6152
ti(Time Step) x NDL Cue Strength x ɛ	5.9641	7.3657	9.5380	< 0.0001
ti(Time Step) x NDL Cue Strength x ɪ	4.5025	5.5366	15.7206	< 0.0001
ti(Time Step) x NDL Cue Strength x i	5.0402	6.6642	5.2974	< 0.0001
ti(Time Step) x NDL Cue Strength x o	6.2244	7.6443	5.8289	< 0.0001
ti(Time Step) x NDL Cue Strength x ʊ	0.3423	8.0000	0.1180	0.0686
ti(Time Step) x NDL Cue Strength x u	1.7787	12.0000	0.3954	0.0319
F2				
Predictor	*edf*	Ref.edf	*F*	*p*
ti(Time Step) x interaction(Tense, Vowel) past : a	3.2410	3.5753	3.3461	0.0132
ti(Time Step) x interaction(Tense, Vowel) present : a	0.7938	1.0814	1.0275	0.3109
ti(Time Step) x interaction(Tense, Vowel) past : æ	0.0001	0.0001	0.0955	0.9971
ti(Time Step) x interaction(Tense, Vowel) present : æ	1.0000	1.0000	9.3759	0.0022
ti(Time Step) x interaction(Tense, Vowel) past : ʌ	1.0001	1.0001	79.9313	< 0.0001
ti(Time Step) x interaction(Tense, Vowel) present : ʌ	0.0002	0.0003	0.1426	0.9948
ti(Time Step) x interaction(Tense, Vowel) past : ɔ	0.0004	0.0007	0.0248	0.9967
ti(Time Step) x interaction(Tense, Vowel) present : ɔ	1.0000	1.0001	5.6575	0.0174
ti(Time Step) x interaction(Tense, Vowel) past : ɛ	1.0001	1.0001	21.9894	< 0.0001
ti(Time Step) x interaction(Tense, Vowel) present : ɛ	0.0001	0.0002	0.0023	0.9995
ti(Time Step) x interaction(Tense, Vowel) past : ɪ	2.8611	3.0021	6.3655	0.0003
ti(Time Step) x interaction(Tense, Vowel) present : ɪ	1.0002	1.0003	0.6001	0.4385
ti(Time Step) x interaction(Tense, Vowel) past : i	1.0001	1.0001	0.7349	0.3913
ti(Time Step) x interaction(Tense, Vowel) present : i	1.0001	1.0001	0.6150	0.4329
ti(Time Step) x interaction(Tense, Vowel) past : o	1.0020	1.0037	0.1485	0.7010
ti(Time Step) x interaction(Tense, Vowel) present : o	1.0014	1.0023	0.0387	0.8446
ti(Time Step) x interaction(Tense, Vowel) past : ʊ	1.0002	1.0003	0.6506	0.4199
ti(Time Step) x interaction(Tense, Vowel) present : ʊ	1.0000	1.0001	2.8852	0.0894
ti(Time Step) x interaction(Tense, Vowel) past : u	2.0246	2.4423	9.0563	< 0.0001
ti(Time Step) x interaction(Tense, Vowel) present : u	1.0001	1.0002	12.2674	0.0005
ti(Time Step) x NDL Cue Strength x a	2.6386	3.4558	4.2515	0.0036
ti(Time Step) x NDL Cue Strength x æ	7.8079	8.8917	12.5061	< 0.0001
ti(Time Step) x NDL Cue Strength x ʌ	6.6042	7.8754	55.6524	< 0.0001
ti(Time Step) x NDL Cue Strength x ɔ	5.0540	6.5404	6.0971	< 0.0001
ti(Time Step) x NDL Cue Strength x ɛ	7.0087	8.4898	44.9558	< 0.0001
ti(Time Step) x NDL Cue Strength x ɪ	6.1318	7.4266	65.7360	< 0.0001
ti(Time Step) x NDL Cue Strength x i	5.7286	6.9988	11.4980	< 0.0001
ti(Time Step) x NDL Cue Strength x o	10.5544	11.4824	24.5982	< 0.0001
ti(Time Step) x NDL Cue Strength x ʊ	0.0008	8.0000	0.0000	0.7873
ti(Time Step) x NDL Cue Strength x u	3.2701	12.0000	2.5342	< 0.0001

As with the previous global analysis, the following results are to be interpreted cautiously due to a lack of proper phonetic modelling of context assimilation.

3.3.4.4.1 Tense (linguistic parameter)

Figure 3.9 illustrates the formant trajectory patterns of the raw F1+F2 data. As stated above, the GAM technique does not readily allow for interpretations of significant differences within a group of items for a bi-factorial predictor like Tense. Instead, Table 3.13 gives the estimates of the significance in the movement of the F1 and F2 formant trajectory curves for both morphological tenses (i.e. significant movement compared to zero, or no movement).

The current model, separated by vowel and formant, found significant effects of Tense. For F1, movement in the past tense was found to be significant for /ɑ/, /ʌ/, /ɪ/, and /i/ while movement was significant in the present tense for /æ/, /ɪ/, /i/, and /o/. This means that both /ɪ/ and /i/ displayed significant F1 movement in both the past and present tense. For F2, movement in the past tense was found to be significant for /ɑ/, /ʌ/, /ɛ/, /ɪ/, and /u/, while movement was significant in the present tense for /ɔ/ and /u/. This means that /u/ displayed significant F2 movement in the past and present tense.

/ɑ/, /ʌ/, and /ɪ/ displayed significant movement in the past tense for both the F1 and F2 dimensions, though no vowel displayed significant movement in the present tense for both the F1 and F2 dimensions. This means that no vowel displayed significant movement in both the past and present tense for both the F1 and F2 dimensions.

The results indicate that Tense is a significant predictor of formant movement, with six of the ten vowels showing significant movement when predicted by Tense in the F1 dimension, and another six vowels showing the same in the F2 dimension.

3.3.4.4.2 NDL Cue Strength (paradigmatic support)

The GAM analyses' predictions for the NDL Cue Strength are illustrated in Figure 3.10 with the estimates for the smoothness terms given in Table 3.13. Nine vowels patterned with NDL Cue Strength in at least one formant dimension (/ʊ/ did not show any significance in formant movement). Of all the vowels for both the first and second formant, only the F1 of /ɔ / and /ʊ/ and F2 of /ʊ/ did not show a significant effect for the paradigmatic NDL measure. For all the other eight vowels, there is a significant positive effect of NDL Cue Strength on each vowels' overall trajectory movement in both formant dimensions.

However, as Figure 3.10 illustrates, the pattern of effect NDL Cue Strength has on each vowels' formants is not uniform. For example, the F1 of /o/ begins with lower F1 values that sharply increase at higher NDL Cue Strengths compared to no visible change in formant movement at lower NDL Cue Strengths. The F1 of /ɑ/, however, shows an opposite effect, where the vowel begins high and more sharply decreases at lower NDL Cue Strengths compared to higher NDL Cue Strengths. For comparisons in the F2 dimension, the formant values of /ɪ/ are higher for lower NDL Cue Strengths compared to higher NDL Cue Strengths with formant trajectories gradually increasing across all NDL Cue Strengths. However, the F2 trajectories of /æ/ begin high regardless of NDL Cue strength, and more sharply decrease at low and mid-high NDL Cue Strengths compared to high and mid-low NDL Cue Strengths.

Again, there is an issue of coarticulation and patterns of F2 movement. According to Figure 3.10b, there is relatively little F2 movement for three of the ten vowels - /ʌ /, /o/, and /i/ - compared to the remaining seven vowels. This lack of F2 movement is reminiscent of the previous global model. Once again, it is likely that coarticulation is too strong to discern any noticeable movement.

Overall, baring issues of coarticulation, the general trends are that greater NDL Cue Strengths correlate with higher formant values and less movement in the F1 dimension, and lower formant values and less movement in the F2 dimension, though the formant movement patterns are not consistent amongst all the vowels. These results mirror that of the global analysis. I predicted that greater

NDL Cue Strengths would correlate with more formant movement, and the data do not wholly support my prediction. Though some patterns of movement do support my prediction (such as the F1 of /o/), I do not find uniform support for this directional hypothesis across all vowels and formants.

3.4 Overall Results

My predictions were that the more morphologically uncertain tense (past tense) and greater amounts of paradigmatic support (stronger NDL cue strengths) will correlate with more vowel enhancement (more formant dispersion, deviance, and movement). Table 3.14 gives a summary of the results from all four analyses conducted in this chapter in regards to the predictions made. The main finding is that both Tense and NDL Cue Strength modulate the production of formant frequencies, though their effects vary with vowel and formant. In all of the global analyses that tested for a directional effect of tense (the GAM analysis does not allow for testing a direction effect of tense), I found support for my prediction in the F1 dimension only. Moreover, I found support for my NDL Cue Strength prediction in two of the four global analyses (the offset deviation analysis did not show a strong effect for NDL Cue Strength at all, and the formant movement analysis did not support my prediction).

In the by vowel analyses, I found support for my directional prediction about Tense in the onset deviation analysis only (the dispersion analysis did not show a strong directional effect for Tense either way, and the offset deviance analysis did not support my prediction). The GAM analysis did not allow for testing the directional Tense prediction, but it did find support for an interaction between Tense and formant movement. I also find support for my NDL Cue Strength prediction in three of the four by vowel analyses (again, the analysis of offset deviation did not show a strong effect for NDL Cue Strength), though support is weak in the dispersion and formant movement analyses.

Table 3.14: Summary of results from the four analyses in the current chapter.

Tense		
	global analysis	**by vowel analysis**
LMER vowel dispersion	support for the prediction from F1 model but not from F2 model	lack of support for the prediction due to the directional variation of the effect
LMER onset deviance	support for the prediction from F1 model but not from F2 model	support for the prediction from F1 trend but not from F2 trends or the significant effects
LMER offset deviance	support for the prediction from F1 model but not from F2 model	no support for the prediction seen in the significant effects and the proportional trends
GAM formant movement	a test of the directional prediction is not suppored by the GAM technique; however there is an effect of Tense on the presence of formant movement	a test of the directional prediction is not suppored by the GAM technique; however there is an effect of Tense on the presence of formant movement
NDL Cue Strength		
	global analysis	**by vowel analysis**
LMER vowel dispersion	support for the prediction from F1 model but not from F2 model	weak support for the prediction due to the directional variation of the effect
LMER onset deviance	support for the prediction from both F1 and F2 models	support for the prediction from both F1 and F2 models
LMER offset deviance	no strong effect of NDL in the models	no support for the prediction seen in the significant effects and the proportional trends
GAM formant movement	no support for the prediction as seen in the topographic plots	no support for the prediction seen in the overall F1 and F2 trends, though some individual vowel patterns support the prediction

The advantage of the by vowel models are seen in those analyses where the results greatly differ between the global and by vowel models. This includes the dispersion and formant movement analyses. In the dispersion analysis, the contribution of the surrounding phonetic environment was made apparent in the by vowel models. Whereas the global model of pooled vowel data glosses over the effects of the surrounding phonetic context (which resulted in strong model predictions), the by vowel analyses illustrate how the surrounding phonetic context affects different vowels differently. Thus the once strong global effects are weakened in the by vowel analyses.

The opposite is seen for NDL Cue Strength in the formant movement analyses. The global models of formant movement find evidence for effects of NDL Cue Strength in the opposite predicted direction. The by vowel models find that while the greater proportion trends are also in the opposite predicted direction, they are not true of every vowel. More vowels do exhibit formant movement in the opposite predicted direction (which could possibly contribute to the global models' results), but some vowels instead exhibit formant movement in the predicted direction. More support for the by vowel models of formant movement comes from model comparison (using the compareML function from the *itsadug* R package; van Rij et al., 2015). A comparison of the model scores favours the by vowel models in both the F1 and F2 dimensions (by an ML score difference of 101.79 for F1 and 904 for F2). Thus, allowing the effects of Tense and NDL Cue Strength to vary by model results in better model fits for the formant data.

3.5 Discussion

The current study investigates the influence of morphological tense and paradigm on acoustic variation in irregular English vowels. Specifically, I measured the effects of the morphologically uncertain verb form (past tense) and NDL cue-to-tense activation levels on F1 and F2 vowel dispersion, F1 and F2 deviance from vowel onset and offset, and amount of F1 and F2 formant trajectory movement. My analyses show that, while there is an overall effect of morphological tense and NDL cue-to-tense activation levels on the production of acoustic detail, these effects are split in both the significance of their influence, and the direction and magnitude of their influence.

I used morphological tense and NDL cue-to-tense activation levels to test two hypotheses: the Smooth Signal Redundancy Hypothesis (Aylett and Turk, 2004, 2006) and the Paradigmatic Signal Enhancement Hypothesis (Kuperman et al., 2007). The Smooth Signal Redundancy Hypothesis predicts that for any linguistic property and an acoustic detail, there will be a consistent relationship that reduces redundancy in the signal. Less redundancy, or uncertainty, in the linguistic properties or acoustic detail of the signal is advantageous: it facilitates either speaker production or listener processing. Thus, this hypothesis would not be supported if there is double redundancy: linguistically uncertain forms and acoustic reduction.

Support for this hypothesis is split between the analyses in this chapter. The Smooth Signal Redundancy Hypothesis would predict that the more morphologically uncertain verb form, the past tense form (Bybee and Slobin, 1982), would be produced with more enhanced dispersion and formant deviations compared to the present tense. Though this directional prediction is not testable under the analysis of formant movement, I do find support for this prediction in all the global analyses of formant dispersion and deviation, as well in the by vowel analyses of formant deviation from onset. However, I find support for the opposite effect in the by vowel analysis of formant deviation from vowel offset: the past tense (linguistically uncertain form) correlates with less dispersion and formant deviations compared to the present tense (comparatively more acoustic reduction), resulting in double redundancy. There is lack of support for either predictive direction of morphological tense in the by vowel analysis of formant dispersion. This is explained in the Results section in terms of context assimilation, with more discussion given below.

There are several possible explanations for not finding support for the Smooth Signal Redundancy Hypothesis. One simple explanation is that this hypothesis was not intended to be applied to bivariate linguistic properties. As stated in the Introduction to this chapter, the hypothesis was originally proposed for scalar linguistic properties, such as word frequency, where there is a clear uncertainty continuum. Applying the hypothesis to morphology assumes that discrete morphological properties can be quantified for uncertainty in a way that mimics scalar properties. Furthermore, the uncertainty of morphology hinges on the theoretical assumption that the past tense is the marked, or more uncertain, verb form. It is worthwhile to apply the Smooth Signal Redundancy Hypothesis to more scalar measures of morphological uncertainty, such as the proportional frequency of the past and present tense verb forms.

The Paradigmatic Signal Enhancement Hypothesis is similar in its predictions about acoustic variation. This hypothesis holds that more paradigmatic support correlates with phonetic enhancement. For the current data, this hypothesis would predict more vowel dispersion, deviation from onset/offset, and formant movement for higher NDL cue-to-tense activation levels.

Overall, the current chapter finds support for the Paradigmatic Signal Enhancement Hypothesis. Vowels with strong NDL cue-to-tense activation strengths (strong paradigmatic support) are produced with enhanced acoustic details (seen in formant dispersion and deviation from vowel onset; formant deviation from vowel offset analyses did not find an effect of NDL cue-to-tense activation strength as a whole), supporting the predictions of the Paradigmatic Signal Enhancement Hypothesis. The formant movement analyses are split on their support of the Paradigmatic Signal Enhancement Hypothesis. While the global effect of formant movement does not support the Paradigmatic Signal Enhancement Hypothesis, some individual vowel patterns do (as discussed previously in more detail).

As discussed in the Introduction, the Smooth Signal Reduction Hypothesis and the Paradigmatic Signal Enhancement Hypothesis are seemingly at odds with one another. The Paradigmatic Signal Enhancement Hypothesis holds that effects of the paradigm supersede effects of linguistic predictors (i.e. effects predicted by the Smooth Signal Reduction Hypothesis). It is possible, however, for the two hypotheses to coexist under more granular, fractionated models of speech production. What a fractionated model would entail is discussed below.

3.5.1 The Need for Fractioning in Theories of Speech Production

Having global analyses over pooled data enables one to make predictive hypotheses of how linguistic properties correlate with acoustic detail. However, previous studies have assumed that global effects over pooled data are predictive of individual items' acoustic details (Aylett and Turk, 2004, 2006; Munson and

Solomon, 2004; Wright, 2004; Gahl et al., 2012, to name a few). For example, it would be predicted that every vowel with high paradigmatic support would be produced with more dispersion, formant deviance, and formant movement. However, the current study illustrates that a global effect may not fully capture how each item behaves. For example, the formant dispersion, deviance, and movement of the high back tense vowel /ʊ/ did not significantly correlate with either morphological tense or paradigmatic support.

Several studies support the idea that there are indeed global relationships between linguistic predictors and acoustic detail, but there is a need to qualify how this global relationship is fractionated. Consider the studies that report that phonetic detail correlates with neighbourhood density one way, while other studies find the opposite correlation (e.g., Munson and Solomon, 2004, compared to the findings of Gahl et al., 2012). Specifically, the following groups of words were found to have different patterns of correlation between vowel dispersion and neighbourhood density based on the data studied from:

1) 20-30 words in read speech produced by Central-Minnesotans from specifically crafted and well-balanced wordlists (Munson and Solomon, 2004);
2) 12,414 monosyllabic CVC words from a spontaneous speech corpus of Central-Ohioan English (Gahl et al., 2012);
3) 680 monosyllabic CVC words in read speech produced by Central-Indianans from a specifically crafted and well-balanced wordlist (Wright, 2004).

All of these studies could be accounted for with a by corpus analysis (akin to the by vowel analyses in the analyses here). Such a model would hold that linguistic predictors like neighbourhood density influence phonetic details like vowel dispersion, and the size and direction of the influence is mitigated based on the variable nature of the stimuli analyzed (e.g., the effect is in one direction for words in read speech, while it is in another direction for words in spontaneous speech).

Furthermore, allowing for fractionation in models of speech production could eliminate the opposition between the Paradigmatic Signal Enhancement Hypothesis and Smooth Signal Redundancy Hypothesis. In cases where a linguistic predictor does not fit the pattern predicted by the Smooth Signal Redundancy Hypothesis, the Paradigmatic Signal Enhancement Hypothesis adds paradigms to the model in an effort to make sense of these findings. For example, the Smooth Signal Redundancy Hypothesis would predict that high-certainty interfixes would be produced with shorter durations; the Paradigmatic Signal Enhancement Hypothesis finds that high-certainty interfixes in a certain paradigm are produced with longer durations than other high-certainty words (Kuperman et al., 2007). In this way, paradigms are introduced to act as intermediary influences (or "pocket of intermediacy," to use the words of Kuperman et al., 2007) on phonetic detail that can oppose the influence of a particular linguistic property. I posit that a more granular, single model is possible, eliminating the need for an intermediary influence such as paradigms to describe these relationships. Recall that the Smooth Signal Redundancy Hypothesis makes its predictions based on extreme values of linguistic predictor and acoustic detail. Perhaps if these values and the scales on which they fall took into account differences between groups of words, the results in Kuperman (2007) would be interpreted differently. The variable nature of the relationship between linguistic predictors and the production of acoustic details, then, is an area where future research is warranted.

It is worth highlighting the importance of analyzing inherently variable phonetic details when formulating theories of speech production. For example, using duration as a measure of phonetic detail can lead to overly simplified theories, because duration behaves the same for every phone/word: it increases for all phones/words in the same conditions, and decreases for all phones/words in the same conditions. Phonetic measures that have the same behaviour for every phone, may lead one to an *a priori* assumption that this is true for all linguistic predictors. Analyzing other phonetic measures, that are inherently variable across phones (such as the formant data seen here), allows for an investigation into the variable nature of the relationship between linguistic predictors and phonetic details while also testing global assumptions made on pooled data.

Of course, there is a trade-off between more granularity in theories of speech production and the ability to make generalizations about correlations between linguistic predictors and acoustic detail. In the past, theories of speech production have made a simple one-to-one mapping between a linguistic predictor and a phonetic detail: for example, more paradigmatic support correlates with enhanced formant dispersion (as predicted by the Paradigmatic Signal Enhancement Hypothesis: Kuperman et al., 2007).

Although the current chapter does initially find evidence for a broad generalization, I show that these broad generalizations do not wholly capture the patterns of variation in the acoustic details. Thus, I call for more fractionated predictions that take into account specific conditions, e.g., that more paradigmatic support correlates with enhanced formant dispersions, deviance, and trajectories for certain vowels in spontaneous speech.

3.5.2 Future Research

There are three possible confounds in the present study that provide areas of future research. The first concerns the analysis of formant detail in spontaneous speech. The intrinsic nature of vowels' formants in spontaneous speech remains understudied in the current phonetic literature. It is difficult, then, to relate the acoustic variation in formant details to acoustic variation in other measures of phonetic detail with confidence. For instance, it is difficult to qualify what 'phonetic enhancement' means for formant trajectory movements. After all, phonetic enhancement is, by definition, an exaggeration of the intrinsic nature of a phoneme's acoustic properties (Lindblom, 1963), which entails that the intrinsic nature of a phoneme's acoustic properties in spontaneous speech must first be known.

Moreover, in order to investigate a vowel's formant trajectories, it is first necessary to subtract the effects of context assimilation from the raw trajectories. Current research on subtracting the influence of the surrounding context from vowel trajectories is conducted on context-balanced and laboratory-controlled data (Nearey, 2013; Broad and Clermont, 2014). However, spontaneous speech data is inherently unbalanced and uncontrolled. There remains no formal means of controlling for the consonantal context when analyzing vowel trajectories in spontaneous speech. In addition to controlling for the consonantal context, it is also necessary to control for vowel duration. Simply, vowels with shorter durations do not have enough time to be produced with great amounts of formant movement, resulting in vowel reduction (Lindblom, 1963). Thus, in quick spontaneous speech, vowels will be produced with shorter durations and, as expected, more reduced formant trajectories. An area of further research is learning more about the dynamic nature of spontaneously produced vowels, methods for parsing out the trajectories from surrounding context, and ecologically valid statistical means of dealing with unbalanced and uncontrolled data.

The second confound concerns the absence of discourse effects in the current study. It is very likely that pragmatic, syntactic, and semantic effects are also contributing to the production of the acoustic detail at hand. H&H Theory (Lindblom, 1990) predicts there to be such discourse effects, as the speaker lends acoustic salience to words that are important or uncertain given the discourse. However, how to best quantify the contribution of the discourse remains largely unknown. Curresnt researchers such as Bell et al. (2003) use word association/collocation scores, hesitations, and position in utterance to quantify discourse effects. These measures were not included in the current study, though their effects could be of interest. An area of further research is including higher levels of linguistic processing in a model of speech production, since spontaneous speech is necessarily comprised of higher level discourse influences.

The final confound concerns the equations used to calculate NDL cue-to-tense activation levels. The current study uses NDL cue-to-tense activation levels that were calculated by Tucker et al. (in preparation) according to the Danks (2003) adaptations of the Rescorla-Wagner equations (1972). The Rescolra-Wagner equations used here adjust the NDL cue-to-tense weights iteratively, as if each occurrence of a verb in the Buckeye Corpus is a novel learning experience. However, this method of weight calculation is at odds with the population of speakers in the current study. The Rescolra-Wagner equations assume that the order in which words appear in the Buckeye Corpus is also the order in which they were learned, as if the time-course of the Buckeye Corpus replicates the time-course of language learning. The order of learning is important when calculating NDL metrics using equations that are based on iterative learning mechanisms such as Rescorla-Wagner. As such, the method of calculating the NDL metrics in this chapter aimed to mimic the learning networks of the speakers though the iterative means of obtaining weights (and, consequently, the individual weights themselves) do not precisely capture speakers' own learning of diphone cues. Simply put: the NDL metrics were calculated based on artificial language learning. An area of further research is formulating an NDL model that mirrors language acquisition theories.

3.6 Conclusions

The current chapter has found support for the modulation of acoustic detail by linguistic properties and paradigms. The results from the analysis of the correlations between vowel dispersion, formant deviance from vowel onset/offset, formant movement, morphological tense, and NDL cue-to-tense activation levels suggest a need for a more fractionated model of speech production. This fractionation is supported by other analyses that do not support the ubiquitous nature of two current hypotheses of speech production: the Smooth Signal Redundancy Hypothesis (Aylett and Turk, 2004, 2006) and the Paradigmatic Signal Enhancement Hypothesis (Kuperman et al., 2007).

Overall, previous research has simplified the relationship between linguistic predictors and acoustic variation. The current chapter shows that the relationship between linguistic predictors and phonetic detail is perhaps not so straightforward. My study suggests that there is a need for future research in order to develop more granular hypotheses about the modulation of fine phonetic detail in speech production. For example, testing the Smooth Signal Redundancy Hypothesis and the Paradigmatic Signal Hypothesis using inherently variable phonetic data, such as electromagnetic articulography, and well-studied linguistic properties and parameters, such as word and paradigm frequency. A granular, fractionated model of inherently variable phonetic data would better capture the patterns of variation between linguistic/paradigmatic predictors and acoustic detail.

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Chapter 4:
The Role of Acoustic Detail: Evidence from Lexical and Morphological Processing

4.1 Introduction

It is possible that some insight into the role acoustic detail plays in speech production can be gained by investigating its subsequent role in speech processing. Previous research has found that speakers produce a messy speech signal with massive amounts of acoustic variation (e.g., Johnson, 2004), yet listeners are able to decode the messy speech signal into meaningful messages (e.g., Ernestus et al., 2002). Thus the speech system is a combination of speakers' effortful productions and listeners' effortful processing. The role of acoustic detail in this dual-natured speech system is captured in two competing hypotheses: acoustic detail either facilitates processing (i.e., there is a link between the production of acoustic detail and speech processing), or it is a consequence of production only (i.e., there is no link between production and processing). The current chapter investigates these hypotheses. To do so, a measure of acoustic detail that is found to be significant in speech production is tested for its subsequent significance in processing. Should the acoustic detail found in production play a role in speech processing, it is possible to propose a link between production and processing.

Current research in speech processing has found that patterns of acoustic variation are important for both speech discrimination and recognition. This is evident at the sub-segmental level, such as phone discrimination in voice onset time (Liberman et al., 1958) and vowel formant movement (see Morrison and Assmann, 2013 for an overview). Moreover, acoustic details at the segmental level also affect the processing of word recognition, as exemplified in studies on consonant reduction (Mitterer and Ernestus, 2006; Tucker and Warner, 2007; Ernestus and Warner, 2011; Tucker, 2011). At higher levels of speech processing, the acoustic detail of the syntactic and semantic context surrounding reduced word forms (Ernestus et al., 2002, van de Ven et al., 2011) and the semantic bias of the sentence (Connine, 1987) exemplify phrasal-level effects on word recognition.

Additional research has found that linguistic properties also play an important role in speech processing. For example, the facilitatory effect of word frequency in speech discrimination and recognition has been widely replicated (Taft, 1979; Connine et al., 1990; Connine et al., 1993; Meunier and Segui, 1999; Baayen et al., 2003; Ernestus and Baayen, 2007). The addition of neighbourhood density and lexical competition amongst phonologically similar neighbours has also been shown to significantly affect speech processing (Landauer and Streeter, 1973; Goldinger et al., 1989; Luce and Pisoni, 1998; Vitevitch et al., 1999; Luce and Large, 2001). Taken together, studies on these two linguistic properties provide insight into the processing of variant phonological forms (Metsala, 1997; Connine, 2004; Ranbom and Connine, 2007; Connine et al., 2008).

Research on speech processing has primarily focused on how acoustic details and linguistic properties affect processing independently. Although studies have found an abundance of evidence for a relationship between specific acoustic details and linguistic properties in speech production (as discussed below), and interpretations of research in speech production are often based on this relationship, little is known about their joint effect on speech processing. The purpose of the current study is to investigate this effect.

4.1.1 Acoustic Detail as a Consequence of Production Only

It is possible that acoustic detail in the speech signal is unrelated to listener processing, and is instead a product of production facilitation, or ease of articulation. Speakers make use of existing acoustic variation/linguistic property relationships in their productions to ease their articulations in producing the speech signal, even when this might cause difficulties for the listener. Many studies have investigated the role that ease of articulation plays in modulating acoustic detail.

The relationship between acoustic duration and word frequency illustrates how acoustic detail and ease of articulation are clearly related. Bell et al. (2009) (see also Pluymaekers et al., 2005a&b) found that content words with higher lexical frequencies are produced with shorter durations than those with lower lexical frequencies, which they interpret in terms of lexical access. Their interpretation holds that high word frequencies enable speakers to access words' phonological forms more quickly, resulting in faster productions. In this way, acoustic variation is the by-product of a facilitation effect in production, not processing.

Likewise, in a study on the effects of neighbourhood density on vowel duration and dispersion (similar to Wright 1997, 2004), Gahl (2012; and Gahl et al., 2012, Yao, 2011) also interprets her findings in terms of lexical access of competing variant phonological forms. Gahl finds that words from denser phonological neighbourhoods are produced with shorter vowel durations and less vowel dispersion, suggesting that speakers vary acoustic detail by how quickly they can access the phonological form. According to Gahl, speakers produce words in dense phonological neighbourhoods with shorter durations even though doing so may inhibit the subsequent processing of those words. This is in contrast to the findings of Wright (1997, 2004), which support a role for ease of listener processing, discussed below.

In their Articulation Proficiency Theory, Tomaschek et al. (2014, Baayen et al., to appear) explain the production of acoustic variation in terms of speaker experience rather than lexical access. They studied the movement of the tongue body when producing vowels and find that there is earlier and more peripheral tongue movement when speakers have more experience with the utterance produced. Speaker experience is quantified in terms of lexical frequency, frequency of the phonetic context surrounding the vowel, and age of the speaker. The Articulation Proficiency Theory predicts that the amount of experience a speaker has with a particular utterance can modulate the production of acoustic variation.

4.1.2 Acoustic Detail as a Link between Production and Processing

Thus far, I have discussed the role of acoustic detail based on speech production data. The studies discussed above have made predictions about the processing of acoustic detail based on relationships between linguistic properties and acoustic detail in production: acoustic detail is produced in such a way that it is either facilitatory or inhibitory to speech processing. However, these predictions are often not directly tested, but are instead formulated based on statistical probabilities.

There are also research-based hypotheses that suggest acoustic detail is produced in a way that facilitates processing (such as Aylett and Turk, 2004, 2006; Ernestus and Baayen, 2007; to name a few.). In order to help disambiguate messy speech signals, speakers may employ existing acoustic detail/linguistic property relationships in their productions. A speaker may vary acoustic variation with the listener's perception in mind, thereby facilitating processing via acoustic detail (otherwise known as 'ease of processing,' or 'listener-driven' speech production). This framework assumes that processing messy speech signals would be more difficult without a shared knowledge of acoustic variation/linguistic property relationships.

This hypothetical link between production and processing is formalized in H&H Theory (Lindblom, 1990). H&H Theory holds that speakers are constantly alternating between a natural hypo-articulation production state (reduction), and more enhanced hyper-articulations. This is presumably in order to balance speakers' tendencies towards production ease with listeners' processing demands. In H&H Theory, speakers are continuously aware of the processing load that acoustic variation presents, so they balance their tendencies for hypo-articulation reductions with more hyper-articulated clear-speech forms.

This balance in producing the right kind and right amount of acoustic detail is also seen in Wright's work with vowel duration and dispersion in 'easy' and 'hard' words (1997, 2004). Wright (as well as Luce, 1986; Luce and Pisoni, 1998) determines the 'easiness' or 'hardness' of a word by its predicted processing load. 'Easy' words are those with higher frequencies and fewer phonological competitors, while 'hard' words are those with lower frequencies and more phonological competitors. In this paradigm, 'hard' words are produced by speakers with enhanced acoustic details in order to ease the listeners' processing of the speech signal. Or, in terms of H&H Theory, 'easy' words are hypo-articulated, and 'hard' words are hyper-articulated.

The Smooth Signal Redundancy Hypothesis (Aylett and Turk, 2004, 2006) adds detail to H&H Theory and Wright's 'easy/hard' paradigm by qualifying at which points in the speech signal speakers will likely reduce and enhance their speech. This Hypothesis can be used to determine probabilistically points in the speech signal with a difficult processing load (similar to being 'hard'). It is at these points, the Hypothesis holds, that speakers intuitively produce enhanced acoustic details in order to ease the listeners' processing of the speech signal. In this way, speech production and speech processing are strongly linked.

Several studies in speech production lend support to this 'ease of processing' role for acoustic variation. Research has shown that speakers reduce the durations of their word productions when the word is predictable from the surrounding context (Pluymaekers et al., 2005a; Pluymaekers et al., 2005b, Kuperman and Bresnan, 2012; Tily and Kuperman, 2012; Pate and Goldwater, 2015). Further, van Son and Pols (2003) found that segments within words are produced with shorter durations only when they are less informative for disambiguating words. Jurafsky et al. (2001) refer to this tendency of producing reduced word forms in contexts that favour processing ease (i.e., in contexts with higher likelihoods of predictability) as the Probabilistic Reduction Hypothesis.

The current study investigates these predictions by taking a production-based probabilistic relationship and testing effects on processing. In this way, the current study directly investigates whether acoustic detail correlates with a linguistic property in processing, using production data.

4.1.3 The Current Study

The production-based relationship to be tested here is derived from an analysis by Tucker et al. (in preparation). The researchers analyzed the vowels in a set of spontaneously produced monosyllabic irregular English verbs where the verbs' vowels differentiate their past/present tense forms. The acoustic variable of interest was the duration of the morphological vowel (e.g., the /i/ or /æ/ in *sing*/*sang*). The linguistic property of interest comes from Naive Discriminative Learning metrics (henceforth NDL; Baayen et al., 2011).

Tucker et al. found that vowel durations in this subset of irregular verbs are modulated by "NDL cue association strengths," which generally measure how strongly the verbs' vowel diphone pairs are associated with, or indicative of, the past tense. A stronger NDL cue association corresponds to a stronger relationship between the vowel diphone pair and the verb's morphological form (i.e., more morphological support). Tucker et al. found that within this subset of verbs, words with stronger NDL cue associations are produced with longer vowel durations. This can be loosely interpreted to mean that more enhanced vowel productions correlate with more morphological support (based on NDL cue association). This production-based relationship between morphological vowel duration and NDL cue association strength is henceforth referred to as a duration-NDL relationship.

Though Tucker et al. do not interpret the duration-NDL relationship in terms of facilitation of either production or processing, their findings have implications for both. According to processing facilitation, the role of acoustic detail (in this case, vowel duration) is to provide the listener with a processing cue to decode the messy speech signal. A listener will process a signal more quickly if the cue is more predictable due to morphological support of the vowel diphone pair for the verb tense (stronger NDL cue association). This processing facilitation view supports a strong link between production and processing: speakers produce vowel durations according to a predictable relationship between vowel duration and morphological support that facilitates processing. On the other hand, a production-only facilitation view holds that acoustic variation (vowel duration) exists to provide a shortcut from lexical access to articulation, irrespective of the word's subsequent processing. This production facilitation view does not support the existence of a link between production and processing. It is unclear whether production facilitation alone is sufficient to explain acoustic variation, or if listener processing also plays a role.

The current chapter tests whether acoustic detail does, in fact, play a facilitatory role in processing by manipulating the Tucker et al. duration-NDL relationship. To investigate how the relationship between NDL cue association strength and vowel duration affect lexical and morphological recognition, two word processing experiments were conducted.

Recall that Tucker et al. (in preparation) found that stronger NDL cue associations correlate with longer vowel durations for irregular English verbs in spontaneous speech. I manipulated this relationship by altering vowel duration, then measuring the resulting processing difficulty compared to unmanipulated words. This allowed me to determine how influential this NDL-duration relationship is on processing load (i.e., whether it provides a link between production and processing by subsequently facilitating recognition).

I hypothesize that acoustic detail (indicated by the NDL-duration relationship) facilitates the processing of irregular English verbs. Acoustic detail links production and processing: the speech signal is produced with informative, probabilistic acoustic variation that has the potential to act as a cue for processing. This follows from my assumption that speakers phonetically enhance (produce with longer durations) the vowels in irregular English verbs when doing so aids the listener in identifying the tense of the verb (as in high NDL cue strength conditions). When a vowel is strongly discouraging of a particular morphological tense (as in low NDL cue strength conditions), speakers do not phonetically enhance the vowel. Thus, I predict that manipulating the acoustic detail will make processing more difficult. This effect will be seen for both vowel lengthening (manipulating the low NDL cue strength conditions) and vowel shortening (manipulating the high NDL cue strength conditions). The alternative to this hypothesis is that the NDL-duration relationship facilitates production only. If this is the case, my manipulation will not result in a difference in processing.

I used two different experimental paradigms to investigate the relationship between NDL-duration and processing: lexical decision and morphological decision. The two paradigms allowed me to investigate two processing tasks: accessing word representations, and accessing morphological representations, respectively. Given that NDL cue strength was calculated based on differences in morphology, it is plausible that the morphological decision task is more sensitive to differences in NDL cue strength than the lexical decision task. Testing both speech processing tasks will allow me to more thoroughly investigate the NDL-duration relationship.

4.2 Experiments

The role of acoustic detail in processing as it correlates with NDL cue strengths is investigated using two paradigms: an auditory lexical decision paradigm and an auditory morphological decision paradigm. The lexical decision paradigm (Experiment I) and morphological decision paradigm (Experiment II) use the same recording methodologies, set of stimuli items, basic experimental procedure, and similar participant populations. The list of experimental items, experiment procedure, and participant groups are discussed for each Experiment, as well as the statistical analysis of the data, results, and local discussions.

4.2.1 Experiment I: Lexical Decision

Experiment I consisted of evaluating reaction times to the manipulated Target items in a lexical decision paradigm.

4.2.1.1 Items

The Target stimuli for the lexical task consisted of irregular monosyllabic English verbs that alternate between their present and past tense forms by only a single vowel (no other phonological differences). For example, this would include words like sing/sang but not words like is/was or weep/wept. English has 127 such verb pairs (i.e., 127 lemmas). The current project focuses on a subset of these verbs based on the following criteria:

1) The verbs occur in the Buckeye Corpus of Conversational Speech (Buckeye Corpus; Pitt et al., 2007).
2) The verbs exemplify the correlation between NDL cue association strength and vowel duration found in production data (based on Tucker et al.).

Tucker et al. found that in a set of 60 irregular monosyllabic English verbs, greater NDL cue association strengths correlated with longer vowel durations. Figure 4.1 illustrates their findings using a simple regression line. To meet the requirements for Criterion #2, only those verbs where both the past and present form of the verb fell close to the regression line from the Tucker et al. data were selected as Target word items. This includes 18 verb types (shown in black in Figure 4.1; unused words, where visual inspection of the plot found at least one of the past/present forms fell far away from the regression line, are shown in grey). The present and past tense forms of each word type were included, yielding a total of 36 Target word items.

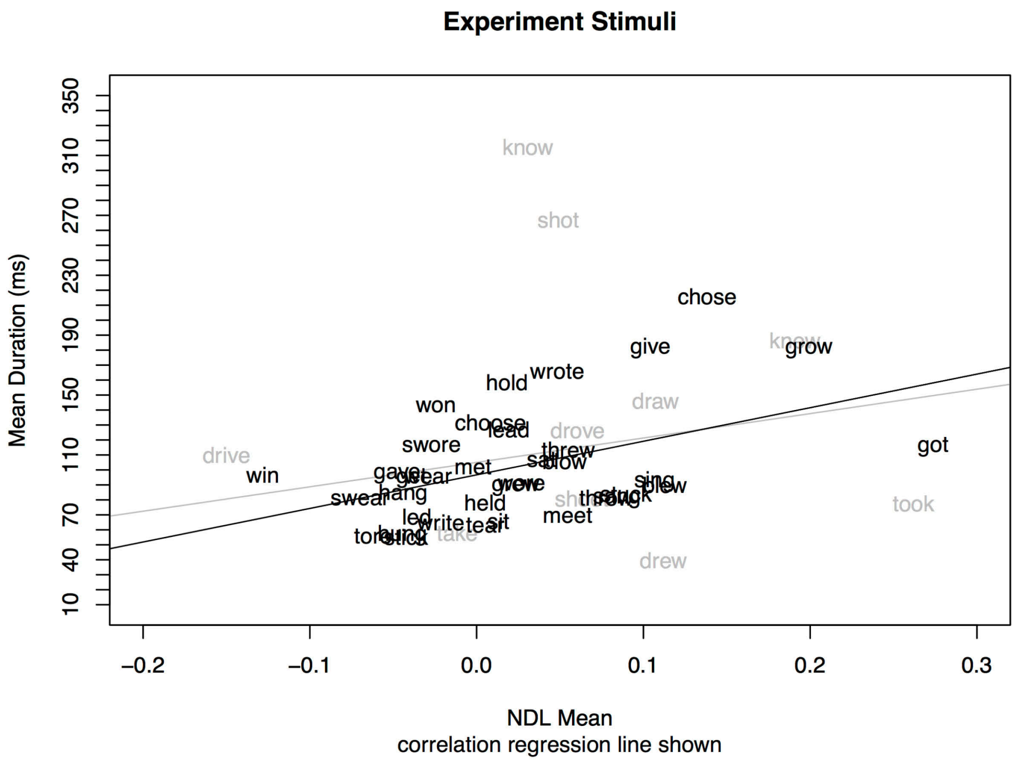

Figure 4.1: Correlations between NDL cue association strength and mean duration based on Tucker et al. Words in black were included in the present stimulus set; words in grey were not included. Regression lines for the correlations between NDL and mean verb duration are also shown.

The experiment lists also included 36 Filler words, which were counterbalanced by word type: 9 irregular verbs that do not alternate between their past and present tenses by a single vowel (4 items in present tense form, 4 items in past tense form, 1 item where the past/present tense form is the same), 18 regular English verbs (6 items that end in /t/, 6 items that end in /d/, and 6 items that end in /əd/), and 9 nouns (4 items in a regular singular form, 4 items in a regular plural form, 1 item in an irregular plural form).

The Nonword items in each experiment list consisted of phonotactically legal pseudowords that are phonologically similar to the Target and Filler items. More specifically, for each Target and Filler item, 10 pseudowords were generated by the program *Wuggy* (Keuleers and Brysbaert, 2010; using the CMU

Dictionary: Weide, 1998) based on a phonological edit distance of 1-2 phones in the; 2 Nonwords were chosen for each item. This yielded 144 Nonword items: 36 Target counterparts (x 2) + 36 Filler counterparts (x 2) = 144 Nonwords.

4.2.1.2 Recording Procedure

Each Target, Filler, and Nonword item was recorded by a 29 year old male who is a monolingual native speaker of Western Canadian English. The speaker is a trained phonetician who had no knowledge of the methodological intent of the recordings. Recordings were made in a sound-attenuated booth.

The speaker was provided with the frame "She clearly said ______ today." on the screen. Real words and pseudowords appeared in the frame one at a time. The speaker was asked to record the whole sentence, including the frame and real word or pseudoword (e.g., "She clearly said sing today."). Pseudowords were presented in IPA transcriptions and were recorded in a separate block from real words. To mitigate list effects in the recordings, the speaker was asked to reproduce each sentence three times, with the second reproduction used as the stimulus.

More natural variations of vowel durations were obtained by recording each real word/pseudoword sentence at 9 speaking rates in order to create stimuli that could be manipulated. Speaking rate was set by a metronome the speaker listened to through headphones. The speaker was instructed to produce one syllable per metronome beat. Speaking rates varied in 5 beats per minute intervals, ranging from very slow, careful speech (110 bpm on the metronome) to very fast and heavily reduced (150 bpm on the metronome). Each of the 9 rates of speech was recorded in separate blocks.

4.2.1.3 Duration Manipulation

Of the three reproductions of each sentence, the second reproduction of each sentence was taken as the stimulus item. Of the nine speaking rates, sentences from recordings produced at the middle (median) speaking rate (130 bpm) served as the referent frame. The durations of all the vowels in all nine speech rate recordings were measured and their durational differences were compared to the original, referent vowel. Vowel duration was shortened or lengthened by splicing vowels from faster or slower recordings, respectively, into the Target/Filler/Nonword of the 130 bpm referent frame (e.g., "She clearly said s_ng today."). Splices in and out of sentences were made at zero-crossings.

Altogether, this method of duration manipulation (as opposed to other methods such as PSOLA) produced more natural sounding vowels by preserving vowels' intrinsic spectral properties and coarticulations with the surrounding phonetic environment. The goal of manipulating the stimuli were to produce words that did not differ noticeably in any other perceptional characteristics other than duration. To check for this, four trained phoneticians listened to the stimuli for distortions, glitches, and unnatural patterns in pitch and formant contours, particularly at the edges of the vowel splices. The phoneticians found that 91% of the 288 Target, Filler, and Nonword items were free of any distortions, glitches, and unnatural pitch and formant patters. None of the Target items were marked for distortions, glitches, and unnatural patterns. The Appendix (Table A.19) lists all items that were marked for disfluencies.

Target words were grouped into high, mid, or low NDL by dividing the NDL continuum into three distinct categories (see Figure 4.1 and Appendix Table A.20 for details). Measures of cue association strength of the NDL continuum used here are the same diphones-cueing-morphological tense measures that were gathered in Chapter 3 of this dissertation. Whether Target vowel durations were increased or decreased (whether a slower or faster vowel was spliced into the referent frame, respectively) was determined by these categories. According to Tucker et al. the effect size of NDL on vowel duration is about 30 ms, i.e., vowels in words with a high NDL cue association strength were about 30 ms shorter than vowels in words with a low NDL cue association strength. Vowel durations of the Target verbs were manipulated in the opposite direction observed by Tucker et al. (see Figure 4.1): words with high NDL cue association strengths were spliced with vowels of shorter durations (by either 15 or 30 ms), and words with low

NDL cue association strengths were spliced with vowels of longer durations (by either 15 or 30 ms). Each Target item, then, contained three levels of manipulations, or three conditions: a normal duration (referent level), a duration that has been altered in the opposite direction of the Tucker et al. predictions, and a duration between the two. A summary of levels of duration manipulation and NDL group is provided in Table 4.1. The remainder of this chapter refers to these duration manipulation conditions by their level names (i.e., shortest, short, normal, long, and longest) and NDL groups by their level names (i.e., high, mid, low).

Table 4.1: Summary of duration manipulations for each NDL group.

	Duration Manipulation				
NDL Group	shortest (-30ms from normal)	short (-15ms from normal)	normal	long (+15ms from normal)	longest (+30ms from normal)
high	X	X	X		
mid		X	X	X	
low			X	X	X

To control for any possible splicing effects, each occurrence of the Target vowel in a normal duration condition was also spliced: the Target vowel in the frame was spliced with another repetition of the same vowel in the same frame. For example, if the 2nd repetition in the recordings served as the Target frame, the normal vowel duration manipulation was taken from the 1st or 3rd repetition of the same recorded item - whichever repetition had the closest vowel duration to the Target frame.

A simple linear regression *a priori* test of the Target vowels in the normal duration condition (130 bpm) confirmed that the productions adhere to the predictions made by Tucker et al. The durations of the vowels produced by the recorded speaker were longer when the vowel's NDL cue association strengths were higher. This is interesting given that the predictions made by Tucker et al. are based on a corpus of spontaneously produced speech, and the current data is based on read list speech. It appears that the relationship between NDL cue strength and vowel duration persists in both spontaneous and more laboratory elicited speech.

The duration of the stressed vowels in all the Filler and Nonword items were also manipulated. The amount of duration manipulation was randomly assigned for each item and evenly distributed amongst the Fillers and Nonwords. A list of all the Targets, Fillers, Nonwords, and their manipulation levels can be found in the Appendix (Table A.20 and Table A.19).

4.2.1.4 Experiment Stimuli Lists

In the Experiment I stimuli lists, the 18 chosen Target verbs were counterbalanced across six experiment word lists according to their morphology and manipulation level: 2 levels of morphology (past/present) x 3 levels of duration manipulation (normal, between, opposite) = 6 counterbalanced word lists of 18 words each. Each participant heard only one token of each of the 18 word types (either the past or the present tense form of the word, and with only one level of duration manipulation).

In total, each experiment list contained 144 pseudowords and 54 real words (18 Target items + 36 Filler items), for a total of 198 items per list. The 6 counterbalanced lists were psuedo-randomized so that real word items did not occur twice in a row. To mitigate trial effects, the 6 lists were ran forwards from the first item to the 198th item, and backwards from the 198th item to the first item. This yielded 12 total versions of the experiments (6 counterbalanced lists x 2 directions forward/backwards = 12 versions).

4.2.1.5 Participants

Participants were university students who completed the experiment as partial credit for a research participation requirement in a linguistics course. All participants were native speakers of Western Canadian English and grew up speaking only English in the home.

Data from the lexical decision experiment consists of responses from 97 participants (73 identified as female, 24 identified as male; mean age was 20.84 years). Participants were evenly distributed across each of the 12 experiment versions insofar as possible.

4.2.1.6 Procedure

Participants sat in a sound-attenuated booth in front of a computer screen. The screen displayed the frame sentence "She clearly said ______ today." for all auditory stimuli. Through headphones, participants heard the entire stimulus sentence only once, containing both the frame and the Target/Filler/Nonword item (e.g., "She clearly said sang today."). Participants were asked to respond with their first instinct and without deliberation. The inter-stimulus interval was 1000 ms, during which a crosshair fixation point appeared on the screen in place of the frame sentence.

In the lexical decision experimental paradigm for Experiment I, participants were asked to respond by pressing "yes" or "no" on a button box to indicate whether or not the word "she" clearly said today (i.e., following from the frame sentence) was a real word in English.

4.2.1.7 Statistical Analysis

Participants were excluded from the analysis if they did not respond correctly to a predetermined percentage of the stimuli. For the lexical decision task, participants that did not respond correctly for 70% or more of all experiment items were excluded (n=2). Likewise, reaction times less than 200 ms and greater than 2.5 standard deviations from the means were excluded (n=65). The following statistical analyses are based on correct responses only (n=1573).

A set of Linear Mixed Effects Regression (LMER; Baayen et al., 2008) analyses were conducted on the reaction times in the R statistical environment using the package *lme4* (Bates et al., 2014) and *languageR* (Baayen, 2013). The dependent variable was the logged values of the reaction times from Target word offset. The main independent variable of interest was the duration manipulation condition (normal, long, longest, short, and shortest), with the 'normal' level as the reference level in the models.

An initial analysis of the reaction time data was conducted to test for effects on the manipulated vowel duration and the vowel identity. In this simple analysis, reaction times (in milliseconds, log normalized) were predicted by an interaction between the manipulated vowel duration (in milliseconds, log normalized) and the identity of the vowel (e.g. /i/) with random intercepts for participant. It is possible that manipulating the duration of vowels may inherently confuse vowels that differ mostly by vowel length (e.g. /i/ and /ɪ /), resulting in longer reaction times/more processing effort. However, this initial analysis did not find any statistically significant effects for an interaction with vowel duration and vowel identity (the Appendix Table A.21 and Table A.22 contains these initial LMER models' coefficients for the lexical decision and morphological decision tasks). Though it is statistically insignificant, the overall trend in both tasks is that reaction times were faster across all vowels when the duration of the vowel was manipulated to be longer. In post-hoc analyses, the same interaction between vowel duration and vowel identity was added to the final LMER analyses (the final LMER analyses are discussed below). As with the initial analysis, these post-hoc analyses show a statistically insignificant trend for faster reaction times when vowels are longer, across all vowels. Subsequent model criticism involving an analysis of variance (ANOVA) and a comparison of Akaike Information Criterion (AIC) values show that including the interaction between vowel duration and vowel identity does not improve model fit as the final (no interaction) and post-hoc (with interaction) LMER analyses are not significantly different from each other (Appendix Table A.21 and Table A.22). For this reason, the interaction between vowel duration and vowel identity was not included in the final analyses.

In the final LMER analyses of the reaction times, each NDL group was modelled separately since the duration manipulations were not consistent between NDL groups (refer to Table 4.1.). A secondary analysis combined all NDL groups into one LMER model to investigate the effect of linguistic predictors on reaction times across the NDL paradigm as a whole.

The LMER modelling procedure was conducted in a stepwise backwards-fitting fashion. Several predictors were initially checked for their influence on the reaction time data. These include the linguistic predictors of neighbourhood density (Levenshtein distances of phonological neighbours from Balota et al., 2007; scaled and centred around 0 by dividing the densities by their standard deviations), NDL cue association strength, morphological tense (past/present), and various measures of word frequency (including both lemma and word frequencies calculated by local token frequency in the Buckeye Corpus; and a more global token frequency in the CELEX Lexical Database, Baayen et al., 1995). Control predictors include vowel quality (tense/lax; phonetic control), trial and reaction time in the previous trial (experiment controls), and participant age and gender (participant controls). A simple Pearson's test for correlation found no significant pairwise collinearity between any of the numeric predictors. All two- and three-way interactions were checked amongst the predictors; none were found to be significant. Only the main effects that reached statistical significance were left in the final LMER models, resulting in the exclusion of both local and global measures of word and lemma frequency, trial, age, and gender from the final lexical decision model.

Random intercepts for participant and item were added to the final model. The inclusion of random slopes for participant and item did not improve model fit, so random slopes were not included in the final model.

A full listing of the lexical decision model's coefficients is given in the Appendix (Table A.23). Below is a discussion of the results of interest.

4.2.1.8 Results and Discussion

To better make comparisons between the two Experiments, the results of both Experiment I (lexical decision) and Experiment II (morphological decision) are illustrated in Figure 4.2 and Figure 4.3.

Figure 4.2 combines the partial effects results of the LMER models for both the lexical decision and morphological decision tasks. Task is shown in colour (red for lexical decision, blue for morphological decision). NDL group is shown by line label ("h" for high NDL group, "m" for mid NDL group, and "l" for low NDL group). Duration manipulation level is shown on the x-axis, with the "normal" reference level (the reference level) shaded in grey. Reaction time is on the y-axis. Those reaction times at a particular level of duration manipulation that were significantly different than the "normal" reference level within their NDL group are marked with an asterisk (*).

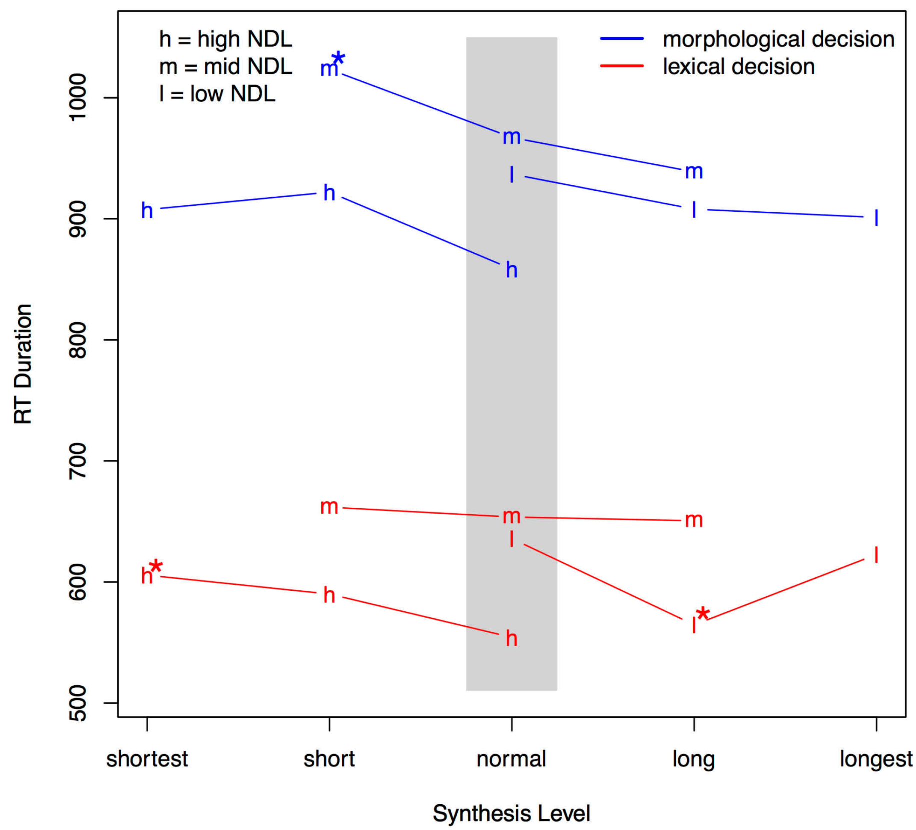

Figure 4.2: Results for the LMER models for each NDL level in the lexical decision experiment (Experiment I) and morphological decision experiment (Experiment II). An asterisk (*) indicates a significant difference in a manipulated Synthesis Level from the 'normal' Synthesis Level (shown in grey shading).

Figure 4.3 illustrates the partial effects of the LMER models for the lexical and morphological decision tasks. Task is coded by line colour with the lexical decision model shown in red and the morphological decision model shown in blue. Reaction time is shown in the y-axis for all panels. Predictors are shown on the x-axis. Panel (a) illustrates the difference in reaction time for each duration manipulation level (compared to the "normal" reference level of duration manipulation - illustrated by a dashed line). The x-axis is arranged in alphabetic order following the "normal" reference level. This panel combines all data from all NDL groups, as opposed to Figure 4.2 that compares models' predictions within NDL groups. The only significant effect shown in this panel is the difference between the 'shortest' and 'normal' levels of manipulation in the lexical decision experiment (shown in red). Panel (b) illustrates the partial effects of neighbourhood density on the reaction time data. The neighbourhood density predictor (x-axis) is scaled and centred around zero. All effects shown are significant. Panel (c) illustrates the partial effects of NDL cue strength. NDL cue strength was predictive in the lexical decision model only. All effects shown are significant. Panel (d) illustrates the partial effects of morphological tense (reference level: past). Tense was predictive in the lexical decision model only. All effects shown are significant.

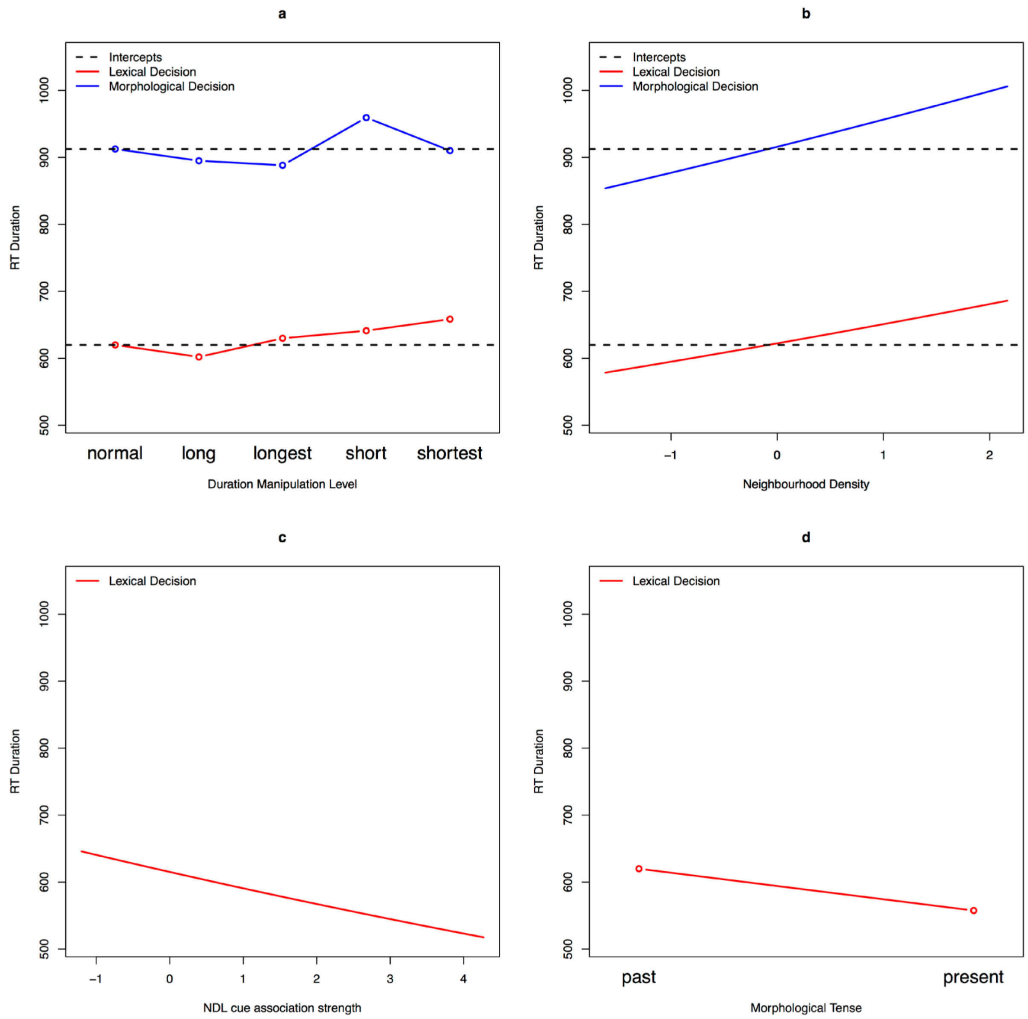

Figure 4.3: Partial effects results for the LMER models in the lexical decision experiment (Experiment I) and morphological decision experiment (Experiment II) for all NDL levels combined. The follow predictors are shown in panels (a-d): (a) duration manipulation level (b) neighbourhood density, scaled and centred around zero (c) NDL cue association strength (d) morphological tense (reference level: past).

Table 4.2 (below) displays the LMER coefficients for four models: one for each NDL group in the primary analysis (by-NDL-group: high, mid, and low) and one for the secondary analysis (all NDL groups combined). It is possible that the duration manipulations affect the lexical processing of each NDL group differently (since each NDL group was manipulated differently), so by-NDL-group analyses were first conducted. The by-NDL-group analyses indicate that lexical decision reaction times were affected by vowel duration manipulation when the word belonged to the high or low NDL group (shown also in Figure 4.2 in red and with asterisks; the normal vowel duration level is shaded). For the high NDL group, response times to words containing vowels with the shortest duration manipulation were significantly slower (compared to the normal group). For the low NDL group, words containing vowels with the long (but not longest) duration manipulation were responded to significantly faster (compared to the normal group). Though the effect is not significant Table 4.2 in each NDL group, the trend is that shorter words are processed more slowly, and longer words are processed more quickly (note this is the same trend seen in the simple, preliminary analysis of a duration/vowel interaction, which was also found to not be statistically significant).

In the secondary analysis that combines all NDL groups, only those words that contained vowels with the shortest level of duration manipulation were significantly different from those words with no duration manipulation (shown in Figure 4.3 in red). The overall trend of duration manipulation for all words, when combining all NDL groups, is that shorter words elicit slower reaction times.

Taking these analyses together, it appears that manipulating the duration of the vowel to be contrary to what is expected in production (as found by Tucker et al.) does not have a strong predictive effect on processing difficulty in lexical decision. In fact, criticism of model fit shows a slight favour for a model of the combined NDL groups when the duration manipulation factor is removed (AIC: 722; compared to leaving in the duration manipulation - AIC: 740).

Tucker et al. found that vowels with high NDL cue association strengths are produced with longer durations, and vice versa. I hypothesized that this is due to an effect of acoustic enhancement: vowels with a stronger association with the past tense are enhanced (produced with longer durations) to serve as an acoustic cue for tense disambiguation. It was predicted that processing would be more difficult (as reflected in slower reaction times) when acoustic enhancement is instead given to vowels that are discouraging of the past tense (reversing the Tucker et al. findings), and when vowels with a strong association with the past tense are reduced. My hypothesis is not supported: the NDL-duration relationship attested for in production is not necessarily facilitatory in processing irregular English verbs across all NDL groups.

However, when evaluating each NDL group individually (as in a one-tailed test: comparing manipulated/unmanipulated), there are slight effects in processing time for manipulating the vowel duration. For vowels that discourage the past tense and were acoustically enhanced (low NDL group with longer durations), the effect is in the opposite predicted direction: reaction times were faster despite the manipulation. For vowels that are strongly associated with the past tense and were acoustically reduced (high NDL group with shorter durations), the effect is in the predicted direction: reaction times were slower, indicating more difficult processing. One possible explanation for this comes from H&H Theory (Lindblom, 1990). H&H Theory predicts that hyper-articulations (such as longer vowel durations) will facilitate production in general. This prediction is irrespective of patterns of correlations between linguistic properties and acoustic detail (such as the correlation NDL cue association strength and vowel duration). In H&H Theory, it is not the linguistic property that matters, but the fact that the acoustic signal has been hyper articulated at all. Disambiguating this H&H Theory prediction from my original prediction (that the correlation NDL cue association strengths and vowel duration is what conditions processing) is not possible in the current analysis since both predictions are in the same direction. However, both predictions entail some form of a link between production and processing.

The influence of other linguistic properties on lexical decision reaction times provide further support for a link between production and processing. The lexical predictors of neighbourhood density, NDL cue-to-tense activation strength, and morphological tense were each significant in predicting variance in reaction time responses. Past tense words result in slower responses than present tense words.

NDL cue-to-tense association strength is inversely related to reaction time: words with stronger NDL cue association strengths were responded to faster than words with weaker NDL cue association strengths. Though the effect of NDL cue association is weak, model criticism shows no preference for removing or including the NDL cue association predictor (leaving out the NDL predictor - AIC: 669; leaving in the NDL predictor - AIC: 670). Though I originally predicted that manipulating the Tucker et al. NDL-duration relationship would result in processing difficulty overall, what I find instead is that stronger NDL cue-to-tense association strengths allow for faster processing overall. Tucker et al. find that stronger NDL association strengths lead to more enhanced vowel productions (longer durations), I similarly find that stronger NDL association strengths lead to more enhanced processing, irrespective of the production of vowel duration. This association between greater NDL association strengths and ease of processing is also attested for in studies on reading (Baayen et al., 2011).

In addition to the effects of morphological tense and NDL cue association strength, neighbourhood density is positively associated with reaction time; words with larger phonological neighbourhoods pattern with longer reaction times. Recall that previous research in speech production predicted opposing effects of phonological neighbourhood density in speech processing. While Wright (1997, 2004) predicted that phonological neighbourhood density would inhibit speech processing based on his findings in speech production, Gahl (2012; also Gahl et al., 2012) predicted the opposite based on her interpretations of speech production data. In the current lexical decision experiment, there is a clear inhibitory effect of neighbourhood density in speech processing: words belonging to more dense phonological neighbourhoods are recognized more slowly than words with fewer neighbours. The effect of neighbourhood density here follows the predictions made by Wright.

Table 4.2: Table of coefficients for the lexical decision experiment (Experiment I) for models with NDL groups separated and combined.

High NDL Group			
Predictor	Estimate	Standard Error	*t*
Intercept (Manipulation Level: normal Morphological Tense: past Vowel Quality: lax)	4.901	0.232	21.104
Manipulation Level: long			
Manipulation Level: longest			
Manipulation Level: short	0.069	0.037	1.888
Manipulation Level: shortest	0.111	0.037	3.037
Previous Reaction Time (ms)	0.205	0.033	6.148
Morphological Tense: present	0.023	0.075	0.303
NDL Cue Association Strength (scaled and centred)	-0.005	0.036	-0.130
Phonological Neighbourhood Density (scaled and centred)	0.007	0.037	0.189
Vowel Quality: tense	0.049	0.074	0.667

Mid NDL Group			
Predictor	Estimate	Standard Error	*t*
Intercept (Manipulation Level: normal Morphological Tense: past Vowel Quality: lax)	5.471	0.171	31.908
Manipulation Level: long	-0.019	0.024	-0.793
Manipulation Level: longest			
Manipulation Level: short	0.027	0.024	1.086
Manipulation Level: shortest			
Previous Reaction Time (ms)	0.157	0.025	6.250
Morphological Tense: present	-0.147	0.055	-2.693
NDL Cue Association Strength (scaled and centred)	-0.021	0.038	-0.556
Phonological Neighbourhood Density (scaled and centred)	0.033	0.025	1.304
Vowel Quality: tense	0.085	0.084	1.011

Low NDL Group			
Predictor	Estimate	Standard Error	*t*
Intercept (Manipulation Level: normal Morphological Tense: past Vowel Quality: lax)	5.137	0.243	21.161
Manipulation Level: long	-0.083	0.039	-2.144
Manipulation Level: longest	0.011	0.038	0.294
Manipulation Level: short			
Manipulation Level: shortest			
Previous Reaction Time (ms)	0.195	0.035	5.566
Morphological Tense: present	-0.094	0.068	-1.376
NDL Cue Association Strength (scaled and centred)	0.000	0.032	-0.003
Phonological Neighbourhood Density (scaled and centred)	0.014	0.041	0.326
Vowel Quality: tense	0.320	0.141	2.265

All NDL Groups Combined			
Predictor	Estimate	Standard Error	*t*
Intercept (Manipulation Level: normal Morphological Tense: past Vowel Quality: lax)	5.551	0.121	45.698
Manipulation Level: long	-0.029	0.019	-1.547
Manipulation Level: longest	0.016	0.030	0.520
Manipulation Level: short	0.034	0.019	1.744
Manipulation Level: shortest	0.060	0.030	1.997
Previous Reaction Time (ms)	0.133	0.018	7.581
Morphological Tense: present	-0.106	0.035	-3.068
NDL Cue Association Strength (scaled and centred)	-0.041	0.021	-1.946
Phonological Neighbourhood Density (scaled and centred)	0.045	0.017	2.612
Vowel Quality: tense	0.097	0.043	2.269

4.2.2 Experiment II: Morphological Decision

Experiment II follows from the procedure, stimuli, and analysis presented in Experiment I. Rather than focusing the experimental task on word recognition, Experiment II focuses on morphology recognition in a morphological decision paradigm.

4.2.2.1 Experiment Stimuli Lists

Stimulus items from Experiment I served as the basis for the experiment stimuli lists in Experiment II. For the morphological decision experiment, the 9 noun Filler items and their 18 Nonword counterparts were removed from each of the 12 items list versions. This yielded 126 pseudowords and 45 real words (18 Target items + 27 Filler items), for a total of 171 items per morphological decision list. As with Experiment I, lists were pseudo-randomized and counterbalanced into 12 experiment versions.

4.2.2.2 Participants

Similar to Experiment I, participants for Experiment II were also university students completing the experiment as partial credit for a research participation requirement in an introductory linguistics course. No student participated in both Experiment I and Experiment II. Experiment II consists of responses from 69 participants (51 identified as female, 17 identified as male, 1 identified as other gendered; mean age was 19.58 years). As with Experiment I, participants were evenly distributed across each of the 12 experiment versions insofar as possible.

4.2.2.3 Procedure

The overall procedure for Experiment II is the same as Experiment I. In the morphological decision experiment, however, participants were asked to respond by pressing “past” or “present” on a button box to indicate whether the word “she” clearly said (from the frame sentence "She clearly said _____ today") was in the past or present tense. Additionally, for the morphological experiment only, participants were told that some of the words "she" said were made-up English verbs. Participants were asked to decide on instinct whether these made-up words sounded more like they were referring to the past or present tense.

4.2.2.4 Statistical Analysis

Error rates for the real words in the lexical decision task were 6.7%, while error rates for the real words in the morphological decision task were 22.5%. Because the morphological decision task was harder than the lexical decision task, the percentage of correctness threshold was lowered for discarding participant responses. Participants that did not respond correctly for 60% or more of the time were excluded (n=8). Reaction times less than 200 ms and greater than 2.5

standard deviations from the means were excluded (n=390). The following statistical analyses are based on correct responses only (n=807).

The LMER analyses of the reaction time data for Experiment II proceeded in the same way as Experiment I. Statistical models were created for each NDL group separately, and a secondary analysis combined all NDL groups together. The same dependent variable, set of predictors, and random effects structure in Experiment I were used in Experiment II. A simple Pearson's test for correlation found no colinearity between any of the numeric predictors. All two- and three-way interactions were checked amongst the predictors; none were statistically significant. For the morphological decision experiment, six predictors (NDL cue association strength, morphological tense, frequency, trial, age, and gender) were thus omitted from the final morphological decision model.

A full listing of the lexical decision model's coefficients is given in the Appendix (Table A.24). Below is a discussion of the results of interest.

4.2.2.5 Results and Discussion

Overall, morphological decision reaction times were 340 ms longer than lexical decision reaction times ($t = -22.684$, $df = 1209.797$, $p < 0.001$). Along with the increased proportion of incorrect responses, the slower responses in the morphological decision task indicate that the task was much harder than the lexical decision task in Experiment I.

Table 4.3 (below) shows the LMER coefficients for four models: one for each NDL group in the primary analysis (by-NDL group: high, mid, and low) and one for the secondary analysis (all NDL groups combined). It is possible that the duration manipulations affect the morphological processing of each NDL group differently (since each NDL group was manipulated differently), so by-NDL-group analyses were first conducted. The by-NDL-group analyses indicate that lexical decision reaction times were affected by vowel duration manipulation only when the word belonged to the mid NDL group (shown in Figure 4.2 in blue and with asterisks; the normal vowel duration level is shaded). Whereas duration manipulation affected response times at the tail ends of the NDL cue association strength scale in Experiment I, response times for words in the middle scale were affected in Experiment II. Words with a middle level of NDL cue association strength that contained a ‘short’ level of vowel duration manipulation are responded to significantly slower than words without duration manipulations. This follows the trend displayed in Experiment I where shorter words were more difficult to process.

A secondary analysis with all vowels combined, however, did not find a significant effect of vowel duration manipulation across all NDL groups. Model criticism shows no preference for removing or including the duration manipulation predictor (leaving out the predictor - AIC: 624; leaving in the predictor - AIC: 627). It was predicted that processing would be more difficult (as reflected in slower reaction times) when acoustic enhancement is instead given to vowels that are discouraging of the past tense (reversing the Tucker et al. findings), and when vowels with a strong association with the past tense are reduced. My hypothesis is not supported: the NDL-duration relationship attested for in production is not necessarily facilitatory in the morphological processing irregular English verbs.

Interestingly, I do not find any effect of NDL cue-to-tense association strength on morphological processing. As NDL cue-to-tense association strength gauges how strongly associated a particular vowel is with the past tense, it is surprising that this measure of paradigmatic support is not predictive of morphological processing (as measured in the current experiment). The lack of predictive significance for vowels’ duration manipulation and NDL association strengths in the current experiment leads me to believe that Experiment II does not gain much more understanding about a possible link between production and processing. The manipulation of the production-based NDL-duration relationship had no real significance in morphological processing under the current paradigm. Given the more difficult nature of the morphological decision task, it is possible that there is additional noise and unaccounted for variation in my data. A comparison of the residual errors in the morphological decision and lexical decision LMER models illustrates this possibility (lexical decision residual error

= 0.0753; morphological decision residual error: 0.1154). Overall, there is more research to be done in this method of investigating morphological processing.

Though I did not find an effect of NDL or duration manipulation in the morphological decision analysis, I do find a strong effect of neighbourhood density. Here, the effect of neighbourhood density is the same as its effect in the lexical decision analysis: words with more dense phonological neighbourhoods were responded to slower than words from sparser phonological neighbourhoods. This pattern again provides more support for Wright's (1997, 2004) predictions based on speakers' productions.

Table 4.3 Table of coefficients for the morphological decision experiment (Experiment II) for models with NDL groups separated and combined.

High NDL Group				Mid NDL Group			
Predictor	Estimate	Standard Error	*t*	Predictor	Estimate	Standard Error	*t*
Intercept (Manipulation Level: normal)	5.557	0.328	16.919	Intercept (Manipulation Level: normal)	5.495	0.247	22.257
Manipulation Level: long				Manipulation Level: long	0.008	0.043	0.193
Manipulation Level: longest				Manipulation Level: longest			
Manipulation Level: short	0.028	0.062	0.446	Manipulation Level: short	0.086	0.042	2.034
Manipulation Level: shortest	0.027	0.064	0.422	Manipulation Level: shortest			
Previous Reaction Time (ms)	0.173	0.047	3.706	Previous Reaction Time (ms)	0.191	0.034	5.552
Phonological Neighbourhood Density (scaled and centred)	0.027	0.028	0.975	Phonological Neighbourhood Density (scaled and centred)	0.036	0.020	1.792

Low NDL Group				All NDL Groups Combined			
Predictor	Estimate	Standard Error	*t*	Predictor	Estimate	Standard Error	*t*
Intercept (Manipulation Level: normal)	4.877	0.331	14.746	Intercept (Manipulation Level: normal)	5.519	0.176	31.366
Manipulation Level: long	-0.091	0.062	-1.453	Manipulation Level: long	-0.019	0.032	-0.599
Manipulation Level: longest	-0.050	0.065	-0.769	Manipulation Level: longest	-0.027	0.048	-0.559
Manipulation Level: short				Manipulation Level: short	0.050	0.033	1.540
Manipulation Level: shortest				Manipulation Level: shortest	-0.003	0.051	-0.051
Previous Reaction Time (ms)	0.279	0.047	5.995	Previous Reaction Time (ms)	0.186	0.025	7.551
Phonological Neighbourhood Density (scaled and centred)	0.031	0.028	1.115	Phonological Neighbourhood Density (scaled and centred)	0.043	0.014	3.107

4.3 General Discussion

The goal of Experiments I and II was to test whether a relationship between acoustic details and linguistic properties found in speech production is of consequence to speech processing. The Experiments find that manipulating Tucker et al.'s production-based NDL-duration relationship does not strongly affect processing in the lexical and morphological decision tasks overall. It appears that the effect the NDL-duration relationship has on processing is somewhat mitigated by the task at hand. While manipulations to the relationship weakly affect words belonging to the tail ends of the NDL cue association strength scale in the lexical decision task, the same manipulations weakly affect words in the middle of the NDL cue association strength scale in the morphological decision task. However, when pooling together all NDL cue association strengths, it is apparent that manipulating the duration of vowels does not affect processing in directions that are otherwise not predicted by other theoretical assumptions, such as H&H Theory (Lindblom, 1990).

However, Experiment I finds that NDL cue-to-tense association strengths are facilitatory in lexical decision. Though I originally predicted that manipulating acoustic detail will cause a disruption in the link between production and processing, I find instead that stronger links between form and meaning (i.e. greater NDL cue association strengths) correlate with both the enhancement of acoustic details and the enhancement of processing speed. In this way, speech production and processing are linked.

Moreover, I find support for Wright's (1997, 2004) predictions made about neighbourhood density: words from more dense neighbourhoods are produced with more enhanced acoustic details when they correlate with more processing effort (greater reaction times), as seen in both the lexical and morphological decision tasks. The effects of neighbourhood density on processing suggest that a correlation, or a link, between speech production and speech processing does exist.

Taken together, the Experiments here also suggest that lexical and morphological decision tasks may make use of different cues. The processing of lexical recognition is affected by the linguistic properties of neighbourhood density, NDL cue association strength, and morphological tense. However, the processing of morphological recognition corresponds only with neighbourhood density. Whereas some processing theories assume that the recognition of a word also accesses the word's morphology (such as Manelis and Tharp, 1977), the current analyses show that is possible that explicit morphological recognition is processed differently than recognizing a word as an existing lexical form. Different cues can play a more influential role for different tasks. The possibility of morphological and lexical processing using different cues is a future area of research. It would be interesting to directly test the difference in cue usage between the two processing tasks. This would provide further evidence for a more nuanced link between production and processing: the link is strengthened depending on task and cue, which could allow more graded predictions about the role of acoustic detail in speech production and processing.

Thus, the current study highlights the importance of conducting follow-up processing studies to qualify the simple, straightforward generalizations made in production studies about the role of acoustic detail in speech. As production is only one half of the speech system, any predictions made about the purpose of producing acoustic detail and its processing consequences should be tested in subsequent processing-based experiments.

4.4 Conclusion

The current chapter has found support for the processing consequences of a relationship that exists between acoustic detail and a linguistic property, as attested for in spontaneously produced speech. Results gathered from lexical decision and morphological decision experiments point towards the need to reevaluate the role of acoustic detail in speech. This stems from two approaches towards the processing of acoustic detail that previous research in speech production have taken: acoustic detail is either facilitatory for processing, or is facilitatory for production. Instead of dichotomizing the role of acoustic detail into either production-based (no link between production/processing) or processing-based (strong link between production/processing) approaches, the current chapter discusses a different approach towards understanding the role of acoustic detail: acoustic detail provides a weak link between speech production and processing.

It is proposed that the production of acoustic detail has the potential to play a facilitatory role in speech processing, but not necessarily so. Therefore, production studies should interpret relationships between production data and its subsequent processing with caution. The current study also finds that the relationship between acoustic detail and a linguistic property might be facilitatory in one type of processing (e.g., morphological decision) but not in another (e.g., lexical decision).

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Chapter 5: Conclusions

This dissertation has investigated the production and processing of acoustic detail in spontaneous speech. The study of acoustic detail in this dissertation was limited to vowels' formant trajectories, dispersions, and durations within a subset of irregular English verbs from the Buckeye Corpus of Conversational English (Pitt et al., 2007). The two production studies in this dissertation focus on how spontaneously produced vowel formants compare to research on carefully produced vowel formants, as well as how linguistic properties influence acoustic detail. The set of recognition experiments in this dissertation evaluate how the relationship between vowel duration and morphology affect processing.

In what follows, the general findings of the three studies contained in this dissertation are reiterated to answer the research questions posed in the first Chapter of this dissertation. The implications of these results for current theories of the mental lexicon are then discussed. In the discussion of the mental lexicon, the current Chapter first asserts one theoretical stance that best captures the relationship between morphology and the mental lexicon as seen in the Studies presented in this dissertation. The remainder of this Chapter then discusses the main focus of this dissertation: the representation of acoustic detail in the mental lexicon.

5.1 General Findings

Overall, the three Studies presented in this dissertation find support for the inclusion of variation in both the production and processing of acoustic detail. Different types of variation in acoustic detail is seen in all three Studies: for Study 1, there is variation in the production of phonetic details; for Study 2, there is variation in how phonetic details are modulated by morphology; and for Study 3, there is variation in how acoustic variation facilitates lexical and morphological processing.

5.1.1 Study 1 - Dynamic Formant Movement in Spontaneous Speech Vowels

The first study of this dissertation focuses on the presence of formant movement in spontaneous speech. It asks whether the quick nature of spontaneous speech allows for the types of formant trajectory patterns seen in citation speech (Nearey, 1989), and, if there are such patterns, whether formant movement can be captured by current VISC models (Morrison and Nearey, 2007; Morrison, 2013).

To address these questions, formant trajectories were gathered from all the vowels in a subset of irregular English verbs. These formant trajectories were both descriptively and statistically analyzed for their amount and direction of movement, using vowel plots, simple tests of significant differences (t-tests), and Linear Mixed-Effects Regression modelling techniques. Subsequent discriminant analyses evaluated how the formant trajectory patterns were captured under three hypotheses of vowel formant movement.

The results of Study 1 indicate that though vowels in spontaneous speech are shorter in duration than vowels in careful speech, they nevertheless display formant trajectory patterns that are reminiscent of careful speech patterns. Though it has been predicted that coarticulation and vowel space centralization effects would inhibit the production of formant trajectory patterns (Strange et al., 1989), the results of Study 1 indicate otherwise. Moreover, the spontaneously produced formant trajectory patterns found in Study 1 are best captured by the same onset-offset phonetic model that better captures carefully produced formant trajectory patterns.

Taken together, the findings of Study 1 highlight the nature of acoustic variation in spontaneous speech in the context of one measure of phonetic detail (formant movement). Formant movement is highly variable not only amongst vowels but amongst productions of the same vowel. Nevertheless, a pattern of formant movement emerges for most (though not all) spontaneously produced vowels in this subset of irregular English verbs.

5.1.2 Study 2 - Morphological Influence of Vowel Dispersion and Dynamic Formant Movement

The second study of this dissertation expands upon Study 1 by investigating how linguistic parameters correlate with the production of acoustic detail. Specifically, Study 2 asks whether the formant trajectory patterns in Study 1 are influenced by morphology and morphological paradigms. This question is prompted by two theoretical assumptions: 1) linguistic uncertainty is balanced with phonetic enhancement (Aylett and Turk, 2004, 2006); 2) more paradigmatic support correlates with phonetic enhancement (Kuperman et al., 2007).

The formant data were evaluated for their correlation with morphological uncertainty and paradigmatic support using global models (data pooled across all vowels) of formant dispersion, deviation from vowel onset and offset, and formant movement. These models indicate an overall effect of morphology and paradigmatic support on the production of vowel formants. Further analyses were conducted to test for effect of morphological uncertainty and paradigmatic support when the formant data was split by vowel. These additional results in Study 2 indicate that the effects of morphological uncertainty and paradigmatic strength on the production of the formant data are better captured in the by vowel analyses. This is discussed in terms of model comparison and better representation of the data in the predictive trends.

As such, Study 2 highlights the importance of allowing fractionation, or by item subtype analyses, in models of speech production.

5.1.3 Study 3 - The Role of Acoustic Detail: Evidence from Lexical and Morphological Processing

Finally, the third study of this dissertation expands upon Study 2 by investigating the subsequent processing of an acoustic detail/linguistic property relationship. The basis for Study 3 is the untested assumption that production and processing are linked by acoustic detail (Lindblom, 1990; Aylett and Turk, 2004, 2006). Study 3 experimentally manipulates an attested measure of acoustic detail (vowel duration; Tucker et al., in preparation) and investigates its combined effect with a linguistic property (morphological NDL cue association strength) on processing.

Study 3 uses stimuli with vowels whose durations were manipulated to be the opposite of that predicted by Tucker et al. based on their NDL cue association strengths. The effect of manipulating the duration-NDL relationship is then tested in lexical and morphological decision experiments. The rationale is that if a produced vowel duration corresponded to NDL cue association strength in a way that aids in processing (as is the hypothesis being tested), disrupting the relationship will in turn disrupt processing.

The results of Study 3 find inhibition in processing; however, the inhibition is not correlated with disrupting the NDL-duration relationship. Instead, Study 3 finds that irrespective of vowel duration, neighbourhood density and morphological paradigmatic support (i.e. NDL cue association strengths) influence processing speed. Both lexical and morphological recognition were inhibited when words had more phonological neighbours, and lexical recognition was inhibited when words had weak paradigmatic support. Previous research on speech production has found that 'hard’ words with more phonological neighbours (Wright, 1997, 2004) and words with more paradigmatic support (Kuperman et al., 2007; Tucker et al., in preparation) are phonetically enhanced (e.g. are produced with longer durations). These production-based studies predict that phonetic enhancement is used by listeners to distinguish between 'hard' words and disambiguate morphological tense. Study 3 finds support for these production-based predictions. In this way, speech production and speech processing are linked.

Thus, Study 3 finds that the role of acoustic detail in speech processing is different than what was originally predicted. It was originally predicted that acoustic detail's role is captured in its distinct patterns with linguistic properties (if these distinct patterns are disrupted, processing will be inhibited). However, Study 3 finds that these distinct patterns are of less importance in speech perception than originally predicted. Instead of acoustic detail necessarily providing cues for perception (i.e., a strong link between production and processing), Study 3 shows that acoustic detail has the potential to provide cues for perception (i.e., a weaker link between production and processing). As compared to acoustic detail, linguistic properties provide a stronger link between speech production and perception. Linguistic properties such as neighbourhood density and paradigmatic support correlate with enhancement in both speech production (longer durations) and perception (faster processing).

5.2 Theoretical Implications for the Mental Lexicon

The remainder of the current Chapter discusses the implications from the three Studies reviewed above on the structure of the mental lexicon and the mental representation of acoustic detail. The three Studies contained in this dissertation address this question by analyzing the acoustic differences in the production and processing of different morphological forms. It is therefore prudent to first establish a theoretical stance on the mental representation of morphology. This stance will set the framework within which the mental representation of acoustic detail will be discussed.

5.2.1 The Representation of Morphological Information

Since the main focus of the current dissertation (the mental representation of acoustic detail) hinges on morphological production and processing, it is necessary to first discuss the mental representation of morphology. Recall from Chapter 1 that there are three main approaches to the representation of morphology: the morphology-process approach, morphology-storage approach, and morphology-generalization approach. Each of these approaches makes different predictions about the relationship between morphological information and the mental lexicon. These predictions are evaluated here in the context of the results of Studies 2 and 3 presented in this chapter.

The morphology-process approach states that morphological information is stored and accessed independently of both lexical representation and the acoustic signal, but connects the two (Taft and Forster, 1975; Marsden-Wilson, 1994a&b; Levelt et al., 1999; Cohen-Goldberg, 2013). Because the morphological process encodes morphological information only, this approach would lead one to predict that morphology does not play a direct role in the production of acoustic detail. However, Study 2 suggests that there is indeed a direct effect of morphology on the production of acoustic detail.

Moreover, Study 3 finds a direct effect of morphology on the subsequent processing of acoustic detail. Because morphological decoding must first happen to gain access to lexical representations, the morphology-process approach would also predict that lexical recognition entails morphological recognition. Should morphological recognition be difficult to process, lexical recognition will also be difficult to process. However, Study 3 shows that lexical processing and morphological processing were affected by different experimental conditions. In light of these production and processing results, this dissertation does not support a morphological-process view of the mental lexicon.

The morphology-storage approach, on the other hand, posits that related words with different morphological forms may be produced with differences in acoustic detail (Manelis and Tharp, 1977; Stemberger and MacWhinney, 1986; Caramazza, 1988). However, these differences in acoustic detail can only be attributed to differences in lexical storage. That is, this approach does not stipulate *patterns* of morphological influence, as morphological information (and, subsequently, its effects) is not inherently generalizable, but an individual property of each mental representation.

The same is true for generalizing morphological patterns in speech recognition. Any differences in processing various morphological forms can only be attributed to accessing the individual lexical representations of those forms since there is no mechanism to account for any overarching morphological association. However, the results of Study 2 and Study 3 do find evidence for such patterns of influence, both in production and processing. Though these patterns are variable in terms of their direction and magnitude of effect, they nevertheless are generalizable across morphological forms. So, the results of this dissertation do not support a morphological-storage approach.

The predictions made by the morphology-generalization approach best capture the results of this dissertation. This approach predicts that morphological information directly affects production and the processing of word meanings (Seidenberg and Gonnerman, 2000; Baayen et al., 2011). Specifically, the connection between acoustic form (input/output, or the speech signal) and the mental lexicon (storage of meanings) depends on learned morphological associations that are specific to each form-meaning connection. These connections will vary - for example, in speech production, morphology may correlate with vowel enhancement for one form-meaning pairing, and vowel reduction for another form-meaning pairing. That is, the individual patterns between morphology and acoustic details may vary between different conditions. But an overall pattern emerges: morphology correlates with acoustic detail. Thus, these learned associations can be generalized into a statistical pattern of morphological influence. Both Studies 2 and 3 call for such variation in morphological influence.

The results of this dissertation are best interpreted using the morphological-generalization approach towards the relationship between morphology and the mental lexicon. By adopting this approach, it is proposed that morphology has a direct and gradient influence both in the representations in the mental lexicon and in the acoustic signal. The Studies in this dissertation were not specifically designed to test such an assumption. The research questions tested and the hypotheses proposed in the Studies were not formulated to specifically test the representation of morphology. However, because the morphological-generalization approach lends itself to a more harmonious interpretation of the results in this dissertation, it is adopted in order to serve as a framework for evaluating the mental representation of acoustic detail.

5.2.2 The Representation of Acoustic Detail

Having adopted a morphological-generalization view of the lexicon, this section turns towards the representation of acoustic detail. It will become apparent that this relationship (i.e., whether acoustic detail resides inside or outside of the lexicon) follows from the morphological-generalization assumption I have just established. In the next section, the results of this dissertation's Studies are briefly discussed in terms of current theories of the mental lexicon.

5.2.2.1 The Representation of Acoustic Detail in Current Theories of the Mental Lexicon

The representation of acoustic detail can loosely be defined in terms of the speech system level in which it resides: at the top (mental representations), or at the bottom (phonetic implementation). As such, there are two broad views about the status of acoustic detail in the mental lexicon. The first holds that all instances of acoustic detail are stored with lexical representations in the mental lexicon (acoustic-detail-storage accounts). The second holds that abstract phonological forms are extracted from acoustic detail, and these abstract phonological forms are stored in the mental lexicon (acoustic-detail-abstraction accounts).

The results found in the current Studies do not wholly support either the acoustic-detail-storage account or acoustic-detail-abstraction account. This dissertation finds evidence for the acoustic signal to be both directly and variably influenced by morphology. Neither the acoustic-detail-storage account nor the acoustic-detail-abstraction account is able to account for both direct and variable influences of morphology. Acoustic-detail-storage accounts view acoustic detail in terms of lexical representations. Under an acoustic-detail-storage approach to the mental lexicon, lexical representations are fully specified for their phonological form. For example, the presence of variation in the acoustic details amongst words of different morphological forms is inferred to be the result of a direct property of the particular words, rather than directly effected by a morphological pattern.

A lack of direct morphological influence on the realization of acoustic detail is also indicative of acoustic-detail-abstraction accounts. Unlike acoustic-detail-storage, acoustic-detail-abstraction views acoustic details as noise. Here, the phonological forms of a lexical representation are discrete abstractions stripped of any acoustic variation. It is these phonological abstractions that interface with higher levels of speech processing (such as morphology and lexical representations). Any higher levels in the processing system (such as morphology), then, have no direct influence on the acoustic detail in the speech signal. However, Studies 2 and 3 show that a higher level of processing (morphology) does have a direct influence on the production and processing of the speech signal.

5.2.2.2 Contributions of the Current Dissertation to the Representation of Acoustic Detail and the Mental Lexicon

Since neither acoustic-detail-storage accounts nor acoustic-detail-abstraction accounts can readily accommodate the results presented in this dissertation, an alternative framework for the relationship between acoustic detail and the mental lexicon is proposed. This alternative framework centres on both the adoption of a morphological-generalization approach towards the mental lexicon and the central findings of this dissertation: acoustic detail variably affects both speech production and speech processing.

The variable nature of acoustic detail in speech processing entails that acoustic detail (such as vowel duration) acts as a potential cue to aid in encoding and decoding the acoustic signal, though whether acoustic detail serves as a speech processing facilitator is dependent upon task and condition. The adoption of a morphological-generalization approach towards the mental lexicon further entails that the presence of acoustic detail is the result of learned association patterns between the acoustic signal (form) and mental lexicon representations (meaning). According to the results presented in this dissertation, the relationship between the mental lexicon and acoustic detail, then, must be contained in task/condition dependent association patterns.

The linguistic system offers several tools to derive form and meaning from one another. One such tool is the statistically learned pattern between morphology and vowel formants (i.e., the relationship between a linguistic property and a measure of acoustic detail). Another tool is the statistically learned pattern between morphology and vowel dispersion; and yet another tool is the statistically learned pattern between word frequency and vowel duration, and so on. These tools are developed and refined (or learned) as the language user encounters them. A language user can add to his knowledge of, for example, his morphology/vowel dispersion tool by learning that this particular tool is associated with phonetic enhancement for one form/meaning pairing, and phonetic reduction for a different form/meaning pairing. Just as a hammer can have variable uses (it can both drive a nail into a wall and pull it out), so can a morphology/vowel formant tool (it can both enhance and reduce the speech signal). This accounts for the variable nature of relationships between acoustic detail and linguistic parameters. Whereas previous research assumes the relationship between acoustic detail and linguistic parameters is ubiquitous (Aylett and Turk, 2004, 2006), Study 2 of this dissertation finds that this effect is less severe.

The tool analogy can also account for the variable role acoustic detail places in speech processing. Whereas previous studies assume linguistic property/acoustic detail relationships necessarily affect speech processing (Lindblom, 1990), Study 3 of this dissertation finds that this effect is dependent on task and condition. A particular linguistic tool is used only when the task and condition at hand call for its use. Just as a hammer would not be used in tightening a screw, a morphology/vowel duration tool would not be used in recognizing morphological information when the diphone/paradigmatic association strength tool is more informative. That is to say, some tools are not associated with some tasks and conditions.

This dissertation accounts for the variable nature of morphological influence on acoustic detail in speech production and processing by viewing the morphology/acoustic detail relationship as a potential tool at speakers' and listeners' disposal. The relationship between acoustic detail and the mental lexicon lies in statistical associations with linguistic properties between speech signal forms and mental representation meanings. In this way, production and processing are weakly linked. The acoustic detail tool is available for production and processing (i.e., they are linked), but the tool need not be used all the time (i.e., the link is weak). When a particular measure of acoustic detail will be used as a tool is determined by the statistical learning of associations between production and processing. This conclusion is drawn based on the assumption that morphology has a direct and variable influence on the processing of acoustic detail, which is not assumable under several theories of representations in the mental lexicon.

Thus, the role of acoustic detail in the mental lexicon is to serve as a tool in forming statistically learned associations between speech production and speech processing. The use of the information provided by acoustic details is dependent upon one's learned associations between form and meaning, which can capture (amongst other things) linguistic task and condition.

5.3 Future Research

This dissertation offers several proposals for pursuing further research in the processing of acoustic detail. In addition to the directions of future research offered in Chapters 2, 3, and 4 for the individual Studies, a few broader areas of possible work are outlined here:

- Performing experimentation in both speech production and speech recognition in tandem to gain a broader picture of how the two are linked: It would be of interest to extend the Studies contained in this dissertation to other measures of acoustic detail and linguistic properties. Replication of the variable findings seen in this dissertation would provide more evidence for the mental representation of acoustic detail.
- Testing for the explicit knowledge of these linguistic properties/acoustic detail relationships in order to study the status of the relationships in the mental lexicon: For example, if it is found that people do have explicit knowledge of these relationships, it would suggest that they are stored within the mental lexicon.
- Conducting more ecologically valid experiments on spontaneous speech: This dissertation finds that task and condition play a role in speech recognition (see also Ernestus et al., 2002). If the goal of research on acoustic detail is to understand how humans process speech on an everyday basis, then tasks and conditions related to the everyday use of language should be examined. This extends to the use of more ecologically valid speech corpora, such as databases of spontaneous speech.
- Embracing the acoustically variable nature of the speech signal and the variability with which it is used in speech processing: The use of less ecologically valid experimental designs often comes from the need to impose control over an inherently variable phenomenon. This imposition of control, however, leads to oversimplified generalizations about the speech system. With the development of new statistical techniques and quantitative theories of linguistics, there is a growing possibility of gleaning meaningful inferences over inherently variable phenomena.

Overall, these areas of further exploration will bring linguistic research closer to a better understanding of the role of acoustic detail and its implications for theories of speech production and processing.

5.4 Concluding Remarks

This dissertation studied the production of acoustic detail, the influence of morphology on acoustic variation in speech production, and the consequences of that influence on speech processing. The three Studies presented in this dissertation find evidence for 1) patterns of formant movement in spontaneous speech, 2) variable morphological influence of those patterns in speech production, and 3) morphological and vowel duration facilitation effects in speech processing. These results are interpreted under the assumption that the relationship between morphology and the mental lexicon is contained in associations, or connections, between the speech signal and mentally stored meanings. While adopting this view of the speech system, this dissertation contributes a new framework for evaluating the relationship between the mental lexicon and acoustic detail. This framework stipulates that different correlations between acoustic detail and linguistic properties, as contained in associations between form/meaning, provide different tools that are available to the language user for both encoding and decoding the speech signal. As a tool in the speech system, acoustic detail can play many roles in speech production and speech processing. Ultimately, understanding the uses of acoustic detail will lead to a better understanding of the human capacity for speech.

5.5 References

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Appendix

A.1 Supplementary Information for Chapter 2

Table A.1: Information about the voicing of the surrounding phonetic context and gender.

Vowel	Voicing	Sex	Frequency in Previous Segment	Frequency in Following Segment
a	voiced	female	1995	1547
		male	2464	1827
	voiceless	female	112	553
		male	126	749
æ	voiced	female	133	182
		male	77	189
	voiceless	female	49	0
		male	119	7
ʌ	voiced	female	700	1442
		male	1267	1869
	voiceless	female	917	147
		male	1106	371
ɔ	voiced	female	63	217
		male	91	322
	voiceless	female	224	56
		male	301	35
ɛ	voiced	female	1743	1267
		male	1414	1120
	voiceless	female	98	567
		male	154	448
ɪ	voiced	female	3136	2352
		male	3899	2870
	voiceless	female	511	1295
		male	581	1596
i	voiced	female	504	1666
		male	350	1610
	voiceless	female	1869	504
		male	1967	462
o	voiced	female	5327	3710
		male	6139	4403
	voiceless	female	91	686
		male	84	658
ʊ	voiced	female	14	49
		male	21	49
	voiceless	female	420	385
		male	413	378
u	voiced	female	567	539
		male	672	658
	voiceless	female	126	84
		male	161	140

Table A.2: Information about the place of articulation in the surrounding phonetic context and gender.

Vowel	Place	Females: Frequency in Previous Segment	Females: Frequency in Following Segment	Males: Frequency in Previous Segment	Males: Frequency in Following Segment
a	alveolar	35	1127	35	1645
	consonant	0	7	0	14
	dental	0	0	0	7
	diphthong	0	7	28	35
	glottal	0	777	0	630
	labial	7	91	0	70
	labio-dental	14	0	35	14
	lax	0	77	0	133
	palatal	2023	14	2436	28
	palato-alveolar	21	0	49	0
	rhotic	0	0	0	0
	tense	7	0	7	0
æ	alveolar	126	140	126	91
	consonant	0	0	0	0
	dental	0	0	0	0
	diphthong	0	0	0	0
	glottal	21	14	49	14
	labial	0	0	0	0
	labio-dental	14	0	0	7
	lax	0	0	0	0
	palatal	21	28	21	77
	palato-alveolar	0	0	0	0
	rhotic	0	0	0	7
	tense	0	0	0	0
ʌ	alveolar	581	343	1036	385
	consonant	0	0	0	7
	dental	0	56	7	63
	diphthong	0	14	35	49
	glottal	7	77	35	245
	labial	56	889	42	973
	labio-dental	0	0	14	21
	lax	14	154	28	259
	palatal	959	49	1169	182
	palato-alveolar	0	0	0	35
	rhotic	0	0	7	0
	tense	0	7	0	21
ɔ	alveolar	196	119	336	98
	consonant	0	0	0	7
	dental	0	56	0	49
	diphthong	0	0	0	0
	glottal	14	49	0	7
	labial	21	14	21	21
	labio-dental	49	0	35	0
	lax	0	35	0	154
	palatal	7	0	0	7

	palato-alveolar	0	0	0	0
	rhotic	0	0	0	0
	tense	0	0	0	14
ɛ	alveolar	210	1288	147	1036
	consonant	0	7	0	7
	dental	0	28	0	14
	diphthong	0	7	0	28
	glottal	21	455	28	301
	labial	385	21	266	77
	labio-dental	28	7	21	7
	lax	14	14	7	77
	palatal	1183	7	1092	21
	palato-alveolar	0	0	0	0
	rhotic	0	0	0	0
	tense	0	0	7	0
ɪ	alveolar	532	2268	567	2702
	consonant	0	7	0	21
	dental	0	35	0	56
	diphthong	0	21	0	21
	glottal	7	672	14	658
	labial	0	42	35	182
	labio-dental	0	406	7	567
	lax	21	91	14	98
	palatal	3059	98	3801	140
	palato-alveolar	7	0	21	14
	rhotic	0	0	0	7
	tense	21	7	21	0
i	alveolar	2051	609	2044	504
	consonant	14	14	0	7
	dental	0	371	0	252
	diphthong	28	42	0	42
	glottal	0	126	0	119
	labial	140	308	182	273
	labio-dental	35	28	21	42
	lax	49	469	28	567
	palatal	0	126	35	182
	palato-alveolar	0	21	7	21
	rhotic	14	21	0	21
	tense	42	35	0	42
o	alveolar	5285	273	5747	546
	consonant	0	28	0	42
	dental	14	595	0	700
	diphthong	14	483	28	259
	glottal	35	273	70	252
	labial	14	1281	14	1428
	labio-dental	0	126	0	84
	lax	21	1001	224	1295
	palatal	7	189	112	294

	palato-alveolar	28	70	0	35
	rhotic	0	7	0	14
	tense	0	70	28	112
ʊ	alveolar	420	0	427	0
	consonant	0	0	0	0
	dental	14	7	0	0
	diphthong	0	0	0	0
	glottal	0	0	0	7
	labial	0	0	0	7
	labio-dental	0	0	0	0
	lax	0	21	0	21
	palatal	0	406	7	392
	palato-alveolar	0	0	0	0
	rhotic	0	0	0	0
	tense	0	0	0	0
u	alveolar	553	140	665	154
	consonant	0	0	0	0
	dental	0	133	14	105
	diphthong	0	35	0	7
	glottal	0	14	7	42
	labial	0	42	0	84
	labio-dental	0	7	0	14
	lax	0	217	0	350
	palatal	14	7	7	21
	palato-alveolar	126	0	140	7
	rhotic	0	0	0	0
	tense	0	28	0	14

Table A.3: Information about the manner of articulation in the surrounding phonetic context and gender.

Vowel	Manner	Females		Males	
		Frequency in Previous Segment	Frequency in Following Segment	Frequency in Previous Segment	Frequency in Following Segment
a	affricate	0	0	0	0
	approximate	7	21	35	21
	diphthong	0	7	28	35
	diphthong-nasal	0	0	0	0
	flap	0	525	0	889
	fricative	63	0	84	70
	lax	0	77	0	133
	lax-nasal	0	0	0	0
	nasal	0	56	35	63
	nonnasal	0	0	0	0
	rhotic	0	0	0	0
	rhotic-nasal	0	0	0	0
	stop	2030	1407	2401	1358
	syllabic	0	7	0	7
	tense	7	0	7	0
	tense-nasal	0	0	0	0
æ	affricate	0	0	0	0
	approximate	112	0	56	0
	diphthong	0	0	0	0
	diphthong-nasal	0	0	0	0
	flap	0	7	0	21
	fricative	49	0	119	7
	lax	0	0	0	0
	lax-nasal	0	0	0	0
	nasal	0	154	0	133
	nonnasal	0	0	0	0
	rhotic	0	0	0	7
	rhotic-nasal	0	0	0	0
	stop	21	21	21	28
	syllabic	0	0	0	0
	tense	0	0	0	0
	tense-nasal	0	0	0	0
ʌ	affricate	0	0	0	14
	approximate	322	28	217	98
	diphthong	0	14	7	49
	diphthong-nasal	0	0	28	0
	flap	0	28	7	70
	fricative	7	133	91	266
	lax	14	154	21	259
	lax-nasal	0	0	7	0
	nasal	287	1141	756	1176
	nonnasal	0	0	0	0

	rhotic	0	0	7	0
	rhotic-nasal	0	0	0	0
	stop	987	84	1232	287
	syllabic	0	0	0	0
	tense	0	7	0	21
	tense-nasal	0	0	0	0
ɔ	affricate	0	0	0	0
	approximate	49	91	70	84
	diphthong	0	0	0	0
	diphthong-nasal	0	0	0	0
	flap	0	14	0	0
	fricative	217	112	294	77
	lax	0	35	0	154
	lax-nasal	0	0	0	0
	nasal	7	7	21	21
	nonnasal	0	0	0	0
	rhotic	0	0	0	0
	rhotic-nasal	0	0	0	0
	stop	14	14	7	7
	syllabic	0	0	0	0
	tense	0	0	0	14
	tense-nasal	0	0	0	0
ɛ	affricate	0	0	0	0
	approximate	259	140	175	112
	diphthong	0	7	0	28
	diphthong-nasal	0	0	0	0
	flap	0	406	0	476
	fricative	70	35	91	63
	lax	14	14	7	77
	lax-nasal	0	0	0	0
	nasal	322	42	196	112
	nonnasal	0	0	0	0
	rhotic	0	0	0	0
	rhotic-nasal	0	0	0	0
	stop	1176	1190	1092	700
	syllabic	0	0	0	0
	tense	0	0	7	0
	tense-nasal	0	0	0	0
	affricate	7	0	7	14
	approximate	42	14	105	63
	diphthong	0	21	0	21
	diphthong-nasal	0	0	0	0
	flap	7	875	0	1043
	fricative	406	483	511	679
	lax	21	91	14	98

ɪ	lax-nasal	0	0	0	0
	nasal	42	70	7	252
	nonnasal	0	0	0	0
	rhotic	0	0	0	7
	rhotic-nasal	0	0	0	0
	stop	3101	2086	3815	2289
	syllabic	0	0	0	0
	tense	21	7	21	0
	tense-nasal	0	0	0	0
i	affricate	0	14	0	7
	approximate	266	224	154	245
	diphthong	28	42	0	42
	diphthong-nasal	0	0	0	0
	flap	0	147	0	98
	fricative	1771	539	1883	483
	lax	49	462	28	560
	lax-nasal	0	7	0	7
	nasal	98	98	126	105
	nonnasal	0	0	0	0
	rhotic	14	21	0	21
	rhotic-nasal	0	0	0	0
	stop	105	574	126	455
	syllabic	0	7	0	7
	tense	42	35	0	42
	tense-nasal	0	0	0	0
o	affricate	28	28	0	14
	approximate	364	1099	490	1477
	diphthong	0	483	0	259
	diphthong-nasal	14	0	28	0
	flap	7	28	14	56
	fricative	42	1106	70	1155
	lax	14	1001	175	1295
	lax-nasal	7	0	49	0
	nasal	4914	168	5341	196
	nonnasal	0	0	0	0
	rhotic	0	7	0	14
	rhotic-nasal	0	0	0	0
	stop	28	399	28	483
	syllabic	0	7	0	0
	tense	0	70	28	112
	tense-nasal	0	0	0	0
	affricate	0	0	0	0
	approximate	14	0	21	0
	diphthong	0	0	0	0
	diphthong-nasal	0	0	0	0

ʊ	flap	0	0	0	0
	fricative	14	7	7	0
	lax	0	21	0	21
	lax-nasal	0	0	0	0
	nasal	0	0	0	7
	nonnasal	0	0	0	0
	rhotic	0	0	0	0
	rhotic-nasal	0	0	0	0
	stop	406	406	406	399
	syllabic	0	0	0	0
	tense	0	0	0	0
	tense-nasal	0	0	0	0
u	affricate	77	0	56	0
	approximate	147	42	217	63
	diphthong	0	35	0	7
	diphthong-nasal	0	0	0	0
	flap	0	7	0	42
	fricative	49	231	105	217
	lax	0	217	0	350
	lax-nasal	0	0	0	0
	nasal	406	7	448	14
	nonnasal	0	0	0	0
	rhotic	0	0	0	0
	rhotic-nasal	0	0	0	0
	stop	14	56	7	91
	syllabic	0	0	0	0
	tense	0	28	0	14
	tense-nasal	0	0	0	0

Table A.4: Information about the vowels in the skewed contexts.

Vowel	Segment	Position Relative to the Vowel	Number of Tokens	Percent of All Contexts
/æ/	r	Previous	25	43.1
/ɛ/	g	Previous	310	59.39
/ɪ/	t	Following	934	72.23
/i/	s	Previous	514	74.49
/o/	n	Previous	1465	87.78

Table A.5: Coefficients for all statistical tests of significant difference (t-tests) in F1 and F2 onsets/offsets.

		F1			F2		
Sex	Vowel	*t*	df	*p*	*t*	df	*p*
combined	/ɑ/	-15.1249	1363.5646	< 0.0001	17.9218	1356.6325	< 0.0001
	/æ/	-0.7109	113.5317	0.4786	-0.7517	113.5557	0.4538
	/ʌ/	-1.2041	1261.3325	0.2288	5.4779	1257.3996	< 0.0001
	/ɔ/	-2.6044	229.3068	0.0098	2.5839	215.8241	0.0104
	/ɛ/	-9.4565	1041.7743	< 0.0001	6.8190	917.8200	< 0.0001
	/ɪ/	-13.4831	2587.0081	< 0.0001	14.4922	2466.4822	< 0.0001
	/i/	1.3911	1372.9665	0.1644	-8.0704	1377.0482	< 0.0001
	/o/	4.3909	3335.5521	< 0.0001	35.5412	3301.1423	< 0.0001
	/ʊ/	0.5656	242.2468	0.5722	2.5292	255.0060	0.0120
	/u/	-1.6402	452.2902	0.1017	7.6504	451.9113	< 0.0001
males	/ɑ/	-15.6961	737.7871	< 0.0001	16.9182	719.4579	< 0.0001
	/æ/	-0.1623	53.2227	0.8717	-0.9411	52.5563	0.3510
	/ʌ/	-1.7817	741.9516	0.0752	5.9019	718.6278	< 0.0001
	/ɔ/	-3.0494	128.5063	0.0028	2.4726	133.5978	0.0147
	/ɛ/	-8.1064	460.0874	< 0.0001	5.7659	395.9615	< 0.0001
	/ɪ/	-11.9196	1427.9808	< 0.0001	12.4234	1294.4411	< 0.0001
	/i/	1.5164	669.0459	0.1299	-7.4411	675.9984	< 0.0001
	/o/	2.8121	1782.9199	0.0050	24.4748	1777.3998	< 0.0001
	/ʊ/	0.1580	105.6833	0.8747	1.8719	129.8401	0.0635
	/u/	-1.3052	251.7107	0.1930	5.1424	251.5022	< 0.0001
females	/ɑ/	-12.5623	598.5682	< 0.0001	11.5263	604.9215	< 0.0001
	/æ/	-1.0659	57.3276	0.2910	-0.2328	55.5983	0.8168
	/ʌ/	-0.0878	518.4669	0.9301	2.5793	516.8187	0.0102
	/ɔ/	-1.3408	87.7809	0.1834	1.4575	77.7007	0.1490
	/ɛ/	-7.6961	577.0638	< 0.0001	5.2237	463.4531	< 0.0001
	/ɪ/	-9.3610	1155.4231	< 0.0001	12.4349	1091.4634	< 0.0001
	/i/	0.7895	698.3772	0.4301	-7.8321	699.2930	< 0.0001
	/o/	4.2203	1544.0125	< 0.0001	32.0401	1546.7384	< 0.0001
	/ʊ/	0.6481	121.3161	0.5181	2.3710	123.9969	0.0193
	/u/	-1.3937	200.0834	0.1650	6.6795	202.4229	< 0.0001

Table A.6: Coefficients for all linear mixed effects regression models of F1 and F2 onsets/offsets.

/ɑ/	F1			F2		
	Estimate	Std. Error	*t*	Estimate	Std. Error	*t*
Intercept	568.5194	23.3880	24.3082	1843.4175	37.9573	48.5656
F0	0.2000	0.0300	6.6663	0.5688	0.0505	11.2629
Duration (ms)	0.7586	0.0291	26.0247	-1.0191	0.0491	-20.7561
Sex: male	-157.1596	19.6401	-8.0020	-153.9017	29.5236	-5.2128
Timestep: 30%	43.2662	3.7705	11.4749	-61.7937	6.3532	-9.7264
Timestep: 40%	78.1071	3.7712	20.7116	-113.7056	6.3543	-17.8942
Timestep: 50%	101.8548	3.7727	26.9976	-150.4007	6.3570	-23.6592
Timestep: 60%	111.0000	3.7744	29.4088	-171.3249	6.3597	-26.9391
Timestep: 70%	108.9242	3.7762	28.8447	-182.2139	6.3628	-28.6372
Timestep: 80%	93.6662	3.7784	24.7897	-190.2890	6.3666	-29.8889
Previous Segment Contrasts: ey	30.7883	33.1645	0.9284	29.1911	55.8776	0.5224
Previous Segment Contrasts: f	39.1965	27.5795	1.4212	-370.8950	46.4640	-7.9824
Previous Segment Contrasts: g	-13.3896	16.2310	-0.8249	6.5496	27.3448	0.2395
Previous Segment Contrasts: iy	-32.1599	25.4085	-1.2657	4.8049	42.8075	0.1122
Previous Segment Contrasts: k	-34.5731	18.2804	-1.8913	-81.9778	30.7964	-2.6619
Previous Segment Contrasts: n	183.9396	27.5112	6.6860	-344.5462	46.3514	-7.4334
Previous Segment Contrasts: nx	128.5237	32.3362	3.9746	-363.8400	54.4821	-6.6782
Previous Segment Contrasts: r	24.8999	33.1021	0.7522	-361.8623	55.7702	-6.4885
Previous Segment Contrasts: s	116.1332	25.8244	4.4970	-309.0233	43.5095	-7.1024
Previous Segment Contrasts: sh	-3.7557	17.5188	-0.2144	-163.0616	29.5145	-5.5248
Previous Segment Contrasts: t	85.8289	35.7895	2.3982	-182.6011	60.2940	-3.0285
Previous Segment Contrasts: w	-9.3408	39.8266	-0.2345	-412.5794	67.0819	-6.1504
Previous Segment Contrasts: y	-35.9573	20.5200	-1.7523	-16.3254	34.5723	-0.4722
Following Segment Contrasts: ao	-0.1155	17.3622	-0.0067	4.7775	29.2441	0.1634
Following Segment Contrasts: aw	22.5257	14.8549	1.5164	93.4860	25.0290	3.7351
Following Segment Contrasts: ay	-447.2096	40.5833	-11.0195	250.8389	68.3788	3.6684
Following Segment Contrasts: b	-1.4646	12.0036	-0.1220	-14.9282	20.2236	-0.7382
Following Segment Contrasts: d	-13.6109	9.2745	-1.4676	26.0183	15.6255	1.6651
Following Segment Contrasts: dh	28.7510	28.2028	1.0194	228.6744	47.5141	4.8128
Following Segment Contrasts: dx	6.9294	6.6097	1.0484	31.9368	11.1351	2.8681
Following Segment Contrasts: eh	-39.7277	14.9649	-2.6547	62.5852	25.2129	2.4823
Following Segment Contrasts: el	-60.0715	20.0791	-2.9917	-34.8681	33.8297	-1.0307
Following Segment Contrasts: en	56.7764	29.6264	1.9164	51.4899	49.8793	1.0323
Following Segment Contrasts: ey	-67.0985	27.4612	-2.4434	327.6086	46.2701	7.0804
Following Segment Contrasts: f	-90.1033	23.4778	-3.8378	-2.1455	39.5564	-0.0542
Following Segment Contrasts: g	-49.9511	20.3163	-2.4587	-94.7578	34.2298	-2.7683
Following Segment Contrasts: hh	-25.9227	13.9023	-1.8646	105.2761	23.4225	4.4947
Following Segment Contrasts: ih	-148.4508	32.5823	-4.5562	-184.8466	54.8991	-3.3670
Following Segment Contrasts: IVER	-121.4508	21.6317	-5.6145	63.3826	36.4451	1.7391
Following Segment Contrasts: k	-29.0689	16.9015	-1.7199	130.6500	28.4769	4.5879
Following Segment Contrasts: l	-29.1919	18.1923	-1.6046	-62.9542	30.6518	-2.0538
Following Segment Contrasts: m	0.0904	11.6662	0.0078	-65.0092	19.6557	-3.3074
Following Segment Contrasts: n	15.7157	22.1482	0.7096	173.8165	37.3158	4.6580
Following Segment Contrasts: nx	65.4889	35.6603	1.8365	-26.3254	60.0772	-0.4382
Following Segment Contrasts: p	-26.5863	12.9731	-2.0493	72.4864	21.8547	3.3167
Following Segment Contrasts: r	-108.5455	34.0370	-3.1890	-86.4537	57.3391	-1.5078
Following Segment Contrasts: t	-1.1009	6.6135	-0.1665	38.5877	11.1420	3.4633
Following Segment Contrasts: tq	18.6093	6.5523	2.8401	5.0072	11.0390	0.4536
Following Segment Contrasts: VOCNOISE	-39.8913	36.6637	-1.0880	186.8704	61.7740	3.0251
Following Segment Contrasts: w	10.2759	20.1005	0.5112	-136.8784	33.8659	-4.0418

/æ/						
	F1			F2		
	Estimate	Std. Error	*t*	Estimate	Std. Error	*t*
Intercept	525.3463	167.1701	3.1426	1877.3526	217.1793	8.6443
F0	0.8530	0.4232	2.0157	-1.3196	0.6759	-1.9523
Duration (ms)	1.1240	0.2625	4.2824	0.2696	0.4784	0.5635
Sex: male	-93.8224	70.9866	-1.3217	-420.2037	82.7046	-5.0808
Timestep: 30%	13.5775	17.0586	0.7959	-2.6727	32.9606	-0.0811
Timestep: 40%	13.6140	17.0863	0.7968	-12.0993	32.9971	-0.3667
Timestep: 50%	15.9969	17.0694	0.9372	-11.8239	32.9748	-0.3586
Timestep: 60%	12.5701	17.0856	0.7357	-8.8749	32.9962	-0.2690
Timestep: 70%	2.6954	17.0931	0.1577	-10.8411	33.0062	-0.3285
Timestep: 80%	-16.0730	17.1088	-0.9395	-5.4507	33.0268	-0.1650
Previous Segment Contrasts: g	-208.5747	159.7407	-1.3057	89.9083	180.5293	0.4980
Previous Segment Contrasts: hh	-123.3051	183.0491	-0.6736	294.5315	199.9645	1.4729
Previous Segment Contrasts: p	-156.7389	114.6341	-1.3673	629.1870	144.5212	4.3536
Previous Segment Contrasts: s	-145.9211	147.7434	-0.9877	238.6779	167.6940	1.4233
Previous Segment Contrasts: w	-182.9100	183.6897	-0.9958	425.2221	193.4858	2.1977
Following Segment Contrasts: dx	10.9530	36.1462	0.3030	79.7008	66.7516	1.1940
Following Segment Contrasts: er	141.0152	162.5880	0.8673	336.3379	180.7438	1.8609
Following Segment Contrasts: n	-27.7195	150.4808	-0.1842	172.9992	176.0175	0.9829
Following Segment Contrasts: ng	80.0516	107.6528	0.7436	395.8310	122.6223	3.2280
Following Segment Contrasts: t	-23.9145	143.2533	-0.1669	0.3702	159.5267	0.0023
Following Segment Contrasts: tq	133.3770	89.5006	1.4902	255.6591	110.9942	2.3034
Following Segment Contrasts: v	113.9320	36.8167	3.0946	-55.7691	70.0194	-0.7965

/ʌ/						
	F1			F2		
	Estimate	Std. Error	*t*	Estimate	Std. Error	*t*
Intercept	604.5177	64.8073	9.3279	1560.7658	98.3503	15.8695
F0	0.1159	0.0497	2.3314	0.0583	0.0768	0.7583
Duration (ms)	0.5740	0.0520	11.0476	-0.1080	0.0805	-1.3407
Sex: male	-118.6069	30.0341	-3.9491	-212.9720	36.4333	-5.8455
Timestep: 30%	11.4820	6.3393	1.8112	-14.5754	9.8361	-1.4818
Timestep: 40%	19.4951	6.3401	3.0749	-31.7497	9.8373	-3.2275
Timestep: 50%	20.7201	6.3414	3.2674	-50.0496	9.8393	-5.0867
Timestep: 60%	18.6690	6.3426	2.9434	-66.0315	9.8411	-6.7098
Timestep: 70%	12.0765	6.3441	1.9036	-78.1025	9.8434	-7.9345
Timestep: 80%	0.5265	6.3460	0.0830	-91.5144	9.8463	-9.2943
Previous Segment Contrasts: ahn	145.9425	68.8861	2.1186	126.8153	106.8476	1.1869
Previous Segment Contrasts: b	55.4316	53.6799	1.0326	25.4141	83.2358	0.3053
Previous Segment Contrasts: d	171.7044	62.9744	2.7266	37.0993	97.6871	0.3798
Previous Segment Contrasts: dx	125.7795	66.2578	1.8983	-88.7145	102.7892	-0.8631
Previous Segment Contrasts: er	178.8512	68.0101	2.6298	-109.1239	105.4968	-1.0344
Previous Segment Contrasts: f	184.5486	57.3107	3.2201	91.0669	88.8975	1.0244
Previous Segment Contrasts: g	138.2840	51.5265	2.6837	325.4373	79.9265	4.0717
Previous Segment Contrasts: hh	247.6430	54.6139	4.5344	215.5596	84.7158	2.5445
Previous Segment Contrasts: ih	-118.6133	65.8679	-1.8008	301.7988	102.1721	2.9538
Previous Segment Contrasts: k	199.1288	54.3206	3.6658	45.4919	84.2541	0.5399
Previous Segment Contrasts: l	21.3796	59.7944	0.3576	-221.1071	92.7522	-2.3838
Previous Segment Contrasts: n	127.7649	49.5973	2.5760	89.9652	76.9382	1.1693
Previous Segment Contrasts: nx	131.3116	49.7827	2.6377	103.2454	77.2317	1.3368
Previous Segment Contrasts: ow	208.3276	69.0378	3.0176	-34.8763	107.0769	-0.3257

Previous Segment Contrasts: own	92.7081	53.2292	1.7417	39.0124	82.5670	0.4725
Previous Segment Contrasts: r	162.5571	51.2397	3.1725	13.0617	79.4843	0.1643
Previous Segment Contrasts: s	183.8916	53.6902	3.4250	41.0526	83.2838	0.4929
Previous Segment Contrasts: t	80.0432	55.3879	1.4451	362.0751	85.9194	4.2141
Previous Segment Contrasts: th	246.2399	72.7571	3.3844	201.1255	112.8462	1.7823
Previous Segment Contrasts: w	154.3803	52.4099	2.9456	-186.9536	81.2980	-2.2996
Previous Segment Contrasts: y	130.4108	54.8270	2.3786	459.8564	85.0494	5.4069
Following Segment Contrasts: ae	-170.3596	43.6436	-3.9034	-73.8454	67.7084	-1.0906
Following Segment Contrasts: ah	-175.2544	33.7578	-5.1915	-4.1315	52.3713	-0.0789
Following Segment Contrasts: ay	-85.4925	37.2095	-2.2976	-25.7789	57.7267	-0.4466
Following Segment Contrasts: ch	-199.0958	55.3127	-3.5995	77.0882	85.8061	0.8984
Following Segment Contrasts: d	-96.6519	45.7372	-2.1132	22.0495	70.9426	0.3108
Following Segment Contrasts: dh	-180.7779	35.0399	-5.1592	172.6207	54.3599	3.1755
Following Segment Contrasts: dx	-123.1695	35.9992	-3.4215	-22.0283	55.8445	-0.3945
Following Segment Contrasts: eh	-170.4890	40.3483	-4.2254	177.6310	62.5894	2.8380
Following Segment Contrasts: en	-22.1539	74.5067	-0.2973	178.8998	115.5739	1.5479
Following Segment Contrasts: f	-201.7412	45.6198	-4.4222	-169.5301	70.7730	-2.3954
Following Segment Contrasts: g	-177.0012	55.1450	-3.2097	89.4490	85.5446	1.0456
Following Segment Contrasts: hh	-71.5575	34.3337	-2.0842	55.3276	53.2637	1.0387
Following Segment Contrasts: ih	-149.3244	36.5127	-4.0897	-115.6047	56.6376	-2.0411
Following Segment Contrasts: IVER	-184.3532	37.4157	-4.9272	49.8858	58.0442	0.8594
Following Segment Contrasts: iy	-70.6711	44.9472	-1.5723	29.5171	69.7338	0.4233
Following Segment Contrasts: jh	-285.2564	55.4007	-5.1490	155.2264	85.9421	1.8062
Following Segment Contrasts: k	-85.9815	40.3808	-2.1293	-197.4750	62.6436	-3.1524
Following Segment Contrasts: l	105.4173	56.3059	1.8722	593.4803	87.3181	6.7968
Following Segment Contrasts: LAUGH	-105.0290	56.9092	-1.8456	265.0644	88.2768	3.0026
Following Segment Contrasts: m	-165.1196	38.5521	-4.2830	-15.3585	59.7970	-0.2568
Following Segment Contrasts: n	-146.6750	34.6139	-4.2375	26.2853	53.6979	0.4895
Following Segment Contrasts: ng	-171.8116	35.7421	-4.8070	-110.2847	55.4483	-1.9890
Following Segment Contrasts: nx	-170.7782	34.7375	-4.9163	47.4596	53.8903	0.8807
Following Segment Contrasts: ow	-127.3190	54.7723	-2.3245	-240.2647	84.9777	-2.8274
Following Segment Contrasts: p	-143.2759	42.5897	-3.3641	-14.5359	66.0708	-0.2200
Following Segment Contrasts: r	-352.5847	43.0270	-8.1945	-115.4912	66.7320	-1.7307
Following Segment Contrasts: s	-170.6955	37.8198	-4.5134	28.5380	58.6736	0.4864
Following Segment Contrasts: sh	-133.6486	41.4111	-3.2274	68.0138	64.2446	1.0587
Following Segment Contrasts: SIL	-212.2914	38.1932	-5.5584	-75.0583	59.2484	-1.2668
Following Segment Contrasts: t	-199.3647	35.7122	-5.5825	70.2671	55.4017	1.2683
Following Segment Contrasts: th	-55.0774	53.9019	-1.0218	92.7650	83.6316	1.1092
Following Segment Contrasts: tq	-147.7582	35.6027	-4.1502	16.6859	55.2275	0.3021
Following Segment Contrasts: v	-183.9651	40.6875	-4.5214	-20.9346	63.1130	-0.3317
Following Segment Contrasts: VOCNOISE	-185.1965	36.9292	-5.0149	67.3877	57.2932	1.1762
Following Segment Contrasts: w	-133.1858	40.6209	-3.2787	-215.7373	63.0087	-3.4239
Following Segment Contrasts: y	-172.9432	35.5359	-4.8667	189.6542	55.1328	3.4400

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	F1			F2		
	Estimate	Std. Error	*t*	Estimate	Std. Error	*t*
Intercept	636.6944	31.8820	19.9703	1149.4495	39.6427	28.9953
F0	-0.0764	0.0726	-1.0517	-0.2540	0.0973	-2.6110
Duration (ms)	0.2240	0.0481	4.6560	-0.2918	0.0645	-4.5256
Sex: male	-121.4348	29.3130	-4.1427	-201.8842	32.5625	-6.1999
Timestep: 30%	20.9586	6.9416	3.0193	-30.9569	9.3470	-3.3120
Timestep: 40%	32.8456	6.9444	4.7298	-51.7523	9.3506	-5.5346
Timestep: 50%	40.0063	6.9462	5.7594	-61.9720	9.3531	-6.6258

Timestep: 60%	40.4751	6.9481	5.8253	-63.2909	9.3556	-6.7650
Timestep: 70%	37.5383	6.9525	5.3992	-61.0573	9.3615	-6.5222
Timestep: 80%	30.6163	6.9557	4.4016	-52.6487	9.3658	-5.6214
Previous Segment Contrasts: g	60.9496	34.8714	1.7478	552.3091	46.7779	11.8070
Previous Segment Contrasts: hh	-79.0095	62.7740	-1.2586	-90.2669	70.0118	-1.2893
Previous Segment Contrasts: n	120.0846	22.7645	5.2751	479.7760	30.3950	15.7847
Previous Segment Contrasts: r	27.1848	16.2619	1.6717	204.7334	21.8096	9.3873
Previous Segment Contrasts: s	47.0797	15.0359	3.1312	281.5588	20.1616	13.9651
Previous Segment Contrasts: t	-148.2172	45.7984	-3.2363	153.1563	61.2525	2.5004
Previous Segment Contrasts: w	-57.6005	38.3319	-1.5027	153.7526	51.4429	2.9888
Following Segment Contrasts: ah	-27.9155	17.0898	-1.6335	-37.8245	22.9699	-1.6467
Following Segment Contrasts: ao	98.3905	19.5276	5.0385	15.6766	26.2767	0.5966
Following Segment Contrasts: b	-23.2195	28.6352	-0.8109	-154.5551	38.4973	-4.0147
Following Segment Contrasts: dh	-43.4937	17.8595	-2.4353	-48.9912	24.0037	-2.0410
Following Segment Contrasts: dx	84.8189	26.0335	3.2581	8.8671	35.0033	0.2533
Following Segment Contrasts: em	46.8948	25.6655	1.8272	18.4846	34.5407	0.5352
Following Segment Contrasts: en	100.1552	31.0288	3.2278	125.7971	41.6960	3.0170
Following Segment Contrasts: g	-26.2851	28.6230	-0.9183	63.3939	38.4899	1.6470
Following Segment Contrasts: hh	2.3324	22.3892	0.1042	-38.2153	29.9707	-1.2751
Following Segment Contrasts: ih	-16.4834	20.9834	-0.7855	-75.3505	28.1613	-2.6757
Following Segment Contrasts: l	-1.7920	19.3027	-0.0928	36.8146	25.9535	1.4185
Following Segment Contrasts: m	15.8241	20.9923	0.7538	-63.0391	28.1658	-2.2381
Following Segment Contrasts: r	-32.6616	41.2269	-0.7922	-210.8641	55.3612	-3.8089
Following Segment Contrasts: s	-29.8409	22.3710	-1.3339	20.0743	29.8347	0.6729
Following Segment Contrasts: SIL	-87.8557	21.6535	-4.0574	21.9229	29.0794	0.7539
Following Segment Contrasts: t	1.2480	31.8460	0.0392	63.8030	42.7486	1.4925
Following Segment Contrasts: VOCNOISE	-71.8612	21.1494	-3.3978	-70.0979	28.4232	-2.4662
Following Segment Contrasts: w	-40.9694	26.4666	-1.5480	41.0591	35.3115	1.1628
Following Segment Contrasts: y	33.8088	31.8711	1.0608	172.8176	42.7859	4.0391

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	F1			F2		
	Estimate	Std. Error	*t*	Estimate	Std. Error	*t*
Intercept	424.1323	32.0998	13.2129	1869.4798	65.0236	28.7508
F0	0.3400	0.0330	10.3149	0.5723	0.0660	8.6728
Duration (ms)	0.5418	0.0362	14.9879	0.3798	0.0723	5.2520
Sex: male	-87.8804	15.0400	-5.8431	-284.0619	33.5095	-8.4771
Timestep: 30%	26.6034	4.4482	5.9808	-17.8301	8.8921	-2.0052
Timestep: 40%	48.2853	4.4485	10.8542	-41.7017	8.8928	-4.6894
Timestep: 50%	63.7051	4.4492	14.3182	-69.8602	8.8942	-7.8546
Timestep: 60%	70.9528	4.4502	15.9438	-97.7169	8.8961	-10.9842
Timestep: 70%	71.3814	4.4515	16.0354	-125.8692	8.8987	-14.1446
Timestep: 80%	64.5350	4.4534	14.4912	-152.8009	8.9026	-17.1637
Previous Segment Contrasts: b	69.1406	28.9752	2.3862	-226.7901	57.9283	-3.9150
Previous Segment Contrasts: f	61.0568	29.7732	2.0507	-101.0503	59.5283	-1.6975
Previous Segment Contrasts: g	-18.5709	28.0138	-0.6629	135.7919	56.0065	2.4246
Previous Segment Contrasts: hh	116.2552	34.3277	3.3866	-201.1492	68.6438	-2.9303
Previous Segment Contrasts: ih	-47.0107	40.5714	-1.1587	204.9542	81.1409	2.5259
Previous Segment Contrasts: iy	-43.2753	40.7967	-1.0608	262.7115	81.6063	3.2193
Previous Segment Contrasts: k	27.5546	30.8687	0.8926	52.9229	61.7182	0.8575
Previous Segment Contrasts: l	108.3786	33.1250	3.2718	-197.0853	66.2290	-2.9758
Previous Segment Contrasts: m	119.9389	28.0801	4.2713	-124.7454	56.1390	-2.2221
Previous Segment Contrasts: n	49.3011	32.1691	1.5326	-213.0512	64.3199	-3.3124
Previous Segment Contrasts: nx	140.0741	32.0817	4.3662	-158.9347	64.1395	-2.4780

Previous Segment Contrasts: r	54.0070	28.8793	1.8701	-225.9748	57.7388	-3.9137
Previous Segment Contrasts: s	28.6344	29.8646	0.9588	-51.2459	59.7085	-0.8583
Previous Segment Contrasts: t	62.1684	36.5930	1.6989	163.9701	73.1690	2.2410
Previous Segment Contrasts: w	98.0014	30.7871	3.1832	-225.0988	61.5599	-3.6566
Previous Segment Contrasts: y	-8.3335	31.7631	-0.2624	79.5396	63.5052	1.2525
Following Segment Contrasts: aw	112.8956	23.8695	4.7297	131.7744	47.7468	2.7599
Following Segment Contrasts: ay	14.3737	34.4038	0.4178	197.4898	68.9321	2.8650
Following Segment Contrasts: d	-11.8112	11.9190	-0.9910	107.3165	23.8353	4.5024
Following Segment Contrasts: dh	-93.0950	17.3532	-5.3647	15.7529	34.7125	0.4538
Following Segment Contrasts: dx	6.1515	9.8346	0.6255	62.0883	19.6636	3.1575
Following Segment Contrasts: eh	40.1956	34.3668	1.1696	106.5680	68.8562	1.5477
Following Segment Contrasts: en	-22.7763	21.8189	-1.0439	106.2765	43.6216	2.4363
Following Segment Contrasts: ey	-42.6555	23.4044	-1.8225	174.4976	46.7934	3.7291
Following Segment Contrasts: hh	-30.0777	18.3615	-1.6381	210.5985	36.7147	5.7361
Following Segment Contrasts: ih	-75.7616	19.2290	-3.9400	307.7622	38.4444	8.0054
Following Segment Contrasts: IVER	-45.9012	29.6039	-1.5505	-110.5918	59.1876	-1.8685
Following Segment Contrasts: k	-15.2934	20.1187	-0.7602	60.3075	40.2251	1.4992
Following Segment Contrasts: l	41.8906	18.9891	2.2060	-184.6224	37.9890	-4.8599
Following Segment Contrasts: m	-13.2710	15.9352	-0.8328	107.4337	31.8680	3.3712
Following Segment Contrasts: n	-67.2287	14.2106	-4.7309	157.0741	28.4163	5.5276
Following Segment Contrasts: p	-4.7312	21.7612	-0.2174	3.8899	43.5051	0.0894
Following Segment Contrasts: r	-80.4597	15.8515	-5.0758	-47.4606	31.7081	-1.4968
Following Segment Contrasts: s	-30.2232	23.0235	-1.3127	155.2378	46.0302	3.3725
Following Segment Contrasts: t	-0.0909	9.9504	-0.0091	56.9475	19.8957	2.8623
Following Segment Contrasts: th	-17.4562	29.2448	-0.5969	-105.4862	58.4650	-1.8043
Following Segment Contrasts: tq	1.7524	10.0301	0.1747	73.7203	20.0554	3.6758
Following Segment Contrasts: v	-41.9364	22.8291	-1.8370	61.2138	45.6771	1.3401
Following Segment Contrasts: w	31.3338	29.6822	1.0556	-126.8514	59.3454	-2.1375
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	F1			F2		
	Estimate	Std. Error	*t*	Estimate	Std. Error	*t*
Intercept	406.9112	31.4253	12.9485	1912.8188	74.2702	25.7549
F0	0.3420	0.0409	8.3669	0.9120	0.0930	9.8029
Duration (ms)	0.5744	0.0499	11.5202	0.1861	0.1133	1.6425
Sex: male	-61.9294	13.2610	-4.6700	-265.0133	43.2114	-6.1329
Timestep: 30%	12.2039	5.0495	2.4169	-20.7235	11.3777	-1.8214
Timestep: 40%	24.6035	5.0496	4.8724	-44.2239	11.3778	-3.8868
Timestep: 50%	35.5058	5.0498	7.0312	-72.3769	11.3783	-6.3609
Timestep: 60%	41.4569	5.0501	8.2090	-104.4172	11.3792	-9.1761
Timestep: 70%	43.0810	5.0507	8.5297	-135.2720	11.3805	-11.8863
Timestep: 80%	40.3192	5.0512	7.9820	-171.9832	11.3817	-15.1105
Previous Segment Contrasts: ch	-174.7340	28.9712	-6.0313	203.0411	65.5208	3.0989
Previous Segment Contrasts: d	43.3628	46.6957	0.9286	368.5425	105.5051	3.4931
Previous Segment Contrasts: dx	19.1546	51.6806	0.3706	613.0019	116.7440	5.2508
Previous Segment Contrasts: f	123.1630	52.5452	2.3439	243.2602	118.8787	2.0463
Previous Segment Contrasts: g	-24.0621	8.9503	-2.6884	390.3046	20.2585	19.2663
Previous Segment Contrasts: hh	-122.8457	31.9735	-3.8421	338.7255	73.1661	4.6295
Previous Segment Contrasts: ih	-191.8703	29.8137	-6.4356	688.7004	67.5344	10.1978
Previous Segment Contrasts: IVER	-151.8553	30.2764	-5.0156	399.5680	68.4103	5.8408
Previous Segment Contrasts: iy	30.3016	33.4020	0.9072	-35.3445	75.9314	-0.4655
Previous Segment Contrasts: k	-22.5399	14.7942	-1.5236	484.8885	33.4835	14.4814
Previous Segment Contrasts: n	73.0677	19.7821	3.6936	24.6602	44.7419	0.5512
Previous Segment Contrasts: ng	-29.7989	29.4750	-1.0110	316.9928	66.5593	4.7626

Previous Segment Contrasts: nx	190.5543	31.8556	5.9818	296.4509	72.1555	4.1085
Previous Segment Contrasts: p	0.0097	25.3330	0.0004	207.4675	57.4063	3.6140
Previous Segment Contrasts: r	-17.8126	14.7700	-1.2060	126.1944	33.5563	3.7607
Previous Segment Contrasts: s	-37.5214	10.5313	-3.5628	277.4004	23.8264	11.6426
Previous Segment Contrasts: sh	33.9503	29.7635	1.1407	18.2702	67.3712	0.2712
Previous Segment Contrasts: t	20.0309	15.7770	1.2696	103.8318	35.6283	2.9143
Previous Segment Contrasts: uw	-97.4065	28.4777	-3.4204	452.9101	64.2251	7.0519
Previous Segment Contrasts: w	19.1770	15.1221	1.2681	-76.3704	34.2163	-2.2320
Previous Segment Contrasts: y	-43.3685	19.1133	-2.2690	464.3221	43.1692	10.7559
Previous Segment Contrasts: z	48.2487	35.5259	1.3581	330.0610	80.4197	4.1042
Previous Segment Contrasts: zh	-0.2100	33.0987	-0.0063	377.9498	74.6435	5.0634
Following Segment Contrasts: ae	35.9360	38.8910	0.9240	-382.4494	87.9205	-4.3499
Following Segment Contrasts: ah	-11.7800	28.8697	-0.4080	-357.5406	65.1133	-5.4911
Following Segment Contrasts: aw	-23.6473	33.5470	-0.7049	-297.1625	75.6668	-3.9273
Following Segment Contrasts: ay	-49.6259	37.5250	-1.3225	-383.8106	84.6069	-4.5364
Following Segment Contrasts: b	-14.3452	29.2938	-0.4897	-263.7398	66.0827	-3.9911
Following Segment Contrasts: ch	-51.8917	32.5806	-1.5927	-113.4898	73.4486	-1.5452
Following Segment Contrasts: d	-16.7672	27.4196	-0.6115	-252.9660	61.8326	-4.0911
Following Segment Contrasts: dh	-84.0928	27.8816	-3.0161	-163.8841	62.8733	-2.6066
Following Segment Contrasts: eh	-17.5559	28.4158	-0.6178	-209.5419	64.0853	-3.2697
Following Segment Contrasts: em	-47.5064	31.4563	-1.5102	-241.9150	70.9263	-3.4108
Following Segment Contrasts: en	6.2800	38.1561	0.1646	-602.8721	86.1051	-7.0016
Following Segment Contrasts: er	5.8142	37.7949	0.1538	-325.9891	85.2321	-3.8247
Following Segment Contrasts: ey	1.0728	39.3789	0.0272	-111.9772	88.9525	-1.2588
Following Segment Contrasts: f	-43.7166	29.4118	-1.4864	-308.2291	66.3121	-4.6482
Following Segment Contrasts: g	-172.9261	51.0692	-3.3861	-236.9826	115.3319	-2.0548
Following Segment Contrasts: hh	39.4946	30.8373	1.2807	-321.9757	69.5840	-4.6271
Following Segment Contrasts: ih	-25.4574	29.6495	-0.8586	-304.9151	66.9253	-4.5561
Following Segment Contrasts: IVER	-297.0992	42.6982	-6.9581	-515.1796	96.3980	-5.3443
Following Segment Contrasts: k	-45.5403	31.0139	-1.4684	-17.5928	69.9821	-0.2514
Following Segment Contrasts: l	-20.2135	37.8120	-0.5346	69.2221	85.2726	0.8118
Following Segment Contrasts: m	-44.5728	28.3925	-1.5699	-225.3088	64.0290	-3.5189
Following Segment Contrasts: n	-49.7694	29.7706	-1.6718	-123.6212	67.1603	-1.8407
Following Segment Contrasts: ng	30.8084	28.2726	1.0897	-145.1528	63.7659	-2.2763
Following Segment Contrasts: nx	-19.2729	32.9111	-0.5856	-153.9030	74.2160	-2.0737
Following Segment Contrasts: ow	123.2197	43.3933	2.8396	-474.1461	98.2305	-4.8269
Following Segment Contrasts: p	6.5389	30.9810	0.2111	-332.7418	69.9329	-4.7580
Following Segment Contrasts: r	-50.7871	33.3060	-1.5249	-416.9055	75.1013	-5.5512
Following Segment Contrasts: s	-35.7774	29.2201	-1.2244	-334.0653	65.9081	-5.0687
Following Segment Contrasts: SIL	1.1874	38.3599	0.0310	-345.5239	86.5005	-3.9945
Following Segment Contrasts: th	-48.1814	33.6114	-1.4335	-316.0886	75.8528	-4.1671
Following Segment Contrasts: v	-51.0729	27.4531	-1.8604	-225.4982	61.8999	-3.6429
Following Segment Contrasts: VOCNOISE	-78.8417	37.2168	-2.1184	-183.8117	83.8889	-2.1911
Following Segment Contrasts: w	-51.0641	29.0140	-1.7600	-197.5266	65.4501	-3.0180
Following Segment Contrasts: y	-92.9453	38.2937	-2.4272	-278.8546	86.3480	-3.2294
Following Segment Contrasts: z	-34.7617	33.4742	-1.0385	-235.2720	75.6037	-3.1119
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	F1			F2		
	Estimate	Std. Error	*t*	Estimate	Std. Error	*t*
Intercept	374.8605	22.9362	16.3436	1864.6181	83.8847	22.2284
F0	0.1317	0.0330	3.9948	-0.3575	0.1217	-2.9388
Duration (ms)	-0.1062	0.0252	-4.2164	0.9153	0.0929	9.8494
Sex: male	-51.1866	15.6668	-3.2672	-426.2387	55.1434	-7.7296

Timestep: 30%	-3.1003	3.8054	-0.8147	92.4271	14.0644	6.5717
Timestep: 40%	-8.1284	3.8054	-2.1360	157.1495	14.0643	11.1737
Timestep: 50%	-12.0844	3.8054	-3.1756	197.0958	14.0642	14.0140
Timestep: 60%	-16.2501	3.8054	-4.2703	219.5571	14.0643	15.6110
Timestep: 70%	-20.1611	3.8055	-5.2979	224.7171	14.0647	15.9774
Timestep: 80%	-23.1247	3.8057	-6.0764	208.9821	14.0655	14.8578
Previous Segment Contrasts: ay	191.3792	16.3452	11.7086	4.0646	60.4008	0.0673
Previous Segment Contrasts: d	11.3891	13.4070	0.8495	-155.2889	49.5179	-3.1360
Previous Segment Contrasts: eh	30.3615	18.8222	1.6131	-22.0536	69.5350	-0.3172
Previous Segment Contrasts: en	26.4042	13.0782	2.0189	35.3525	48.3286	0.7315
Previous Segment Contrasts: er	70.2022	13.8339	5.0747	-285.1734	51.1141	-5.5792
Previous Segment Contrasts: ey	68.8333	14.4368	4.7679	120.9165	53.3092	2.2682
Previous Segment Contrasts: f	28.0857	12.0661	2.3276	-26.7790	44.5607	-0.6010
Previous Segment Contrasts: g	71.0304	21.3273	3.3305	-199.5093	78.1422	-2.5532
Previous Segment Contrasts: ih	53.2603	12.2125	4.3611	63.2270	45.1135	1.4015
Previous Segment Contrasts: iy	26.3633	11.9772	2.2011	110.5057	44.2348	2.4982
Previous Segment Contrasts: k	-75.2078	53.0861	-1.4167	106.0984	188.3209	0.5634
Previous Segment Contrasts: l	34.8379	11.5891	3.0061	-100.7779	42.7973	-2.3548
Previous Segment Contrasts: m	60.9251	10.9016	5.5886	-72.9123	40.2591	-1.8111
Previous Segment Contrasts: n	15.6006	15.1272	1.0313	3.0259	55.8758	0.0542
Previous Segment Contrasts: nx	64.8336	11.8622	5.4656	-30.6003	43.8311	-0.6981
Previous Segment Contrasts: p	-5.5922	16.5366	-0.3382	-157.7810	60.8566	-2.5927
Previous Segment Contrasts: r	49.8481	11.4009	4.3723	-192.5488	42.1026	-4.5733
Previous Segment Contrasts: sh	-24.7950	27.3359	-0.9070	-109.9787	100.9409	-1.0895
Previous Segment Contrasts: SIL	17.8493	12.3976	1.4397	143.7683	45.8011	3.1390
Previous Segment Contrasts: t	-28.7948	15.5635	-1.8502	-18.2477	57.4238	-0.3178
Previous Segment Contrasts: w	216.3770	23.1347	9.3529	-388.7240	85.4472	-4.5493
Following Segment Contrasts: b	-49.7735	22.9828	-2.1657	8.7850	84.8849	0.1035
Following Segment Contrasts: ch	-64.6928	36.2809	-1.7831	499.1474	132.2898	3.7731
Following Segment Contrasts: d	-31.6188	16.0209	-1.9736	484.0210	59.1828	8.1784
Following Segment Contrasts: dx	-29.9080	16.6238	-1.7991	438.1523	61.4046	7.1355
Following Segment Contrasts: eh	123.3799	23.3318	5.2881	513.9351	86.2042	5.9618
Following Segment Contrasts: ey	7.7175	21.9147	0.3522	378.1913	80.9701	4.6708
Following Segment Contrasts: f	9.1595	28.0211	0.3269	574.2576	102.6705	5.5932
Following Segment Contrasts: g	3.5812	19.9745	0.1793	244.2329	73.7701	3.3107
Following Segment Contrasts: ih	75.4569	27.2147	2.7726	396.3868	100.4648	3.9455
Following Segment Contrasts: k	12.0784	21.4307	0.5636	533.9409	79.0017	6.7586
Following Segment Contrasts: l	60.4071	23.6995	2.5489	198.2746	87.4973	2.2661
Following Segment Contrasts: m	15.1457	23.6524	0.6403	273.7065	87.3869	3.1321
Following Segment Contrasts: ng	-84.8036	23.0586	-3.6777	451.3963	85.1605	5.3005
Following Segment Contrasts: s	-108.6201	26.7802	-4.0560	230.0258	98.9453	2.3248
Following Segment Contrasts: t	-34.5006	17.2150	-2.0041	530.8461	63.5858	8.3485
Following Segment Contrasts: tq	-38.5396	17.3155	-2.2257	506.1487	63.9576	7.9138
Following Segment Contrasts: v	-56.6788	27.1151	-2.0903	611.2210	99.6642	6.1328
Following Segment Contrasts: VOCNOISE	46.0043	22.1875	2.0734	461.2368	81.9709	5.6268

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	F1			F2		
	Estimate	Std. Error	*t*	Estimate	Std. Error	*t*
Intercept	623.3583	38.5223	16.1818	1612.8497	86.5631	18.6321
F0	-0.1918	0.0594	-3.2279	0.1063	0.1345	0.7903
Duration (ms)	-0.0199	0.0351	-0.5659	-0.4319	0.0797	-5.4200
Sex: male	-127.5997	21.2339	-6.0093	-144.0127	45.2261	-3.1843
Timestep: 30%	1.9346	5.5150	0.3508	-26.0199	12.5232	-2.0777

Timestep: 40%	-0.3816	5.5155	-0.0692	-58.5403	12.5242	-4.6742
Timestep: 50%	-9.8896	5.5163	-1.7928	-92.4639	12.5262	-7.3817
Timestep: 60%	-21.4564	5.5172	-3.8890	-123.5935	12.5282	-9.8652
Timestep: 70%	-32.5749	5.5189	-5.9024	-143.7729	12.5321	-11.4724
Timestep: 80%	-44.5274	5.5219	-8.0638	-147.4293	12.5387	-11.7579
Previous Segment Contrasts: ah	34.4119	24.7685	1.3893	42.2356	56.2287	0.7511
Previous Segment Contrasts: ahn	158.3954	31.6386	5.0064	-18.1404	71.8008	-0.2526
Previous Segment Contrasts: ch	8.5614	34.0988	0.2511	158.9399	77.2891	2.0564
Previous Segment Contrasts: d	-17.0070	33.3378	-0.5101	-75.7316	75.6387	-1.0012
Previous Segment Contrasts: dx	-26.2758	30.9626	-0.8486	58.9339	70.2697	0.8387
Previous Segment Contrasts: eh	71.0198	39.9514	1.7777	388.6233	90.6494	4.2871
Previous Segment Contrasts: hh	-81.8318	28.5134	-2.8699	-313.5695	64.7097	-4.8458
Previous Segment Contrasts: ih	47.7889	28.1644	1.6968	120.4621	63.9333	1.8842
Previous Segment Contrasts: ihn	-71.4643	29.2794	-2.4408	59.5957	66.4702	0.8966
Previous Segment Contrasts: iy	-41.4541	29.9477	-1.3842	188.0340	67.9945	2.7654
Previous Segment Contrasts: k	58.3275	41.5910	1.4024	-231.9534	94.3427	-2.4586
Previous Segment Contrasts: l	-19.8220	29.7007	-0.6674	-265.4589	67.4109	-3.9379
Previous Segment Contrasts: own	75.9526	29.4438	2.5796	-78.1344	66.8229	-1.1693
Previous Segment Contrasts: p	-64.7975	32.1835	-2.0134	-130.2135	73.0410	-1.7827
Previous Segment Contrasts: r	7.1192	26.6577	0.2671	-105.9308	60.5006	-1.7509
Previous Segment Contrasts: t	60.7247	32.4930	1.8689	134.6985	73.7584	1.8262
Previous Segment Contrasts: th	-144.5203	36.6972	-3.9382	-14.6806	83.1577	-0.1765
Previous Segment Contrasts: tq	135.0252	46.1303	2.9270	-44.8086	104.5546	-0.4286
Previous Segment Contrasts: uh	85.5073	36.3734	2.3508	-130.6108	82.5626	-1.5820
Previous Segment Contrasts: uhn	130.2063	38.0129	3.4253	296.8486	86.2395	3.4421
Previous Segment Contrasts: uw	39.9422	32.4912	1.2293	99.6472	73.7400	1.3513
Previous Segment Contrasts: w	-51.7527	32.6995	-1.5827	-297.0441	74.1813	-4.0043
Previous Segment Contrasts: y	-29.2844	25.5448	-1.1464	102.0961	57.9969	1.7604
Following Segment Contrasts: ae	104.7720	30.8318	3.3982	110.0866	69.5582	1.5827
Following Segment Contrasts: ah	12.9351	19.5337	0.6622	-108.5097	44.2760	-2.4508
Following Segment Contrasts: ao	0.9659	27.8926	0.0346	-217.4468	63.2976	-3.4353
Following Segment Contrasts: aw	86.2608	23.9332	3.6042	12.4730	54.2705	0.2298
Following Segment Contrasts: ay	-5.8855	24.5991	-0.2393	161.1279	55.7884	2.8882
Following Segment Contrasts: b	-84.4674	22.3360	-3.7817	-32.9283	50.6405	-0.6502
Following Segment Contrasts: d	44.8683	25.1724	1.7824	-165.7747	57.0404	-2.9063
Following Segment Contrasts: dh	22.6945	20.5870	1.1024	-8.8270	46.6703	-0.1891
Following Segment Contrasts: dx	-2.6708	20.6388	-0.1294	-12.6304	46.7887	-0.2699
Following Segment Contrasts: eh	5.8551	25.8294	0.2267	55.4364	58.5921	0.9461
Following Segment Contrasts: ey	150.8135	30.6695	4.9174	-61.3964	69.5902	-0.8823
Following Segment Contrasts: g	10.8254	29.1488	0.3714	-21.6313	66.1343	-0.3271
Following Segment Contrasts: hh	-78.7031	30.0835	-2.6162	-253.1418	68.1759	-3.7131
Following Segment Contrasts: ih	14.3829	22.6898	0.6339	-207.6205	51.4537	-4.0351
Following Segment Contrasts: IVER	-98.3674	36.9748	-2.6604	200.3032	83.8382	2.3892
Following Segment Contrasts: k	-36.0029	20.1252	-1.7889	-104.4591	45.6216	-2.2897
Following Segment Contrasts: l	69.1847	21.5006	3.2178	-204.2300	48.7435	-4.1899
Following Segment Contrasts: m	-13.4368	20.7858	-0.6464	-126.3304	47.1184	-2.6811
Following Segment Contrasts: n	25.4722	25.8941	0.9837	-48.4440	58.7276	-0.8249
Following Segment Contrasts: NOISE	-63.3482	29.2722	-2.1641	7.3231	66.4062	0.1103
Following Segment Contrasts: ow	57.3460	26.1559	2.1925	-206.7158	59.3052	-3.4856
Following Segment Contrasts: p	33.2165	25.2916	1.3133	10.6086	57.3613	0.1849
Following Segment Contrasts: r	-86.6010	27.2464	-3.1784	-286.7342	61.8008	-4.6397
Following Segment Contrasts: s	-40.4365	21.2791	-1.9003	-36.1520	48.1409	-0.7510
Following Segment Contrasts: SIL	-37.7730	21.6427	-1.7453	-145.8493	49.0551	-2.9732

Following Segment Contrasts: t	-19.6718	19.8171	-0.9927	-23.8362	44.9353	-0.5305
Following Segment Contrasts: tq	-23.8433	21.8228	-1.0926	21.0152	49.4815	0.4247
Following Segment Contrasts: uh	9.5644	29.1717	0.3279	-70.2584	66.1770	-1.0617
Following Segment Contrasts: v	-31.8476	22.0112	-1.4469	34.8147	49.8971	0.6977
Following Segment Contrasts: VOCNOISE	50.5607	21.9796	2.3004	-63.3057	49.8428	-1.2701
Following Segment Contrasts: w	12.0340	20.3168	0.5923	-267.3300	46.0632	-5.8035
Following Segment Contrasts: y	-90.5808	24.9069	-3.6368	151.7701	56.4862	2.6869

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	F1			F2		
	Estimate	Std. Error	*t*	Estimate	Std. Error	*t*
Intercept	338.9652	57.8612	5.8582	1437.0778	244.7275	5.8722
F0	0.3421	0.0810	4.2217	0.6845	0.1305	5.2452
Duration (ms)	0.7191	0.1334	5.3893	-1.6471	0.2118	-7.7759
Sex: male	-50.6110	18.3701	-2.7551	-105.3314	79.3753	-1.3270
Timestep: 30%	11.0027	8.6489	1.2721	-21.1128	13.2727	-1.5907
Timestep: 40%	14.6489	8.6509	1.6933	-37.1874	13.2760	-2.8011
Timestep: 50%	12.1235	8.6554	1.4007	-51.0333	13.2837	-3.8418
Timestep: 60%	5.3671	8.6607	0.6197	-60.7705	13.2925	-4.5718
Timestep: 70%	-4.7636	8.6666	-0.5497	-66.9184	13.3025	-5.0305
Timestep: 80%	-17.2124	8.6737	-1.9844	-69.8863	13.3145	-5.2489
Previous Segment Contrasts: k	48.5911	60.8685	0.7983	95.9628	241.0494	0.3981
Previous Segment Contrasts: r	74.6292	55.4805	1.3451	34.9223	237.9516	0.1468
Previous Segment Contrasts: s	171.6636	64.4054	2.6654	-84.0724	243.5579	-0.3452
Previous Segment Contrasts: t	-78.5296	62.1999	-1.2625	282.1740	242.0197	1.1659
Previous Segment Contrasts: th	84.6284	61.4545	1.3771	120.4463	241.4317	0.4989
Following Segment Contrasts: dh	-95.7493	42.7676	-2.2388	153.9513	66.2859	2.3225
Following Segment Contrasts: dx	10.1011	62.5723	0.1614	129.4595	242.2522	0.5344
Following Segment Contrasts: g	178.8470	34.2059	5.2285	28.8576	53.6618	0.5378
Following Segment Contrasts: k	126.7844	31.5482	4.0188	-44.8650	49.5354	-0.9057
Following Segment Contrasts: t	0.6735	57.8290	0.0116	136.2847	239.2974	0.5695
Following Segment Contrasts: tq	-75.6205	39.4636	-1.9162	242.9349	60.8462	3.9926

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	F1			F2		
	Estimate	Std. Error	*t*	Estimate	Std. Error	*t*
Intercept	287.1348	37.7177	7.6127	1878.2541	123.0542	15.2636
F0	0.6398	0.0424	15.0849	0.1332	0.1400	0.9512
Duration (ms)	0.0077	0.0438	0.1763	-0.5973	0.1456	-4.1013
Sex: male	-36.5297	16.7690	-2.1784	-250.6717	44.7611	-5.6002
Timestep: 30%	6.9619	5.5062	1.2644	-26.1037	18.3936	-1.4192
Timestep: 40%	10.6273	5.5062	1.9301	-76.0825	18.3937	-4.1363
Timestep: 50%	12.1414	5.5062	2.2050	-140.6122	18.3936	-7.6446
Timestep: 60%	12.7127	5.5062	2.3088	-208.2720	18.3937	-11.3230
Timestep: 70%	15.0172	5.5063	2.7273	-261.0361	18.3940	-14.1914
Timestep: 80%	16.9967	5.5070	3.0864	-307.6113	18.3964	-16.7213
Previous Segment Contrasts: g	-3.0157	34.9430	-0.0863	-222.0075	116.2963	-1.9090
Previous Segment Contrasts: hh	-18.5234	43.7783	-0.4231	-435.7914	145.8556	-2.9878
Previous Segment Contrasts: l	88.4494	32.9554	2.6839	-438.6781	109.7359	-3.9976
Previous Segment Contrasts: n	56.8969	31.3490	1.8150	-52.0986	104.3633	-0.4992
Previous Segment Contrasts: r	91.6244	31.1673	2.9398	-383.5136	103.7077	-3.6980
Previous Segment Contrasts: sh	-8.8277	37.0824	-0.2381	-205.6986	123.4362	-1.6664
Previous Segment Contrasts: th	43.1778	36.3271	1.1886	-139.1174	120.9475	-1.1502
Following Segment Contrasts: ah	-21.5636	15.1383	-1.4244	160.2872	50.4721	3.1758

Following Segment Contrasts: ao	-4.6548	21.3965	-0.2175	108.8188	71.3892	1.5243
Following Segment Contrasts: ay	10.6308	17.5738	0.6049	225.7965	58.6179	3.8520
Following Segment Contrasts: b	-75.0397	22.1667	-3.3852	152.0441	73.9510	2.0560
Following Segment Contrasts: ch	-29.7519	34.2726	-0.8681	752.4799	114.2546	6.5860
Following Segment Contrasts: d	-37.7534	33.2832	-1.1343	497.1671	111.0146	4.4784
Following Segment Contrasts: dh	-31.2973	15.2269	-2.0554	423.0916	50.7334	8.3395
Following Segment Contrasts: dx	-21.8622	23.3306	-0.9371	451.3075	77.7979	5.8010
Following Segment Contrasts: eh	-15.3188	15.8800	-0.9647	85.6675	52.9259	1.6186
Following Segment Contrasts: f	-55.4887	21.3487	-2.5992	542.8119	70.9559	7.6500
Following Segment Contrasts: g	-77.7633	29.1181	-2.6706	309.1788	96.8819	3.1913
Following Segment Contrasts: hh	-21.5067	17.5710	-1.2240	288.3744	58.2997	4.9464
Following Segment Contrasts: ih	-36.9852	17.1589	-2.1554	117.3864	57.1069	2.0556
Following Segment Contrasts: IVER	-80.4830	56.2321	-1.4313	538.9767	155.8020	3.4594
Following Segment Contrasts: iy	-63.1409	19.7990	-3.1891	162.9471	66.0208	2.4681
Following Segment Contrasts: k	-45.0338	23.3882	-1.9255	303.4867	77.9284	3.8944
Following Segment Contrasts: m	-9.5400	28.3603	-0.3364	354.0792	94.5192	3.7461
Following Segment Contrasts: n	-31.9614	21.7599	-1.4688	410.6735	72.5878	5.6576
Following Segment Contrasts: NOISE	22.1182	22.7219	0.9734	212.7151	75.7575	2.8078
Following Segment Contrasts: ow	0.3739	28.7836	0.0130	-170.5122	95.9582	-1.7769
Following Segment Contrasts: p	-46.7522	28.8440	-1.6209	446.4102	96.0353	4.6484
Following Segment Contrasts: s	-2.7399	29.1816	-0.0939	500.3661	97.2001	5.1478
Following Segment Contrasts: SIL	-32.7765	19.7584	-1.6589	118.0632	65.7648	1.7952
Following Segment Contrasts: t	-20.9551	24.7198	-0.8477	573.7911	82.2842	6.9733
Following Segment Contrasts: th	-68.0650	22.1142	-3.0779	202.0058	73.7651	2.7385
Following Segment Contrasts: tq	-58.0988	30.4572	-1.9076	659.6176	101.3625	6.5075
Following Segment Contrasts: uh	-96.6390	23.6686	-4.0830	164.3241	78.5331	2.0924
Following Segment Contrasts: VOCNOISE	-73.5652	17.7934	-4.1344	168.5474	59.2474	2.8448
Following Segment Contrasts: w	5.5744	16.0909	0.3464	239.2751	53.5821	4.4656
Following Segment Contrasts: y	97.3136	29.9994	3.2439	31.4841	99.6342	0.3160
Following Segment Contrasts: z	-20.1400	34.2788	-0.5875	371.9210	114.1997	3.2568
Following Segment Contrasts: zh	-16.4400	40.9668	-0.4013	447.0736	136.5395	3.2743

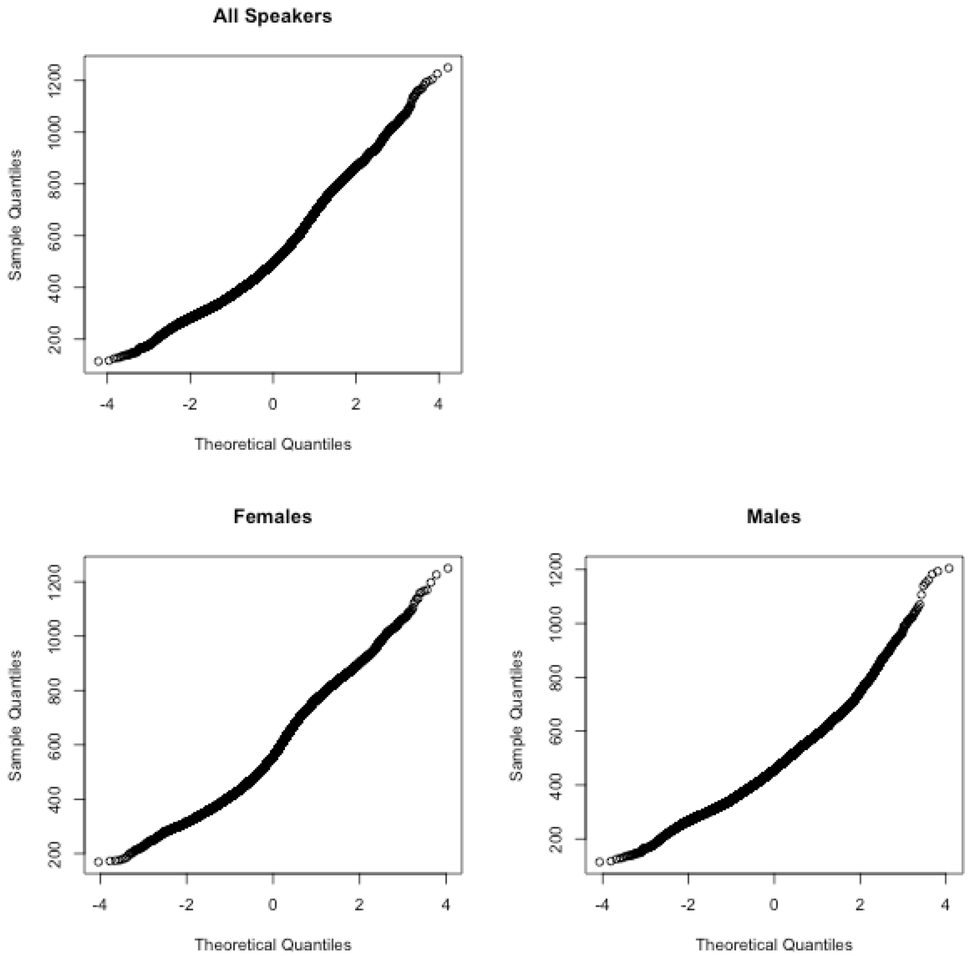

Figure A.1. Quantiles for the first formant by gender.

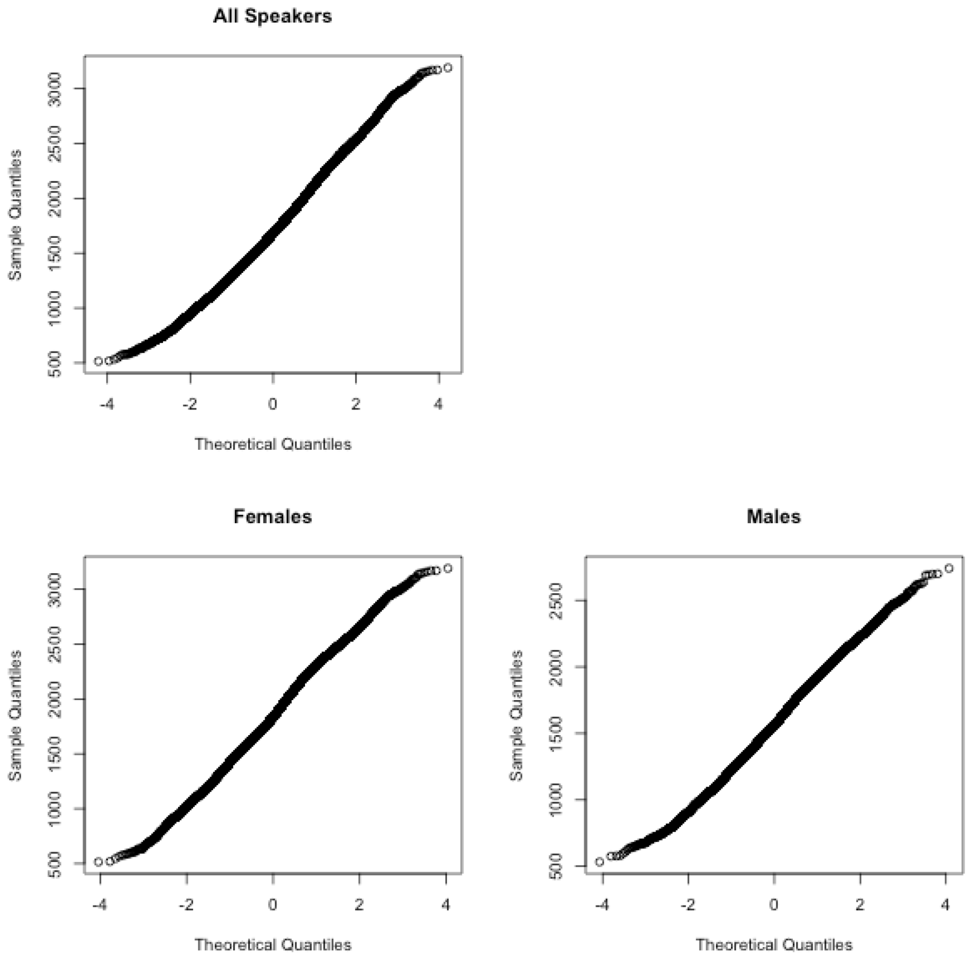

Figure A.2. Quantiles for the second formant by gender.

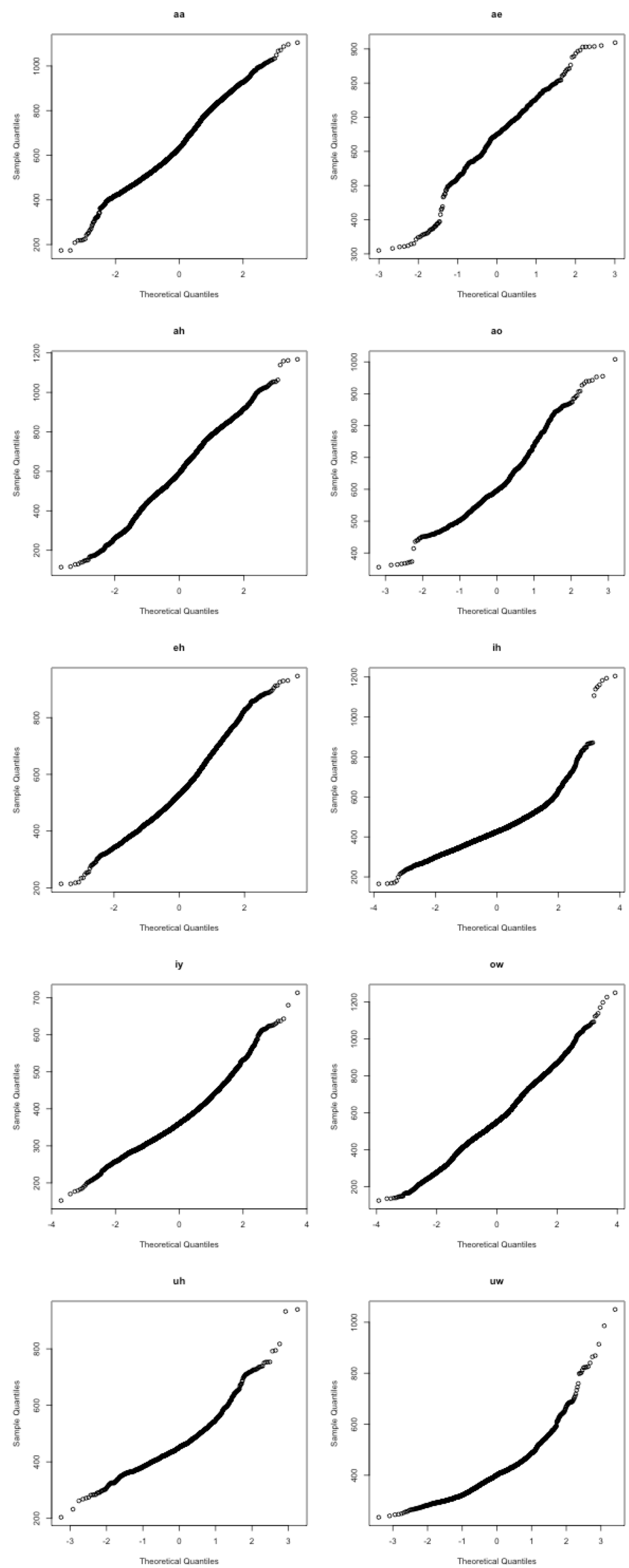

Figure A.3. Quantiles for the first formant by vowel.

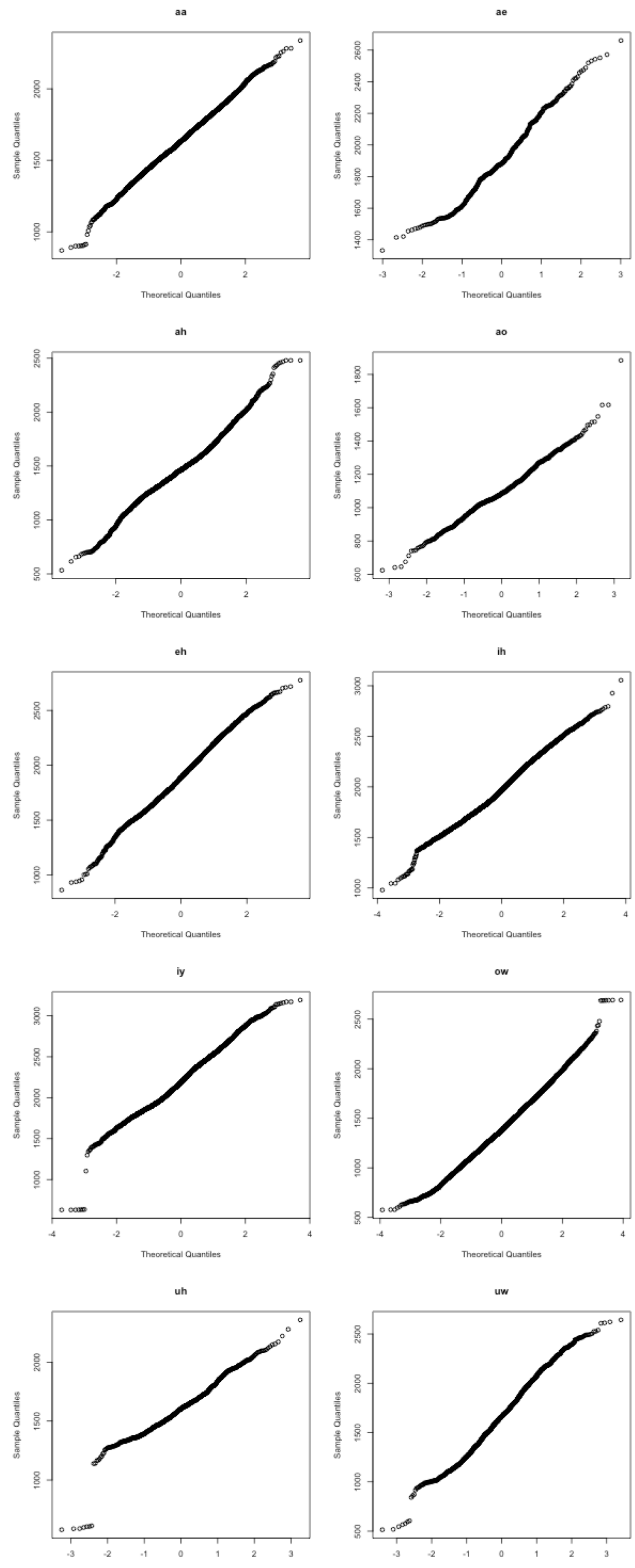

Figure A.4. Quantiles for the second formant by vowel.

A.2 Supplementary Information for Chapter 3

Table A.7: Frequency by gender for each vowel in the Buckeye Corpus irregular English verbs data.

Vowel	Gender	Frequency
aa	female	2107
	male	2590
ae	female	182
	male	196
ah	female	1617
	male	2373
ao	female	287
	male	392
eh	female	1841
	male	1568
ih	female	3654
	male	4480
iy	female	2387
	male	2331
ow	female	5418
	male	6223
uh	female	434
	male	434
uw	female	693
	male	833

Table A.8: Information about the vowels in the data set.

Vowel	Frequency in the Current Data Subset	Number of Speakers Produced by	Frequency in the Buckeye	Average NDL Measure	Number of Present Tense Tokens	Number of Past Tense Tokens
/ɑ/	671	40	6.5108	0.6624	11	660
/æ/	54	26	3.3527	0.1014	11	43
/ʌ/	570	38	5.8917	0.1388	493	77
/ɔ/	97	33	3.8304	0.1970	27	70
/ɛ/	487	40	5.9828	0.1752	335	152
/ɪ/	1160	40	6.4258	0.2183	1141	19
/i/	674	40	5.7009	0.3902	621	53
/o/	1663	40	7.1277	0.3010	1602	61
/ʊ/	124	34	4.7595	0.5331	3	121
/u/	218	38	4.2203	0.2498	41	177

Table A.9: Information about the words in the data set.

Traditional Paradigm/Gang	Lemma	Word	Tense	Frequency in the Current Data Subset	Number of Speakers Produced by	Frequency in the Buckeye	Average NDL Measure (past tense activation)
/i/→/ɛ/	feed	fed	past	4	3	2.3979	-0.0265
		feed	present	8	7	2.6391	0.0427
	meet	met	past	66	24	4.2047	-0.0214
		meet	present	26	14	3.2958	0.0323
	read	read	past	75	26	4.4427	-0.0051
/i/→/eɪ/	drink	drink	present	11	6	3.0445	-0.1644
	eat	eat	present	38	18	3.7136	0.1389
	sing	sang	past	5	2	1.7918	0.0842
		sing	present	6	4	1.9459	-0.0978
/i/→/ʌ/	swing	swing	present	4	2	1.9459	-0.2027
/i/→/ʊ/	sneak	sneak	present	2	2	1.3863	0.0640
/i/→/o/	speak	spoke	past	2	2	1.0986	0.1239
		speak	present	20	15	3.0445	0.0547
	steal	steal	present	3	3	1.0986	0.0041
/i/→/ɑ/	see	saw	past	63	28	4.2627	0.2677
		see	present	543	40	6.3404	0.4957
/ɪ/→/eɪ/	give	gave	past	8	7	3.8067	0.1286
		give	present	148	36	5.0370	0.3438
/ɪ/→/æ/	sit	sat	past	12	8	2.4849	0.1084
		sit	present	104	32	4.6634	0.0652
/ɪ/→/ʌ/	stick	stuck	past	14	10	2.8332	0.0265
		stick	present	5	4	2.7081	-0.0357
	win	won	past	13	8	2.9957	0.0320
		win	present	6	5	2.4849	-0.1190
/ɪ/→/ʊ/	spin	spin	present	1	1	1.0986	0.0237
/ɛ/→/i/	lead	led	past	2	2	1.0986	-0.0359
		lead	present	5	5	2.3979	0.1289
/ɛ/→/o/	wear	wore	past	5	3	1.7918	0.0270
		wear	present	24	15	3.7612	-0.0698
/ɛ/→/ɑ/	get	got	past	725	40	6.6093	0.6873
		get	present	1122	40	7.0273	0.2109
	tread	tread	present	1	1	0.6931	-0.0711
/eɪ/→/ʌ/	hang	hung	past	5	2	1.9459	-0.0500
		hang	present	10	9	2.7081	-0.0013
/eɪ/→/ʊ/	take	took	past	120	35	4.8203	0.5709
		take	present	6	4	5.8171	0.3539
/eɪ/→/o/	tear	tore	past	3	3	1.6094	-0.0433
		tear	present	1	1	0.6931	0.0052
	wake	woke	past	2	2	1.0986	0.1027
	break	broke	past	18	13	2.9957	0.1672
/aɪ/→/ɪ/	hide	hid	past	1	1	1.0986	0.0152
/aɪ/→/ʌ/	strike	struck	past	1	1	0.6931	0.0866
/aɪ/→/u/	fly	flew	past	3	3	1.3863	0.0399
/aɪ/→/o/	drive	drove	past	9	6	2.3026	0.0078
	ride	rode	past	5	3	1.9459	0.0948
	write	wrote	past	22	11	3.1781	0.0093
		write	present	1	1	3.8067	0.1145
/aɪ/→/ɑ/	fight	fought	past	2	2	1.0986	-0.0478
/aɪ/→/aʊ/	find	find	present	3	3	4.8283	0.1993
		found	past	7	6	4.2195	-0.0264
/ʌ/→/eɪ/	come	came	past	7	7	5.0626	-0.1199
		come	present	268	37	5.6312	-0.0334
/ʌ/→/æ/	run	ran	past	26	15	3.2958	0.0298
		run	present	46	21	4.3175	0.1112
/o/→/ɛ/	hold	held	past	7	5	2.0794	0.0053
		hold	present	17	11	3.0445	-0.0119
	swear	swore	past	1	1	0.6931	0.1578
		swear	present	1	1	1.9459	-0.0698
/o/→/u/	blow	blew	past	5	5	1.7918	0.0399
		blow	present	2	2	1.6094	0.0993
	grow	grew	past	47	25	3.9703	0.0402
		grow	present	33	19	3.5264	-0.0089
	know	knew	past	121	33	4.8363	0.3763
		know	present	1729	40	7.4782	0.3209
	throw	threw	past	9	7	2.3026	0.0548
		throw	present	29	19	3.4012	0.1547
/u/→/o/	choose	chose	past	4	4	1.6094	0.2900
		choose	present	21	12	3.0910	0.1308
/u/→/ɑ/	shoot	shot	past	10	6	2.9957	0.1278
		shoot	present	19	10	3.4657	0.1599
/ɑ/→/ɛ/	fall	fall	present	11	10	3.2581	0.0395
		fell	past	3	3	1.3863	-0.0213
/ɑ/→/u/	draw	drew	past	1	1	0.6931	0.1121
		draw	present	11	7	2.7081	0.0784

Table A.10: Model calls for each global and by vowel analysis in Chapter 3.

<table>
<tr><th>Analysis</th><th>Technique</th><th>Model Call</th></tr>
<tr><td>dispersion from vowel space centre</td><td>LMER</td><td>absFvalDispersion ~
predictors of interest
Tense * Percent
+ ObsVowelSupportTenseNP * Percent
# fixed effect of vowel
+ Vowel
# word frequency and vowel duration interaction
+ logmsDur * logBuckeyeFormFreq
# phonetic context
+ Prev_VoicingContrasts + Prev_PlaceContrasts + Prev_MannerContrasts
+ Next_VoicingContrasts + Next_PlaceContrasts + Next_MannerContrasts
# random speaker effects
+ (logmsDur|Speaker)
+ (logBuckeyeFormFreq|Speaker)
+ (1|Speaker)</td></tr>
<tr><td>deviance from vowel onset</td><td>LMER</td><td>absFvalOnsetDeviation ~
predictors of interest
Tense * Percent
+ ObsVowelSupportTenseNP * Percent
# fixed effect of vowel
+ Vowel
# word frequency and vowel duration interaction
+ logmsDur * logBuckeyeFormFreq
# phonetic context
+ Prev_VoicingContrasts + Prev_PlaceContrasts + Prev_MannerContrasts
+ Next_VoicingContrasts + Next_PlaceContrasts + Next_MannerContrasts
# random speaker effects
+ (logmsDur|Speaker)
+ (logBuckeyeFormFreq|Speaker)
+ (1|Speaker)</td></tr>
<tr><td>deviance from vowel offset</td><td>LMER</td><td>absFvalOffsetDeviation ~
predictors of interest
Tense * Percent
+ ObsVowelSupportTenseNP * Percent
# fixed effect of vowel
+ Vowel
# word frequency and vowel duration interaction
+ logmsDur * logBuckeyeFormFreq
# phonetic context
+ Prev_VoicingContrasts + Prev_PlaceContrasts + Prev_MannerContrasts
+ Next_VoicingContrasts + Next_PlaceContrasts + Next_MannerContrasts
# random speaker effects
+ (logmsDur|Speaker)
+ (logBuckeyeFormFreq|Speaker)
+ (1|Speaker)</td></tr>
<tr><td>nonlinear formant movement</td><td>GAM (BAM)</td><td>logFval ~
ti(TimeStep) +
predictors of interest
ti(TimeStep, by=Tense) + Tense +
ti(TimeStep, ObsVowelSupportTenseNP) + ObsVowelSupportTenseNP +
vowel duration and frequency interaction
te(logmsDur, logBuckeyeFormFreq) +
fixed effect of vowel
ti(TimeStep, by=Vowel) + Vowel +
fixed effects of consonant assimilation
ti(TimeStep, by=interaction(Vowel, Prev_MannerContrasts)) + # non-convergence
ti(TimeStep, by=interaction(Vowel, Prev_VoicingContrasts)) + # non-convergence
ti(TimeStep, by=interaction(Vowel, Prev_PlaceContrasts)) + # non-convergence
ti(TimeStep, by=interaction(Vowel, Next_MannerContrasts)) + # non-convergence
ti(TimeStep, by=interaction(Vowel, Next_VoicingContrasts)) + # non-convergence
ti(TimeStep, by=interaction(Vowel, Next_PlaceContrasts)) + # non-convergence
(Prev_MannerContrasts + Prev_VoicingContrasts + Prev_PlaceContrasts) * Vowel +
Vowel * (Next_MannerContrasts + Next_VoicingContrasts + Next_PlaceContrasts) +
random effects of speaker
s(TimeStep, Speaker, by=Vowel, bs="re")</td></tr>
</table>

Table A.11: Coefficients for the F1 and F2 global (all vowels pooled) LMER models of vowel dispersion.

	F1			F2		
Predictor	Estimate	std.Error	t.value	Estimate	std.Error	t.value
(Intercept)	-58.3827	29.2753	-1.9943	-498.4431	74.2501	-6.7130
Tense: past	-32.8123	2.6066	-12.5882	-47.7638	6.9191	-6.9031
Percent: 30	-9.9599	2.1830	-4.5626	4.0708	5.7966	0.7023
Percent: 40	-20.6675	2.1830	-9.4676	8.0062	5.7966	1.3812
Percent: 50	-29.8967	2.1830	-13.6955	13.0229	5.7966	2.2466
Percent: 60	-35.3127	2.1830	-16.1765	17.9984	5.7966	3.1050
Percent: 70	-36.9782	2.1830	-16.9395	21.6940	5.7966	3.7425
Percent: 80	-34.8091	2.1830	-15.9458	23.4357	5.7966	4.0430
NDL Cue Strength	-59.3505	5.9354	-9.9993	-129.4344	15.7576	-8.2141
Vowel: a	35.2117	2.5651	13.7271	-80.7634	6.8104	-11.8588
Vowel: æ	10.7633	4.0242	2.6746	-79.2013	10.6779	-7.4173
Vowel: ɔ	9.7500	3.4576	2.8199	337.3863	9.1794	36.7545
Vowel: ɛ	-31.2273	2.1471	-14.5440	-93.9519	5.7010	-16.4800
Vowel: ɪ	-3.7689	2.0953	-1.7988	-26.3873	5.5629	-4.7434
Vowel: i	62.3089	2.2646	27.5149	224.7182	6.0120	37.3783
Vowel: o	-29.4125	1.8194	-16.1657	108.2589	4.8314	22.4074
Vowel: ʊ	-33.4486	3.8910	-8.5963	22.6628	10.3279	2.1943
Vowel: u	5.8728	2.6796	2.1917	66.7550	7.1134	9.3845
Duration (log)	30.3510	5.1256	5.9214	161.4549	14.0663	11.4781
Frequency (log)	91.1762	12.6142	7.2280	243.7842	32.4483	7.5130
Previous Voicing: voiceless	21.5441	2.6540	8.1176	-54.7933	7.0467	-7.7757
Previous Place: dental	17.2030	9.8372	1.7488	-79.4131	26.1042	-3.0422
Previous Place: diphthong	43.5282	12.0395	3.6154	275.1590	31.9482	8.6127
Previous Place: glottal	30.0689	4.6542	6.4606	281.9279	12.3416	22.8437
Previous Place: labial	11.9971	2.6722	4.4896	23.9764	7.0875	3.3829
Previous Place: labio-dental	25.2603	4.6041	5.4864	113.6556	12.2157	9.3041
Previous Place: lax	56.9125	12.0803	4.7112	54.1151	32.0621	1.6878
Previous Place: palatal	0.6178	3.0861	0.2002	-1.7969	8.1958	-0.2192
Previous Place: palato-alveolar	62.6837	5.2308	11.9835	27.2266	13.8769	1.9620
Previous Place: tense	60.8194	10.0142	6.0733	297.2697	26.5670	11.1894
Previous Manner: approximate	28.0839	8.5230	3.2951	160.1612	22.6005	7.0866
Previous Manner: diphthong	-4.4798	12.0180	-0.3728	-18.3934	31.9192	-0.5762
Previous Manner: flap	77.2486	14.8704	5.1948	116.2946	39.4461	2.9482
Previous Manner: fricative	7.4412	7.6658	0.9707	110.0829	20.3182	5.4180
Previous Manner: lax	-6.3571	9.4375	-0.6736	113.4938	25.0599	4.5289
Previous Manner: nasal	47.6860	8.4085	5.6712	66.5220	22.2951	2.9837
Previous Manner: stop	25.8115	8.3531	3.0900	191.8042	22.1471	8.6605
Next Voicing: voiceless	3.0165	1.5760	1.9140	31.4395	4.1847	7.5130
Next Place: dental	-19.9179	3.2212	-6.1833	39.2946	8.5554	4.5929
Next Place: diphthong	17.8941	9.5555	1.8726	46.7636	25.3757	1.8428
Next Place: glottal	5.3473	1.7311	3.0889	47.3702	4.5968	10.3050
Next Place: labial	1.6234	1.7828	0.9106	58.7536	4.7345	12.4098
Next Place: labio-dental	4.0586	3.4812	1.1659	44.6409	9.2437	4.8294
Next Place: lax	-55.2747	19.5666	-2.8250	-4.4656	51.9656	-0.0859
Next Place: palatal	4.5456	2.1572	2.1072	-28.8190	5.7220	-5.0366
Next Place: palato-alveolar	-3.5265	6.4218	-0.5491	-37.9269	17.0608	-2.2230
Next Place: tense	3.8627	9.9884	0.3867	71.0383	26.5287	2.6778
Next Manner: approximate	-10.3617	9.4358	-1.0981	64.6658	25.0567	2.5808
Next Manner: flap	-7.7542	9.4420	-0.8212	19.5740	25.0727	0.7807
Next Manner: fricative	7.6158	9.1437	0.8329	-36.4178	24.2803	-1.4999
Next Manner: lax	46.9746	17.2197	2.7280	61.0983	45.7338	1.3360
Next Manner: nasal	18.9483	9.5316	1.9879	5.6872	25.3112	0.2247
Next Manner: stop	-6.0402	9.2840	-0.6506	-5.0305	24.6529	-0.2041
Tense: past x Percent: 30	15.4293	3.0640	5.0357	-14.8310	8.1360	-1.8229
Tense: past x Percent: 40	30.5306	3.0640	9.9644	-24.2537	8.1360	-2.9810
Tense: past x Percent: 50	44.8250	3.0640	14.6298	-35.4567	8.1360	-4.3580
Tense: past x Percent: 60	51.6519	3.0640	16.8579	-41.3241	8.1360	-5.0792
Tense: past x Percent: 70	53.1408	3.0640	17.3439	-42.6435	8.1360	-5.2413
Tense: past x Percent: 80	47.3845	3.0640	15.4651	-36.6429	8.1360	-4.5038
Percent: 30 x NDL Cue Strength	19.6106	6.3897	3.0691	10.0258	16.9673	0.5909
Percent: 40 x NDL Cue Strength	42.7670	6.3897	6.6931	33.0379	16.9673	1.9472
Percent: 50 x NDL Cue Strength	59.0337	6.3897	9.2388	63.0881	16.9673	3.7182
Percent: 60 x NDL Cue Strength	67.9969	6.3897	10.6416	85.9819	16.9673	5.0675
Percent: 70 x NDL Cue Strength	68.5464	6.3897	10.7276	97.9981	16.9673	5.7757
Percent: 80 x NDL Cue Strength	62.5850	6.3897	9.7946	95.1271	16.9673	5.6065
Duration (log) x Frequency (log)	-16.8536	2.5821	-6.5270	-66.6849	6.8375	-9.7528

Table A.12: Coefficients for the F1 and F2 by vowel LMER models of vowel dispersion.

i F1

	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	101.3612	55.8088	1.8162	108.6147	57.1842	1.8994	117.3603	57.0012	2.0589	135.9587	57.2284	2.3757	124.8744	57.7932	2.1607	122.5714	57.3604	2.1369	109.1335	56.8694	1.9190
Tense: past	13.4441	21.9450	0.6126	10.8561	22.4707	0.4831	14.3049	22.4073	0.6384	12.1184	22.4532	0.5397	7.8192	22.7054	0.3444	5.1171	22.5240	0.2272	13.6605	22.2775	0.6132
NDL Cue Strength	40.5920	89.7050	0.4525	107.1987	91.8668	1.1669	139.4569	91.3983	1.5258	158.7941	91.4397	1.7366	146.7988	92.3004	1.5904	135.5440	91.7653	1.4771	139.4929	90.8737	1.5350
Duration (log)	0.3145	0.2157	1.4581	0.2948	0.2224	1.3255	0.3155	0.2283	1.3822	0.2366	0.2349	1.0072	0.2787	0.2398	1.1621	0.2396	0.2295	1.0437	0.3356	0.2265	1.4816
Frequency (log)	8.1754	8.8535	0.9234	5.4946	9.0866	0.6047	3.4391	9.1018	0.3779	0.6138	9.1488	0.0671	2.2873	9.2645	0.2469	2.1294	9.1134	0.2337	4.7405	9.0092	0.5262
Previous Voicing: voiceless	32.9359	30.5551	1.0779	33.7478	31.2931	1.0784	43.5400	31.0887	1.4005	41.9400	31.1175	1.3478	49.0522	31.3525	1.5645	50.1943	31.1932	1.6091	47.0121	30.8987	1.5215
Previous Place: diphthong	-2.9590	31.6972	-0.0934	-40.4293	32.5680	-1.2414	-62.3268	32.7136	-1.9052	-84.7987	33.1785	-2.5558	-80.2964	33.5233	-2.3952	-36.7043	32.8364	-1.1178	-23.5159	32.5580	-0.7223
Previous Place: labial	-13.3682	18.2971	-0.7306	-11.7647	18.7165	-0.6286	-12.4560	18.6908	-0.6664	-6.9491	18.7248	-0.3711	-7.1042	18.9708	-0.3745	-3.9888	18.7931	-0.2122	-0.4534	18.5441	-0.0245
Previous Place: labio-dental	39.3080	38.0654	1.0326	67.5281	38.9565	1.7334	73.8930	38.8639	1.9013	80.7245	38.8606	2.0773	78.4722	39.3521	1.9941	75.6410	38.9884	1.9401	80.9541	38.4760	2.1040
Previous Place: lax	32.6829	21.3816	1.5286	10.6389	21.9001	0.4858	9.7495	21.7855	0.4475	7.3134	21.8318	0.3350	12.6475	22.0190	0.5744	21.8856	21.8869	0.9999	30.5714	21.6903	1.4094
Previous Place: palatal	-19.0957	36.8241	-0.5186	-23.6399	37.7259	-0.6266	-24.0603	37.4614	-0.6423	-23.5049	37.5317	-0.6263	-19.5325	37.7658	-0.5172	-4.4941	37.5456	-0.1197	-2.6260	37.2187	-0.0706
Previous Place: palato-alveolar	13.6091	51.8102	0.2627	13.5299	53.1343	0.2546	4.1659	52.4705	0.0794	-5.3588	52.3906	-0.1023	-8.4666	52.4928	-0.1613	-4.4525	52.5642	-0.0847	5.4315	52.3399	0.1038
Previous Place: tense	54.6334	26.7659	2.0412	41.2717	27.4012	1.5062	46.3944	27.3203	1.6982	34.0262	27.4717	1.2386	26.0903	27.7155	0.9414	16.5751	27.4533	0.6038	8.7160	27.1366	0.3212
Previous Manner: fricative	-21.1003	46.4522	-0.4542	-62.3348	47.5827	-1.3100	-79.4152	47.2515	-1.6807	-89.7175	47.2620	-1.8983	-98.3670	47.6080	-2.0662	-99.3701	47.3995	-2.0964	-93.8857	46.9813	-1.9984
Previous Manner: nasal	19.5248	21.5518	0.9059	6.0594	22.0435	0.2749	12.0784	22.0026	0.5490	9.1131	22.0334	0.4136	9.9603	22.3278	0.4461	11.8048	22.1510	0.5329	20.5337	21.8748	0.9387
Previous Manner: stop	22.1288	32.1694	0.6879	7.7574	32.9445	0.2355	3.0698	32.7362	0.0938	-5.8652	32.7934	-0.1789	-17.2251	33.0453	-0.5213	-28.4120	32.8517	-0.8649	-29.2143	32.5278	-0.8981
Next Voicing: voiceless	-6.8857	10.0616	-0.6844	0.4998	10.3131	0.0485	-0.2431	10.2333	-0.0238	4.0764	10.2417	0.3980	7.0456	10.2944	0.6844	4.6446	10.2306	0.4540	0.1701	10.1471	0.0168
Next Place: dental	-8.0548	15.7648	-0.5109	-1.5523	16.1626	-0.0960	-3.6440	15.9962	-0.2278	-1.9121	15.9834	-0.1196	-1.1291	16.0395	-0.0704	-8.4554	15.9974	-0.5285	-16.8122	15.8958	-1.0577
Next Place: diphthong	-42.3693	46.2879	-0.9153	-37.9283	47.4546	-0.7993	-50.0374	46.9360	-1.0661	-58.5538	46.9081	-1.2483	-59.2441	47.0252	-1.2598	-58.9259	46.9334	-1.2555	-80.2944	46.6725	-1.7204
Next Place: glottal	-18.9572	12.1012	-1.5666	-18.3907	12.4101	-1.4819	-18.6783	12.2968	-1.5190	-15.4025	12.3074	-1.2515	-12.5753	12.3496	-1.0183	-20.5096	12.2951	-1.6681	-25.8002	12.2177	-2.1117
Next Place: labial	10.1969	10.7855	0.9454	8.1423	11.0677	0.7357	4.6381	10.9771	0.4225	4.7977	10.9825	0.4368	6.0236	11.0327	0.5460	12.1352	10.9681	1.1064	18.6234	10.8988	1.7088
Next Place: labio-dental	-12.2322	21.8324	-0.5603	-6.9434	22.4407	-0.3094	-5.9617	22.4021	-0.2661	-3.3363	22.5709	-0.1478	7.8840	22.7149	0.3471	10.1492	22.2917	0.4553	14.6468	22.1627	0.6609
Next Place: lax	-24.2561	56.5170	-0.4292	-11.6356	57.9549	-0.2008	-23.2412	57.3205	-0.4055	-32.9672	57.3117	-0.5752	-53.2193	57.4619	-0.9262	-82.2827	57.3819	-1.4339	-124.2913	57.0955	-2.1769
Next Place: palatal	1.9669	12.2959	0.1600	-6.3481	12.6072	-0.5035	-15.2179	12.5502	-1.2126	-18.0647	12.5697	-1.4372	-12.7831	12.6810	-1.0080	4.4327	12.5746	0.3525	20.5750	12.4610	1.6512
Next Place: palato-alveolar	-37.2202	31.3022	-1.1891	-26.0543	32.1019	-0.8116	-21.0055	31.7039	-0.6626	-10.5296	31.6842	-0.3323	5.9788	31.7032	0.1886	14.3369	31.6525	0.4529	7.8072	31.5097	0.2478
Next Place: tense	-3.3141	46.3486	-0.0715	1.3605	47.5170	0.0286	-11.2260	46.9773	-0.2390	-21.7178	46.9370	-0.4627	-21.9693	47.0395	-0.4670	-26.7002	46.9682	-0.5685	-30.5193	46.7138	-0.6533
Next Manner: approximate	-12.1871	44.7426	-0.2724	-4.1650	45.8729	-0.0908	-14.3230	45.3703	-0.3157	-20.4267	45.3283	-0.4506	-14.0220	45.4491	-0.3085	-11.7754	45.3588	-0.2596	-21.3437	45.1016	-0.4732
Next Manner: flap	5.5890	44.4033	0.1259	16.8465	45.5291	0.3700	10.5544	45.0405	0.2343	2.8180	45.0056	0.0626	5.3580	45.1285	0.1187	6.4418	45.0283	0.1431	-1.8522	44.7788	-0.0414
Next Manner: fricative	5.6377	42.8664	0.1315	8.4678	43.9464	0.1927	2.9912	43.4559	0.0688	-1.5904	43.4101	-0.0366	2.8957	43.5197	0.0665	15.2270	43.4465	0.3505	21.1470	43.2019	0.4895
Next Manner: lax	12.8954	36.3514	0.3547	6.8389	37.2935	0.1834	7.7066	36.8901	0.2089	11.8197	36.9099	0.3202	34.7165	37.0046	0.9382	66.5866	36.9565	1.8018	95.5315	36.8023	2.5958
Next Manner: nasal	-7.2386	45.2512	-0.1600	5.1291	46.3917	0.1106	1.7855	45.8737	0.0389	1.9001	45.8315	0.0415	7.4789	45.9454	0.1628	6.1447	45.8737	0.1339	-4.7067	45.6218	-0.1032
Next Manner: stop	13.7037	43.6664	0.3138	20.0644	44.7685	0.4482	16.3342	44.2870	0.3688	13.2013	44.2521	0.2983	19.1913	44.3750	0.4325	25.7667	44.2771	0.5819	26.3136	44.0256	0.5977
Duration (log) x Frequency (log)	-0.0622	0.0368	-1.6931	-0.0494	0.0379	-1.3037	-0.0449	0.0387	-1.1597	-0.0240	0.0397	-0.6037	-0.0263	0.0404	-0.6519	-0.0148	0.0388	-0.3820	-0.0360	0.0383	-0.9399

i F2

	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	228.2286	152.9483	1.4922	144.1246	146.6701	0.9826	167.6011	144.4617	1.1602	157.3339	148.1433	1.0620	140.5099	151.2058	0.9293	124.0010	157.2299	0.7887	83.3357	165.2886	0.5042
Tense: past	-67.6621	61.4094	-1.1018	-31.8767	57.5632	-0.5538	12.8853	56.2541	0.2291	50.6421	57.5496	0.8800	55.0155	58.6901	0.9374	74.5103	61.0114	1.2213	101.9281	64.1238	1.5896
NDL Cue Strength	46.4744	248.2296	0.1872	193.4786	233.6400	0.8281	351.1948	228.5623	1.5365	501.1634	233.7182	2.1443	664.1273	238.3856	2.7859	716.0336	247.9688	2.8876	795.6385	260.5995	3.0531
Duration (log)	1.5539	0.6182	2.5137	1.7623	0.6343	2.7786	1.7343	0.6339	2.7361	1.3608	0.6601	2.0617	1.2932	0.6763	1.9122	1.3367	0.7001	1.9094	1.3521	0.7385	1.8310
Frequency (log)	5.2471	25.0499	0.2095	5.1852	23.7540	0.2183	-1.9433	23.2637	-0.0835	-13.1951	23.8768	-0.5526	-19.5602	24.4011	-0.8016	-21.7136	25.3694	-0.8559	-32.5872	26.6515	-1.2227
Previous Voicing: voiceless	86.1178	84.2371	1.0223	89.7336	79.8257	1.1241	121.1528	78.0722	1.5518	129.3335	79.8637	1.6194	139.8828	81.5078	1.7162	133.2121	84.8108	1.5707	141.1059	89.1127	1.5835
Previous Place: diphthong	310.6670	87.6181	3.5457	229.2164	87.5187	2.6191	184.8218	87.1040	2.1219	150.7313	90.0809	1.6733	76.1109	92.2106	0.8254	38.4302	95.7457	0.4014	8.8359	100.7055	0.0877
Previous Place: labial	-148.1807	51.7971	-2.8608	-109.8541	47.9994	-2.2887	-58.2699	46.6992	-1.2478	-21.9402	47.7193	-0.4598	2.4765	48.6262	0.0509	33.7308	50.5340	0.6675	62.6913	53.1712	1.1790
Previous Place: labio-dental	-25.2720	107.6792	-0.2347	92.4448	99.4916	0.9292	172.5599	96.6028	1.7863	253.4578	98.6306	2.5698	336.3397	100.5799	3.3440	356.4280	104.6316	3.4065	351.3054	110.0125	3.1933
Previous Place: lax	282.3796	58.9623	4.7892	221.5411	56.0116	3.9553	187.8023	54.9903	3.4152	174.6995	56.3555	3.1000	124.0272	57.5045	2.1568	73.4268	59.7889	1.2281	13.6554	62.8869	0.2171
Previous Place: palatal	166.1501	100.9852	1.6453	123.3976	96.6227	1.2771	94.6579	94.7900	0.9986	90.3362	97.1251	0.9301	117.7757	99.1810	1.1875	154.5218	103.1683	1.4978	162.3909	108.3570	1.4987
Previous Place: palato-alveolar	46.2443	137.5275	0.3363	18.2824	133.7648	0.1367	-6.0118	131.8960	-0.0456	-19.4941	135.1152	-0.1443	-35.6798	138.0973	-0.2584	-69.0106	143.7922	-0.4799	-106.8936	150.6715	-0.7094
Previous Place: tense	435.9380	74.9173	5.8189	338.4452	71.2307	4.7514	304.9274	69.7082	4.3743	264.0690	71.4490	3.6959	173.8589	72.9451	2.3834	133.5586	75.8249	1.7614	111.5442	79.6606	1.4002
Previous Manner: fricative	48.1386	127.4511	0.3777	-23.0971	121.0107	-0.1909	-115.5006	118.4205	-0.9753	-184.9062	121.1213	-1.5266	-280.5695	123.6135	-2.2697	-305.9173	128.6387	-2.3781	-332.0710	135.1534	-2.4570
Previous Manner: nasal	179.9364	60.9320	2.9531	217.7590	56.2644	3.8703	204.9857	54.7984	3.7407	184.9527	55.9785	3.3040	143.3691	57.0120	2.5147	95.7031	59.2559	1.6151	47.4364	62.4015	0.7602
Previous Manner: stop	93.6982	89.1441	1.0511	80.1881	84.4618	0.9494	31.5999	82.6244	0.3825	-16.2988	84.6092	-0.1926	-100.9247	86.3925	-1.1682	-160.3563	89.8673	-1.7844	-230.8742	94.3952	-2.4458
Next Voicing: voiceless	23.9457	27.4644	0.8719	43.6686	26.3707	1.6560	49.5764	25.8668	1.9166	62.0707	26.5046	2.3419	70.7359	27.0839	2.6117	102.6005	28.1819	3.6407	120.6288	29.5644	4.0802
Next Place: dental	75.2863	42.5016	1.7714	102.1573	40.9790	2.4929	83.3084	40.2764	2.0684	74.0977	41.2617	1.7958	61.7681	42.1668	1.4648	64.5171	43.8920	1.4699	47.5232	46.0287	1.0325
Next Place: diphthong	-102.0213	124.1441	-0.8218	-13.6517	120.1560	-0.1136	-29.2733	118.3984	-0.2472	24.9673	121.3878	0.2057	75.1887	124.0208	0.6063	107.9533	129.0605	0.8365	210.3973	135.4436	1.5534
Next Place: glottal	-27.9918	32.6509	-0.8573	-8.2405	31.6611	-0.2603	-15.6294	31.1528	-0.5017	-2.1660	31.9354	-0.0678	19.6132	32.6388	0.6009	53.7954	33.9679	1.5837	100.4856	35.6240	2.8207

Next Place: labial	-6.8864	29.1514	-0.2362	-17.1655	28.2653	-0.6073	-39.9898	27.8258	-1.4371	-60.3523	28.5463	-2.1142	-77.0276	29.1917	-2.6387	-97.9997	30.3823	-3.2256	-116.6843	31.8583	-3.6626
Next Place: labio-dental	18.6340	59.2446	0.3145	26.9759	59.0753	0.4566	15.4513	58.9058	0.2623	11.1006	60.9163	0.1822	10.9757	62.3750	0.1760	21.3734	64.7982	0.3298	27.7463	68.1168	0.4073
Next Place: lax	-73.2601	151.0256	-0.4851	31.7838	146.8276	0.2165	14.5957	144.9166	0.1007	49.9567	148.6504	0.3361	47.7976	151.9159	0.3146	-81.8108	158.1124	-0.5174	133.4206	165.9318	0.8041
Next Place: palatal	-35.5552	33.8930	-1.0490	-37.0707	32.3228	-1.1469	-51.5637	31.7055	-1.6263	-38.8888	32.4957	-1.1967	-2.3155	33.1918	-0.0698	34.2915	34.5209	0.9934	86.2881	36.2408	2.3810
Next Place: palato-alveolar	-140.5656	83.3226	-1.6870	-107.2319	81.3717	-1.3178	-117.8067	80.3642	-1.4659	-58.2330	82.5093	-0.7058	-2.0796	84.3651	-0.0246	36.0572	87.7900	0.4107	123.9588	92.0838	1.3462
Next Place: tense	-107.5537	124.2106	-0.8659	-10.9179	120.1978	-0.0908	7.7774	118.4127	0.0657	80.7650	121.3763	0.6654	132.2117	124.0143	1.0661	146.2907	129.0739	1.1334	210.3043	135.4423	1.5527
Next Manner: approximate	-123.2872	120.1462	-1.0261	-17.1265	116.0805	-0.1475	19.1159	114.2965	0.1672	99.3991	117.1477	0.8485	152.6372	119.6985	1.2752	176.4265	124.5859	1.4161	243.2875	130.7315	1.8610
Next Manner: flap	-55.8218	119.2705	-0.4680	30.3536	115.2513	0.2634	39.2973	113.5396	0.3461	103.8938	116.3940	0.8926	166.9855	118.9282	1.4041	202.2954	123.7848	1.6343	275.0710	129.9186	2.1173
Next Manner: fricative	-129.5203	115.1696	-1.1246	-66.8449	111.1201	-0.6016	-42.8130	109.3864	-0.3914	25.0936	112.0878	0.2239	75.8537	114.5157	0.6624	75.7808	119.1952	0.6358	136.8038	125.0719	1.0938
Next Manner: lax	-25.8492	96.6197	-0.2675	-41.6320	94.6732	-0.4397	-17.1408	93.6768	-0.1830	20.7766	96.1863	0.2160	86.5919	98.3500	0.8804	258.8616	102.3681	2.5287	141.1906	107.3962	1.3147
Next Manner: nasal	-47.8117	121.3264	-0.3941	46.4417	117.3059	0.3959	84.2750	115.5573	0.7293	179.3689	118.4434	1.5144	265.5511	121.0131	2.1944	317.7076	125.9495	2.5225	418.4150	132.1681	3.1658
Next Manner: stop	-19.1083	117.3616	-0.1628	68.7561	113.3205	0.6067	91.8483	111.6222	0.8228	157.6723	114.4296	1.3779	220.3143	116.9133	1.8844	245.4563	121.6775	2.0173	321.9057	127.7154	2.5205
Duration (log) x Frequency (log)	-0.1761	0.1047	-1.6814	-0.1521	0.1068	-1.4243	-0.1051	0.1062	-0.9893	-0.0091	0.1101	-0.0827	0.0172	0.1127	0.1522	-0.0039	0.1169	-0.0335	-0.0543	0.1231	-0.4413

ı F1

	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	288.3392	59.1299	4.8764	252.3945	59.0894	4.2714	244.3000	60.3943	4.0451	245.3915	60.8690	4.0315	258.9411	60.9644	4.2474	260.8053	61.3119	4.2537	273.9678	61.7706	4.4352
Tense: past	-14.3792	13.0906	-1.0984	-12.9167	13.1477	-0.9824	-17.8529	13.4852	-1.3239	-22.2461	13.6006	-1.6357	-21.3704	13.5985	-1.5715	-20.6063	13.6880	-1.5054	-9.8309	13.8645	-0.7091
NDL Cue Strength	42.4656	24.7381	1.7166	49.0677	24.8755	1.9725	57.3154	25.5418	2.2440	60.8973	25.7805	2.3621	53.8424	25.7943	2.0874	37.6072	25.9772	1.4477	25.2130	26.3403	0.9572
Duration (log)	-0.7411	0.3273	-2.2643	-0.4229	0.3226	-1.3111	-0.3498	0.3212	-1.0892	-0.2753	0.3222	-0.8545	-0.2307	0.3240	-0.7120	-0.1417	0.3239	-0.4376	-0.1396	0.3231	-0.4321
Frequency (log)	-4.2204	5.5775	-0.7567	0.5236	5.5331	0.0946	1.9641	5.6121	0.3500	1.0852	5.6330	0.1926	0.4547	5.6205	0.0809	1.3815	5.6410	0.2449	1.3708	5.6593	0.2422
Previous Voicing: voiceless	-11.1495	10.5351	-1.0583	-7.0261	10.5989	-0.6629	-5.6735	10.8869	-0.5211	-6.9090	10.9982	-0.6282	-8.6237	11.0075	-0.7834	-4.8409	11.0864	-0.4366	-0.0140	11.2497	-0.0012
Previous Place: glottal	67.9602	29.3553	2.3151	59.2656	29.3304	2.0206	34.9138	30.0288	1.1627	22.3286	30.2471	0.7382	11.9697	30.2247	0.3960	5.7788	30.4262	0.1899	-1.6224	30.7016	-0.0528
Previous Place: labial	3.7058	29.6933	0.1248	4.3244	29.4548	0.1468	5.6080	29.9441	0.1873	4.4027	30.0162	0.1467	8.8005	29.8906	0.2944	17.9797	30.0103	0.5991	33.6629	29.9863	1.1226
Previous Place: labio-dental	-53.0198	46.0120	-1.1523	-55.2473	46.4182	-1.1902	-50.2121	47.7879	-1.0507	-36.9503	48.3132	-0.7648	-31.2290	48.3659	-0.6457	-29.2032	48.7471	-0.5991	-29.8878	49.5904	-0.6027
Previous Place: lax	-133.4681	59.9854	-2.2250	-120.8027	60.3075	-2.0031	-125.3564	61.9278	-2.0242	-135.6572	62.4961	-2.1707	-151.0499	62.5341	-2.4155	-149.4778	62.9686	-2.3738	-159.0448	63.8008	-2.4928
Previous Place: palatal	11.4240	19.2637	0.5930	11.2994	19.3114	0.5851	6.0537	19.7738	0.3061	1.1331	19.9283	0.0569	1.4164	19.9125	0.0711	4.5898	20.0324	0.2291	6.2142	20.2361	0.3071
Previous Place: palato-alveolar	-44.2452	35.2464	-1.2553	-44.4757	35.5268	-1.2519	-45.7818	36.5491	-1.2526	-47.3209	36.9210	-1.2817	-52.7024	36.9907	-1.4247	-51.2092	37.2728	-1.3739	-50.2746	37.8657	-1.3277
Previous Place: tense	-90.8329	60.1422	-1.5103	-83.8474	60.4049	-1.3881	-90.2634	61.9704	-1.4566	-93.3239	62.5128	-1.4929	-97.8120	62.5542	-1.5636	-95.8896	62.9773	-1.5226	-108.6035	63.7473	-1.7037
Previous Manner: approximate	-142.7385	59.0982	-2.4153	-142.5390	59.3908	-2.4000	-143.3460	60.9539	-2.3517	-137.2993	61.4995	-2.2325	-150.1653	61.5484	-2.4398	-160.5057	61.9726	-2.5899	-180.7608	62.7442	-2.8809
Previous Manner: flap	-78.7214	74.7790	-1.0527	-70.4091	75.2336	-0.9359	-73.3234	77.2948	-0.9486	-66.8130	78.0590	-0.8559	-74.0761	78.1360	-0.9480	-87.7273	78.7128	-1.1145	-105.6868	79.8344	-1.3238
Previous Manner: fricative	-136.0664	52.6150	-2.5861	-136.4630	52.8432	-2.5824	-143.7479	54.2099	-2.6517	-142.8737	54.6695	-2.6134	-147.7564	54.6961	-2.7014	-152.2713	55.0601	-2.7655	-164.9861	55.7137	-2.9613
Previous Manner: nasal	-190.0243	60.5942	-3.1360	-160.2535	60.8238	-2.6347	-136.5081	62.3720	-2.1886	-121.7011	62.9046	-1.9347	-127.8453	62.9318	-2.0315	-131.9926	63.3537	-2.0834	-147.3331	64.0915	-2.2988
Previous Manner: stop	-129.7349	55.4731	-2.3387	-129.4703	55.7178	-2.3237	-135.0557	57.1688	-2.3624	-132.4763	57.6769	-2.2969	-142.7469	57.7222	-2.4730	-150.5438	58.1243	-2.5900	-165.9763	58.8346	-2.8211
Next Voicing: voiceless	-7.6204	7.0520	-1.0806	-6.8806	7.0972	-0.9695	-2.5412	7.2836	-0.3489	0.6764	7.3530	0.0920	2.0134	7.3595	0.2736	1.5193	7.4101	0.2050	1.6433	7.5246	0.2184
Next Place: dental	36.4163	20.3127	1.7928	40.5890	20.4632	1.9835	37.4516	21.0133	1.7823	27.5766	21.2168	1.2998	30.6541	21.2289	1.4440	32.3512	21.3760	1.5134	31.7550	21.7308	1.4613
Next Place: diphthong	-29.7970	20.0165	-1.4886	-40.6515	20.1699	-2.0155	-42.4032	20.7340	-2.0451	-35.2914	20.9484	-1.6847	-31.8144	20.9644	-1.5175	-34.7831	21.1191	-1.6470	-37.5942	21.4691	-1.7511
Next Place: glottal	-3.3773	7.5971	-0.4446	-1.7180	7.6445	-0.2247	1.7808	7.8418	0.2271	1.0758	7.9131	0.1360	-2.4288	7.9177	-0.3068	-10.8766	7.9701	-1.3647	-21.1147	8.0937	-2.6088
Next Place: labial	-2.2278	11.5450	-0.1930	-1.4419	11.6149	-0.1241	-0.2913	11.9155	-0.0244	-4.8265	12.0181	-0.4016	-6.9791	12.0132	-0.5810	-8.4323	12.0901	-0.6975	-4.1117	12.2695	-0.3351
Next Place: labio-dental	27.7654	18.9887	1.4622	26.7601	19.1072	1.4005	21.6980	19.6180	1.1060	6.1879	19.8030	0.3125	1.3132	19.8100	0.0663	-3.3053	19.9486	-0.1657	0.7834	20.2517	0.0387
Next Place: lax	-0.1277	11.4362	-0.0112	0.4867	11.5188	0.0423	2.0879	11.8256	0.1766	0.4623	11.9433	0.0387	-5.1160	11.9563	-0.4279	-13.1686	12.0393	-1.0938	-22.7176	12.2364	-1.8566
Next Place: palatal	17.5465	15.7432	1.1145	25.2522	15.7655	1.6017	30.4122	16.1260	1.8859	31.0742	16.2342	1.9141	34.5419	16.2123	2.1306	43.3739	16.3034	2.6604	47.7764	16.4436	2.9055
Next Place: palato-alveolar	12.5881	32.2888	0.3899	13.5575	32.5668	0.4163	11.8916	33.4927	0.3551	7.8848	33.8376	0.2330	8.2506	33.8661	0.2436	7.9270	34.1186	0.2323	9.4970	34.7106	0.2736
Next Place: tense	-22.2797	46.0743	-0.4836	-16.7642	46.4876	-0.3606	-12.1725	47.8416	-0.2544	-10.5820	48.3593	-0.2188	-18.3563	48.4198	-0.3791	-49.4276	48.7944	-1.0130	-75.2306	49.6539	-1.5151
Next Manner: approximate	28.4685	16.8446	1.6901	22.7518	16.9644	1.3412	13.5457	17.4185	0.7777	6.7108	17.5829	0.3817	9.1030	17.5876	0.5176	10.0735	17.7076	0.5689	5.6312	17.9905	0.3130
Next Manner: flap	-9.2197	7.3769	-1.2498	-10.7749	7.4241	-1.4513	-10.3661	7.6192	-1.3605	-11.6478	7.6906	-1.5145	-13.8559	7.6955	-1.8005	-20.3832	7.7479	-2.6308	-25.5564	7.8677	-3.2482
Next Manner: fricative	-13.4956	13.9114	-0.9701	-11.8785	14.0245	-0.8470	-8.0070	14.4103	-0.5556	-0.9317	14.5543	-0.0640	-1.7280	14.5656	-0.1186	-1.3366	14.6699	-0.0911	-6.8504	14.9229	-0.4591
Next Manner: nasal	4.2782	13.5183	0.3165	10.9980	13.5874	0.8094	12.9033	13.9317	0.9262	15.6360	14.0449	1.1133	18.2368	14.0416	1.2988	17.9963	14.1280	1.2738	14.0480	14.3150	0.9813
Duration (log) x Frequency (log)	0.0767	0.0505	1.5184	-0.0021	0.0499	-0.0412	-0.0325	0.0499	-0.6507	-0.0553	0.0500	-1.1061	-0.0673	0.0502	-1.3428	-0.0763	0.0501	-1.5219	-0.0560	0.0502	-1.1166

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	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	-19.2732	140.7130	-0.1370	-16.5323	139.5466	-0.1185	-14.4802	138.1562	-0.1048	-40.1842	142.7234	-0.2816	-85.7854	146.1980	-0.5868	-75.7388	149.3348	-0.5072	-128.6609	152.6074	-0.8431
Tense: past	18.6161	32.3793	0.5749	12.3190	32.0534	0.3843	5.3402	32.0639	0.1665	4.5463	32.8736	0.1383	20.9756	33.4255	0.6275	28.6969	33.9502	0.8453	16.5244	34.6122	0.4774
NDL Cue Strength	47.0050	61.4768	0.7646	57.6651	60.8352	0.9479	50.9974	60.9161	0.8372	64.5941	62.3403	1.0362	36.5483	63.2195	0.5781	-5.0788	64.1146	-0.0792	-23.6474	65.3473	-0.3619
Duration (log)	1.0925	0.6766	1.6147	1.6027	0.6828	2.3471	1.9118	0.6339	3.0160	2.0079	0.6584	3.0495	1.9132	0.6734	2.8409	2.0185	0.6845	2.9489	2.8026	0.7034	3.9843
Frequency (log)	51.6864	13.2140	3.9115	58.0293	13.1182	4.4236	58.4682	12.8682	4.5436	53.7917	13.2638	4.0555	47.5375	13.7625	3.4541	42.2517	14.2028	2.9749	39.2012	14.5218	2.6995
Previous Voicing: voiceless	6.9379	26.1931	0.2649	20.1703	25.9194	0.7782	24.4161	26.0019	0.9390	33.9143	26.4519	1.2821	37.5732	26.7037	1.4070	27.2609	26.9974	1.0098	8.5287	27.4276	0.3110

Previous Place: glottal	237.8878	71.1808	3.3420	211.1991	70.5974	2.9916	173.2638	70.3765	2.4620	141.9680	72.8037	1.9500	111.7564	75.3136	1.4839	85.8007	77.3645	1.1090	56.9041	79.0040	0.7203
Previous Place: labial	170.1093	70.1459	2.4251	110.2892	69.6320	1.5839	68.0280	68.3988	0.9946	20.0268	72.0194	0.2781	-17.1133	75.5702	-0.2265	-76.6986	78.2235	-0.9805	-106.4895	80.2229	-1.3274
Previous Place: labio-dental	-3.7475	116.8578	-0.0321	-11.0846	115.3848	-0.0961	-31.5266	115.9544	-0.2719	-68.7793	117.7991	-0.5839	-81.5950	118.5620	-0.6882	-72.5209	119.7006	-0.6059	-43.1545	121.7841	-0.3544
Previous Place: lax	143.9527	148.7840	0.9675	122.7366	147.0940	0.8344	116.9231	147.0471	0.7951	142.5655	150.8594	0.9450	207.7562	153.1590	1.3565	218.8600	155.3766	1.4086	239.8129	158.3402	1.5145
Previous Place: palatal	177.5896	47.1515	3.7664	167.0986	46.7436	3.5748	146.8651	46.5431	3.1555	138.3362	47.8314	2.8922	119.1287	48.7902	2.4416	91.5218	49.6148	1.8446	68.0999	50.5727	1.3466
Previous Place: palato-alveolar	42.4277	87.8266	0.4831	9.6706	86.7693	0.1115	-23.0850	86.9653	-0.2655	-39.3123	88.9580	-0.4419	-24.4783	89.7671	-0.2727	-17.8980	90.7280	-0.1973	-13.8878	92.3762	-0.1503
Previous Place: tense	128.2803	148.4791	0.8640	78.3428	146.8055	0.5337	62.4572	146.4403	0.4265	70.7509	150.6017	0.4698	142.2592	153.2778	0.9281	194.7271	155.7236	1.2505	243.0160	158.7691	1.5306
Previous Manner: approximate	-77.3704	146.0784	-0.5296	-125.8393	144.3892	-0.8715	-154.6765	143.9910	-1.0742	-160.1617	148.0102	-1.0821	-79.0060	150.3297	-0.5256	-50.8019	152.4555	-0.3332	-11.5549	155.3485	-0.0744
Previous Manner: flap	-279.0990	186.8258	-1.4939	-252.5343	184.6107	-1.3679	-204.0970	184.6494	-1.1053	-101.6417	188.8789	-0.5381	18.1636	191.3540	0.0949	76.9954	193.9316	0.3970	158.2785	197.5604	0.8012
Previous Manner: fricative	-156.2887	129.9632	-1.2026	-192.7523	128.4668	-1.5004	-198.9799	128.0566	-1.5538	-169.4203	131.8905	-1.2846	-97.3321	134.3379	-0.7245	-75.1739	136.5169	-0.5507	-7.8102	139.2320	-0.0561
Previous Manner: nasal	-111.7055	149.8006	-0.7457	-153.6467	148.0654	-1.0377	-163.7886	147.5522	-1.1100	-129.6326	151.8047	-0.8539	-56.4979	154.7145	-0.3652	-61.7959	157.3169	-0.3928	5.4372	160.4000	0.0339
Previous Manner: stop	-105.5821	137.2745	-0.7691	-153.0015	135.6654	-1.1278	-163.2744	135.1987	-1.2077	-148.3359	139.0877	-1.0665	-78.0913	141.5453	-0.5517	-55.8090	143.7925	-0.3881	3.4059	146.6463	0.0232
Next Voicing: voiceless	-26.3678	17.5829	-1.4996	-34.0364	17.3934	-1.9569	-28.6099	17.4120	-1.6431	-11.4067	17.7343	-0.6432	1.4803	17.8979	0.0827	12.4740	18.0909	0.6895	26.7239	18.4067	1.4519
Next Place: dental	15.5407	51.1417	0.3039	40.1431	50.5458	0.7942	63.1295	50.7006	1.2451	68.3226	51.5172	1.3262	72.2924	51.8854	1.3933	78.6027	52.3915	1.5003	78.5552	53.2944	1.4740
Next Place: diphthong	-77.9668	50.5418	-1.5426	-93.6721	49.9363	-1.8758	-82.5543	50.1261	-1.6469	-60.4580	50.9182	-1.1874	-42.4602	51.2892	-0.8279	-40.8267	51.7984	-0.7882	32.1198	52.6789	0.6097
Next Place: glottal	-22.8897	18.9567	-1.2075	-24.0876	18.7500	-1.2847	-8.2212	18.7661	-0.4381	16.2505	19.1131	0.8502	34.5292	19.2915	1.7899	44.7702	19.4994	2.2960	54.2368	19.8400	2.7337
Next Place: labial	14.0738	28.9551	0.4861	22.5616	28.6009	0.7888	21.1441	28.6414	0.7382	-9.2053	29.0906	-0.3164	-15.3189	29.2906	-0.5230	-21.6104	29.5255	-0.7319	-12.6004	29.9464	-0.4208
Next Place: labio-dental	91.1420	47.6163	1.9141	97.3990	47.0693	2.0693	86.8903	47.1352	1.8434	70.5602	48.0570	1.4683	52.9893	48.6031	1.0902	42.8573	49.2124	0.8709	35.1768	50.1060	0.7020
Next Place: lax	-80.5805	28.5849	-2.8190	-85.9258	28.2823	-3.0381	-75.7137	28.3438	-2.6713	-56.6408	28.8043	-1.9664	-30.7144	29.0082	-1.0588	-6.3540	29.2908	-0.2169	18.4681	29.7976	0.6198
Next Place: palatal	20.6338	38.5034	0.5359	45.2660	38.1489	1.1866	65.8813	37.8535	1.7404	107.4884	39.0916	2.7497	133.5910	40.0505	3.3356	153.8047	40.8209	3.7678	175.1328	41.6560	4.2043
Next Place: palato-alveolar	22.3775	81.9170	0.2732	47.0429	80.8980	0.5815	77.7056	81.2108	0.9568	102.4503	82.4923	1.2419	122.4503	82.9942	1.4754	133.2568	83.7513	1.5911	131.7647	85.2103	1.5463
Next Place: tense	228.3962	116.8875	1.9540	243.2347	115.4274	2.1073	284.4230	115.9395	2.4532	335.7747	117.7930	2.8505	384.9886	118.4901	3.2491	408.4339	119.5832	3.4155	362.7865	121.6972	2.9811
Next Manner: approximate	-1.1254	42.4331	-0.0265	-11.9776	41.9215	-0.2857	-7.6621	42.0072	-0.1824	-14.5865	42.6864	-0.3417	-24.0397	42.9889	-0.5592	13.6436	43.3850	0.3145	78.1487	44.1055	1.7719
Next Manner: flap	-20.1689	18.4161	-1.0952	-23.5345	18.2169	-1.2919	-15.9650	18.2475	-0.8749	-1.2611	18.5838	-0.0679	8.5896	18.7600	0.4579	9.7136	18.9657	0.5122	9.3720	19.2975	0.4857
Next Manner: fricative	-33.6207	35.1706	-0.9559	-50.9076	34.7449	-1.4652	-45.3189	34.8672	-1.2998	-32.6292	35.4058	-0.9216	-26.1626	35.6182	-0.7345	-23.5539	35.9426	-0.6553	-21.8466	36.5624	-0.5975
Next Manner: nasal	15.0444	33.5252	0.4487	21.1155	33.1456	0.6371	49.7194	33.1085	1.5017	92.3538	33.8474	2.7285	87.8534	34.2340	2.5663	85.9406	34.6058	2.4834	79.3816	35.1768	2.2566
Duration (log) x Frequency (log)	-0.1198	0.1085	-1.1039	-0.2512	0.1091	-2.3031	-0.3505	0.1029	-3.4066	-0.3986	0.1064	-3.7461	-0.4054	0.1087	-3.7285	-0.4253	0.1105	-3.8495	-0.5324	0.1132	-4.7033

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	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	59.8819	47.2836	1.2664	7.0072	46.7889	0.1498	22.1560	44.9059	0.4934	21.1879	44.6506	0.4745	13.8170	45.6882	0.3024	8.3117	42.1420	0.1972	44.4941	40.5572	1.0971
Tense: past	-22.6973	12.7756	-1.7766	-13.3479	12.5391	-1.0645	-13.6160	11.9980	-1.1349	-7.8823	11.9973	-0.6570	-3.1621	12.2960	-0.2572	1.3257	12.0469	0.1100	-1.2758	12.0403	-0.1060
NDL Cue Strength	-54.4202	27.1619	-2.0036	-40.3830	26.7983	-1.5069	5.9569	26.1166	0.2281	30.8441	26.4022	1.1682	41.7734	27.0455	1.5446	31.5889	27.1088	1.1653	20.5948	27.3786	0.7522
Duration (log)	0.2025	0.2921	0.6934	0.8480	0.2836	2.9904	0.7217	0.2929	2.4639	0.6205	0.3040	2.0409	0.5004	0.3217	1.5558	0.3842	0.3141	1.2232	0.1243	0.3108	0.3998
Frequency (log)	8.4038	8.4477	0.9948	11.8339	8.3334	1.4201	5.9666	8.0289	0.7431	3.2166	8.0028	0.4019	3.7070	8.1874	0.4528	3.6894	7.6661	0.4813	-3.1858	7.4575	-0.4272
Previous Voicing: voiceless	-39.6968	21.6530	-1.8333	-31.0104	21.2103	-1.4620	-22.7845	20.4689	-1.1131	-8.3667	20.6292	-0.4056	-2.5101	21.1344	-0.1188	-9.6687	21.2477	-0.4550	-22.0556	21.5086	-1.0254
Previous Place: glottal	128.4035	39.9362	3.2152	115.4485	39.4068	2.9297	141.9655	37.7113	3.7645	151.7915	37.6897	4.0274	145.1011	38.4855	3.7703	133.6806	36.9967	3.6133	101.3995	36.3982	2.7858
Previous Place: labial	-27.5787	19.4766	-1.4160	-17.5807	19.3255	-0.9097	-8.9647	18.4058	-0.4871	4.1583	18.2795	0.2275	13.4431	18.6948	0.7191	23.5471	17.7378	1.3275	22.2957	17.4077	1.2808
Previous Place: labio-dental	11.1696	36.9879	0.3020	1.7597	36.9708	0.0476	38.6327	35.3722	1.0922	60.2488	35.2122	1.7110	70.0895	35.9652	1.9488	90.4657	34.0789	2.6546	87.5864	33.3662	2.6250
Previous Place: lax	38.3352	36.3055	1.0559	44.4415	35.4422	1.2539	15.5791	34.5097	0.4514	8.3678	35.0939	0.2384	-4.5924	36.2988	-0.1265	3.0111	36.5723	0.0823	31.4530	37.0634	0.8486
Previous Place: palatal	-6.3277	27.6225	-0.2291	10.1389	26.9467	0.3763	-0.8397	26.0503	-0.0322	-13.2943	26.2689	-0.5061	-18.1095	27.0015	-0.6707	-10.1248	27.0628	-0.3741	20.1579	27.3270	0.7377
Previous Place: tense	-13.9131	57.9500	-0.2401	-21.0038	56.2424	-0.3735	-64.1421	53.9652	-1.1886	-81.5896	54.1314	-1.5073	-91.2287	55.5192	-1.6432	-76.8719	56.6082	-1.3580	-37.0701	57.8545	-0.6407
Previous Manner: fricative	16.2151	32.2266	0.5032	16.9195	31.5591	0.5361	-12.0523	30.3725	-0.3968	-29.9752	30.5748	-0.9804	-38.9744	31.3255	-1.2442	-31.6271	31.3202	-1.0098	-12.5781	31.6068	-0.3980
Previous Manner: nasal	30.7334	19.2678	1.5951	36.9017	19.0967	1.9324	36.8475	18.2105	2.0234	35.9275	18.1103	1.9838	26.8134	18.5329	1.4468	15.1434	17.7695	0.8522	20.5454	17.5708	1.1693
Previous Manner: stop	19.7025	23.4612	0.8398	2.2748	22.8101	0.0997	-7.6925	21.8911	-0.3514	-1.7405	21.9818	-0.0792	-7.9235	22.5883	-0.3508	-15.3816	22.6712	-0.6785	-24.8195	22.9504	-1.0814
Next Voicing: voiceless	-17.7525	13.6005	-1.3053	-8.5609	13.3177	-0.6428	4.1035	12.9892	0.3159	1.9012	13.2148	0.1439	6.0278	13.6307	0.4422	12.5016	13.7901	0.9066	16.1260	13.9869	1.1529
Next Place: dental	-69.5706	37.5625	-1.8521	-46.4935	36.6127	-1.2699	-48.9126	35.4628	-1.3793	-45.0589	35.8136	-1.2582	-32.8678	36.9037	-0.8906	-1.5403	37.1366	-0.0415	-3.7909	37.7195	-0.1005
Next Place: diphthong	-36.8899	31.6383	-1.1660	-13.8148	30.8294	-0.4481	14.4279	29.5598	0.4881	32.8459	29.6242	1.1087	46.5037	30.4372	1.5279	67.6315	30.4445	2.2215	75.6114	30.8774	2.4488
Next Place: glottal	-31.0127	13.6399	-2.2737	-25.6801	13.3724	-1.9204	-13.3262	13.0621	-1.0202	-14.6490	13.3013	-1.1013	-6.5710	13.7190	-0.4790	1.9125	13.8818	0.1378	4.9388	14.0772	0.3508
Next Place: labial	5.5888	22.8859	0.2442	-14.8538	22.3799	-0.6637	-32.7746	21.6730	-1.5122	-30.8112	21.8575	-1.4096	-23.5278	22.4137	-1.0497	-16.0655	22.4205	-0.7166	-12.4494	22.6933	-0.5486
Next Place: labio-dental	-45.9119	53.5278	-0.8577	-39.9321	52.8152	-0.7561	-37.5313	51.0469	-0.7352	-34.0137	51.5110	-0.6603	-11.9762	52.8251	-0.2267	14.4046	53.0479	0.2715	6.8892	53.5801	0.1286
Next Place: lax	23.1634	23.9815	0.9659	33.6619	23.5051	1.4321	41.0278	22.6078	1.8148	35.6519	22.6729	1.5724	33.1152	23.2292	1.4256	44.9630	23.2568	1.9333	50.6257	23.5175	2.1527
Next Place: palatal	-5.2182	29.3475	-0.1778	-13.7517	28.6370	-0.4802	-2.5490	27.7084	-0.0920	-0.2314	28.0282	-0.0083	1.7704	28.8428	0.0614	3.5164	29.2595	0.1202	23.0278	29.7957	0.7729
Next Manner: flap	12.5423	18.7769	0.6680	24.0147	18.5264	1.2962	30.6407	17.8130	1.7201	32.2891	17.8434	1.8096	34.0365	18.2465	1.8654	36.7626	17.8705	2.0572	31.3831	17.8604	1.7571
Next Manner: fricative	61.7009	36.6245	1.6847	44.3082	35.8349	1.2365	44.2174	34.6995	1.2743	47.6773	34.9669	1.3635	32.6405	36.0077	0.9065	13.5100	36.1554	0.3737	18.1976	36.6879	0.4960
Next Manner: nasal	54.7146	22.4066	2.4419	81.7456	22.3017	3.6654	97.3166	21.2908	4.5708	94.2633	21.1923	4.4480	93.0561	21.6148	4.3052	100.3917	20.7175	4.8457	94.5829	20.4464	4.6259
Next Manner: stop	39.3216	20.7949	1.8909	40.8021	20.4432	1.9959	38.4962	19.8114	1.9431	39.1104	19.9985	1.9557	33.9688	20.5359	1.6541	30.4769	20.3017	1.5012	22.3979	20.3631	1.0999
Duration (log) x Frequency (log)	-0.0808	0.0476	-1.6996	-0.1819	0.0464	-3.9211	-0.1405	0.0475	-2.9595	-0.1007	0.0489	-2.0597	-0.0689	0.0513	-1.3434	-0.0464	0.0505	-0.9185	-0.0124	0.0505	-0.2453

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Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	344.3450	104.6380	3.2908	251.0597	97.9373	2.5635	180.4706	88.9454	2.0290	142.0202	79.0279	1.7971	134.5897	76.1089	1.7684	166.8783	74.3500	2.2445	227.4423	76.0615	2.9902
Tense: past	-96.0718	28.6156	-3.3573	-71.4325	27.4095	-2.6061	-52.7497	25.8857	-2.0378	-33.9642	24.2812	-1.3988	-11.9834	23.2633	-0.5151	7.5136	22.5144	0.3337	10.4731	23.0029	0.4553
NDL Cue Strength	-159.7242	62.6441	-2.5497	-203.8294	60.4059	-3.3743	-222.6945	57.7731	-3.8546	-216.3797	55.1774	-3.9215	-209.0333	52.7355	-3.9638	-177.9074	50.7233	-3.5074	-125.2823	51.4954	-2.4329
Duration (log)	-1.2972	0.6623	-1.9587	-0.6050	0.6421	-0.9422	-0.1679	0.6166	-0.2724	-0.1933	0.5908	-0.3271	0.0049	0.5729	0.0085	0.0942	0.5574	0.1690	0.1184	0.5673	0.2088
Frequency (log)	4.8019	19.1567	0.2507	14.4403	18.0467	0.8002	20.7156	16.4664	1.2581	22.0989	14.7060	1.5027	22.3418	14.1026	1.5842	15.4110	13.6998	1.1249	2.8406	13.9919	0.2030
Previous Voicing: voiceless	-107.0408	49.0024	-2.1844	-84.5096	47.4533	-1.7809	-42.9771	45.5660	-0.9432	-2.5265	43.6548	-0.0579	17.9439	41.8066	0.4292	23.5857	40.3624	0.5843	-3.0954	41.2249	-0.0751
Previous Place: glottal	40.2075	89.0149	0.4517	91.7738	84.7514	1.0829	144.0494	79.0168	1.8230	202.5566	72.1746	2.8065	225.2663	69.3779	3.2469	249.0111	67.5380	3.6870	282.3512	69.1337	4.0841
Previous Place: labial	105.3975	43.5861	2.4181	66.0403	41.2069	1.6027	29.3996	38.1317	0.7710	11.2997	34.6897	0.3257	-15.8879	33.2497	-0.4778	-40.5788	32.2555	-1.2580	-59.9920	32.9411	-1.8212
Previous Place: labio-dental	26.1968	82.1822	0.3188	40.1734	77.8395	0.5161	89.3441	71.9527	1.2417	155.9698	65.5372	2.3799	133.8321	63.1145	2.1205	101.2757	61.4887	1.6471	65.9477	62.9083	1.0483
Previous Place: lax	-33.3497	83.7062	-0.3984	39.3727	81.1575	0.4851	83.6205	77.9979	1.0721	115.2529	74.9587	1.5376	142.8916	71.6308	1.9948	145.2100	68.8397	2.1094	114.1004	70.0151	1.6297
Previous Place: palatal	59.5148	62.7883	0.9479	67.8093	60.7255	1.1167	70.3862	58.1548	1.2103	86.4358	55.4441	1.5590	103.4232	53.0331	1.9502	119.5465	51.1592	2.3368	116.3513	52.1849	2.2296
Previous Place: tense	253.5227	132.5754	1.9123	259.5087	128.3897	2.0213	265.4877	123.5385	2.1490	249.8369	119.0414	2.0987	231.6306	113.4027	2.0425	221.3752	108.8958	2.0329	220.4139	110.6895	1.9913
Previous Manner: fricative	27.2315	72.7228	0.3745	28.7926	70.1433	0.4105	14.5508	67.1006	0.2169	-12.0184	64.0798	-0.1876	-11.7982	61.3556	-0.1923	-11.3162	59.2688	-0.1909	9.9882	60.5328	0.1650
Previous Manner: nasal	-181.1870	43.0755	-4.2063	-130.5062	40.8860	-3.1919	-71.7665	38.1241	-1.8824	-30.3025	35.1366	-0.8624	5.4724	33.6780	0.1625	35.2659	32.6284	1.0808	55.7338	33.3164	1.6729
Previous Manner: stop	50.8421	52.9521	0.9602	49.5111	51.1395	0.9682	43.3060	48.9865	0.8840	14.0063	46.8358	0.2991	-7.9726	44.7921	-0.1780	-26.9027	43.2222	-0.6224	-28.7037	44.1123	-0.6507
Next Voicing: voiceless	-28.1362	31.3552	-0.8973	-10.8371	30.3790	-0.3567	-11.4053	29.2318	-0.3902	-17.9496	28.1557	-0.6375	-15.4672	26.9412	-0.5741	-13.2416	25.9368	-0.5105	-11.4530	26.3880	-0.4340
Next Place: dental	-169.3824	86.9214	-1.9487	-152.7784	84.2334	-1.8138	-120.5826	80.8248	-1.4919	-94.7657	77.3019	-1.2259	-54.5129	73.6887	-0.7398	-23.1501	70.6987	-0.3274	-10.0368	71.9152	-0.1396
Next Place: diphthong	-11.3540	72.5271	-0.1565	-1.8977	70.0347	-0.0271	-16.5030	66.7072	-0.2474	-21.4701	63.3431	-0.3389	-55.1598	60.4162	-0.9130	-113.4982	58.0874	-1.9539	-140.0451	59.2021	-2.3655
Next Place: glottal	-26.6142	31.4646	-0.8458	-12.6902	30.4973	-0.4161	-9.1894	29.3722	-0.3129	-10.8800	28.3097	-0.3843	-4.5032	27.0929	-0.1662	4.7089	26.0822	0.1805	27.3525	26.5357	1.0308
Next Place: labial	22.6658	52.4769	0.4319	-4.3981	50.8046	-0.0866	-34.1324	48.5648	-0.7028	-72.0775	46.3049	-1.5566	-94.6257	44.2527	-2.1383	-78.8714	42.5996	-1.8515	-10.4166	43.4586	-0.2397
Next Place: labio-dental	124.2868	121.5871	1.0222	123.9932	117.2678	1.0574	121.8846	112.2921	1.0854	81.3262	107.3396	0.7577	30.4107	102.7766	0.2959	-112.5591	99.0660	-1.1362	-198.7819	100.7657	-1.9727
Next Place: lax	-55.2308	54.6679	-1.0103	-55.7475	52.6254	-1.0593	-60.7431	50.1815	-1.2105	-66.7135	47.7809	-1.3962	-98.9310	45.6615	-2.1666	-113.1921	43.9853	-2.5734	-99.9628	44.7297	-2.2348
Next Place: palatal	43.0316	66.9814	0.6424	50.2978	65.0954	0.7727	55.5422	62.8452	0.8838	62.5738	60.7477	1.0301	74.7143	58.0664	1.2867	122.4102	55.8681	2.1911	206.0929	56.9394	3.6195
Next Manner: flap	-68.7262	42.5538	-1.6150	-67.0619	40.8007	-1.6436	-68.4438	38.4386	-1.7806	-71.3650	35.9344	-1.9860	-99.1131	34.4294	-2.8787	-135.1147	33.2876	-4.0590	-159.2632	33.9787	-4.6871
Next Manner: fricative	16.3628	84.9868	0.1925	14.2172	82.2482	0.1729	7.4652	78.7153	0.0948	14.2363	74.9832	0.1899	-16.0978	71.4748	-0.2252	-42.3181	68.5425	-0.6174	-71.0320	69.6358	-1.0200
Next Manner: nasal	-72.0774	50.2052	-1.4357	-63.8858	47.6548	-1.3406	-62.6714	44.2396	-1.4166	-43.6233	40.6210	-1.0739	-63.5338	38.9975	-1.6292	-118.0567	37.8290	-3.1208	-156.6369	38.6399	-4.0538
Next Manner: stop	-23.8252	47.5248	-0.5013	-36.9551	45.7587	-0.8076	-40.6412	43.3861	-0.9367	-36.4901	40.9181	-0.8918	-71.8684	39.1918	-1.8338	-110.8333	37.8432	-2.9288	-147.2957	38.6022	-3.8157
Duration (log) x Frequency (log)	0.1864	0.1101	1.6928	0.0428	0.1069	0.4003	-0.0457	0.1026	-0.4453	-0.0604	0.0981	-0.6161	-0.0970	0.0945	-1.0263	-0.0948	0.0914	-1.0370	-0.0603	0.0928	-0.6500

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Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	199.9549	559.9038	0.3571	-345.8882	533.9590	-0.6478	-815.8350	603.0201	-1.3529	-961.1869	552.3401	-1.7402	-800.6557	539.1309	-1.4851	-676.7610	520.0548	-1.3013	-360.6194	482.2829	-0.7477
Tense: past	23.8396	272.0493	0.0876	353.5220	259.5417	1.3621	555.9055	288.7497	1.9252	603.7377	264.2797	2.2845	500.9801	257.2880	1.9472	420.8978	245.6126	1.7137	231.3984	228.1923	1.0140
NDL Cue Strength	139.7180	473.7893	0.2949	-215.7130	451.0649	-0.4782	-528.2743	505.6999	-1.0446	-624.4532	467.0428	-1.3370	-542.6219	459.7646	-1.1802	-463.8607	422.3173	-1.0984	-302.5883	389.8719	-0.7761
Duration (log)	0.7220	1.0720	0.6734	0.7060	1.0659	0.6623	1.0482	1.0318	1.0158	1.1123	0.8901	1.2496	0.8304	0.7570	1.0969	1.0391	0.7590	1.3691	0.7446	0.8252	0.9023
Frequency (log)	-37.1248	96.5606	-0.3845	33.9932	92.4307	0.3678	119.8900	104.0943	1.1517	148.4384	95.1058	1.5608	125.9715	92.4061	1.3632	104.6476	89.2916	1.1720	57.0530	83.7467	0.6813
Previous Voicing: voiceless	-101.0183	151.1079	-0.6685	28.4476	146.1593	0.1946	161.3859	161.6193	0.9986	215.2073	149.2724	1.4417	202.6115	148.1105	1.3680	158.2264	128.5473	1.2309	105.0458	122.7669	0.8557
Previous Place: glottal	185.9170	181.3536	1.0252	379.6593	172.0669	2.2065	437.6317	190.4661	2.2977	441.0610	171.1914	2.5764	342.0524	161.4728	2.1183	298.4168	169.1033	1.7647	168.7357	155.3205	1.0864
Previous Place: labio-dental	276.5607	269.9703	1.0244	37.6117	260.2460	0.1445	-196.0496	288.7102	-0.6791	-283.1924	265.6827	-1.0659	-251.0017	261.4082	-0.9602	-199.1469	233.1611	-0.8541	-83.3029	220.9989	-0.3769
Next Voicing: voiceless	-9.3701	78.9728	-0.1186	-7.2980	77.2791	-0.0944	-49.5103	83.7746	-0.5910	-27.0900	72.6684	-0.3728	15.1792	62.6477	0.2423	29.7765	63.9864	0.4654	53.0617	61.6816	0.8603
Next Place: glottal	126.3522	71.2477	1.7734	131.6912	70.2581	1.8744	122.7238	73.2287	1.6759	142.5318	63.5233	2.2438	158.8907	56.8782	2.7935	165.6247	59.3199	2.7921	193.8171	59.5734	3.2534
Next Place: labio-dental	113.3002	77.0685	1.4701	95.3716	75.6033	1.2615	45.3632	77.3268	0.5866	41.9975	65.2555	0.6436	57.8634	54.1778	1.0680	31.6937	53.9874	0.5871	3.2990	54.4809	0.0606
Next Manner: stop	18.8058	62.0499	0.3031	-4.6410	60.9602	-0.0761	-31.8645	62.4696	-0.5101	-57.7673	52.9990	-1.0900	-76.4376	45.5708	-1.6773	-77.7104	43.7567	-1.7760	-87.7821	44.3284	-1.9803
Duration (log) x Frequency (log)	-0.2408	0.3407	-0.7068	-0.2099	0.3410	-0.6156	-0.3136	0.3301	-0.9498	-0.3098	0.2864	-1.0818	-0.1898	0.2420	-0.7845	-0.1787	0.2434	-0.7340	-0.0419	0.2681	-0.1563

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Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	1720.5810	1115.7919	1.5420	1644.3521	1128.8080	1.4567	1829.2535	1035.5178	1.7665	1994.7120	1093.8744	1.8235	1959.4296	1166.7824	1.6793	1972.6093	1156.6252	1.7055	1908.5247	1139.8390	1.6744
Tense: past	-1021.1387	540.6095	-1.8889	-938.0772	542.2250	-1.7301	-1031.0734	496.4862	-2.0767	-1107.6978	523.4404	-2.1162	-1046.2868	556.7637	-1.8792	-938.1517	549.3492	-1.7078	-905.9574	539.4573	-1.6794
NDL Cue Strength	972.6752	942.6029	1.0319	932.1499	962.5147	0.9685	1036.4621	880.9414	1.1765	1255.1331	924.6985	1.3573	1425.3529	977.3380	1.4584	1874.2369	952.5628	1.9676	2154.3687	933.6539	2.3075
Duration (log)	1.1136	2.1554	0.5167	1.4328	1.9687	0.7278	1.8526	1.7211	1.0764	2.5641	1.6328	1.5704	3.0072	1.5012	2.0032	3.8569	1.6275	2.3698	4.4453	1.6410	2.7089
Frequency (log)	-188.3920	193.0349	-0.9759	-204.1820	194.9860	-1.0472	-233.0026	178.4768	-1.3055	-262.6174	187.4513	-1.4010	-268.6518	198.5745	-1.3529	-291.3007	197.3969	-1.4757	-277.8239	194.8268	-1.4260
Previous Voicing: voiceless	-394.4943	304.8818	-1.2939	-392.7624	309.7133	-1.2681	-459.3051	280.8918	-1.6352	-522.4181	285.4403	-1.8302	-544.0896	291.1490	-1.8688	-580.7862	278.5242	-2.0852	-513.7141	272.3183	-1.8864
Previous Place: glottal	-566.6805	358.0245	-1.5828	-455.1617	351.1458	-1.2962	-493.5960	322.8871	-1.5287	-497.1516	347.1343	-1.4322	-364.4532	377.0017	-0.9667	-181.7780	380.6376	-0.4776	-131.2322	374.8006	-0.3501
Previous Place: labio-dental	594.3103	543.0025	1.0945	622.2327	550.9875	1.1293	703.8158	500.8926	1.4051	823.2264	513.9723	1.6017	854.6870	529.2846	1.6148	919.2127	509.2105	1.8052	913.2823	497.0415	1.8374
Next Voicing: voiceless	109.4855	164.0605	0.6673	156.3029	162.9349	0.9593	137.7227	145.5311	0.9463	107.8914	144.0486	0.7490	29.4975	139.4502	0.2115	-55.5279	130.4733	-0.4256	-17.8311	124.1784	-0.1436

Next Place: glottal	139.1673	145.6261	0.9556	181.7813	135.6501	1.3401	179.0915	121.2056	1.4776	156.3534	117.9795	1.3253	103.2410	112.8382	0.9149	69.2750	115.5216	0.5997	20.5812	113.1144	0.1820
Next Place: labio-dental	-58.4700	159.8603	-0.3658	-79.0459	152.5046	-0.5183	-93.2926	134.2985	-0.6947	-101.3609	128.5752	-0.7883	-50.4683	116.3299	-0.4338	-21.3627	103.7413	-0.2059	14.2896	95.5398	0.1496
Next Manner: stop	4.5528	128.4413	0.0354	-31.4484	121.8158	-0.2582	-51.0907	107.7640	-0.4741	-56.9534	103.9745	-0.5478	-11.9909	95.1158	-0.1261	-23.5566	85.4762	-0.2756	-54.9793	79.0689	-0.6953
Duration (log) x Frequency (log)	-0.1447	0.6835	-0.2118	-0.1300	0.6180	-0.2104	-0.1833	0.5424	-0.3380	-0.3548	0.5099	-0.6957	-0.5568	0.4677	-1.1906	-1.0629	0.5118	-2.0767	-1.4456	0.5143	-2.8107

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Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	184.1459	106.5488	1.7283	175.1926	102.4843	1.7095	123.9042	102.4192	1.2098	51.9348	101.0417	0.5140	47.8368	101.5204	0.4712	45.8714	103.4578	0.4434	53.9358	105.6678	0.5104
Tense: past	-100.4809	36.8257	-2.7286	-94.3232	35.3198	-2.6705	-76.1595	35.4190	-2.1502	-47.2989	34.9388	-1.3538	-36.8431	35.0932	-1.0499	-34.9015	35.6888	-0.9779	-35.6784	36.4963	-0.9776
NDL Cue Strength	124.9351	86.3725	1.4465	112.1614	82.8307	1.3541	70.4572	82.8660	0.8503	32.7702	81.7345	0.4009	14.9702	82.0560	0.1824	32.4398	83.7003	0.3876	52.0768	85.7372	0.6074
Duration (log)	0.1322	0.3865	0.3420	0.3087	0.3801	0.8122	0.4858	0.3732	1.3015	0.5086	0.3678	1.3828	0.6842	0.3691	1.8537	0.5859	0.3808	1.5386	0.3204	0.3896	0.8224
Frequency (log)	-37.6269	16.2523	-2.3152	-31.7653	15.6606	-2.0284	-21.9425	15.7169	-1.3961	-8.6101	15.4995	-0.5555	-1.1050	15.5726	-0.0710	0.9012	15.7969	0.0571	-1.2206	16.1283	-0.0757
Previous Voicing: voiceless	99.9291	38.3303	2.6071	72.8428	36.8118	1.9788	57.9339	36.8175	1.5735	40.4532	36.3142	1.1140	31.2640	36.4645	0.8574	40.4425	37.1783	1.0878	49.3059	38.0491	1.2958
Previous Place: dental	-227.7498	96.4753	-2.3607	-209.0723	92.2784	-2.2657	-160.6690	92.7546	-1.7322	-100.5526	91.5340	-1.0985	-59.6761	91.9735	-0.6488	-28.8932	93.3700	-0.3094	4.5842	95.4960	0.0480
Previous Place: diphthong	104.2609	74.8483	1.3930	88.5966	71.7399	1.2350	53.8917	71.6882	0.7518	12.0212	70.7274	0.1700	-13.7452	71.0663	-0.1934	-19.4983	72.4417	-0.2692	-5.7326	73.9987	-0.0775
Previous Place: glottal	179.2676	66.6331	2.6904	164.2292	64.3662	2.5515	156.2657	64.9756	2.4050	116.5181	64.0969	1.8178	99.5114	64.4231	1.5447	92.2834	65.0262	1.4192	104.9412	66.2461	1.5841
Previous Place: labial	86.0800	34.1003	2.5243	65.1516	32.5204	2.0034	43.4691	32.6783	1.3302	28.2962	32.2540	0.8773	25.6762	32.4231	0.7919	28.3810	32.8927	0.8628	33.3336	33.6276	0.9913
Previous Place: labio-dental	48.9759	73.8118	0.6635	60.5707	70.4906	0.8593	80.4408	70.9143	1.1343	67.7904	69.9955	0.9685	42.3279	70.3587	0.6016	28.7743	71.3362	0.4034	18.7645	72.9210	0.2573
Previous Place: lax	57.4063	90.2490	0.6361	46.8369	86.7657	0.5398	28.2406	86.4951	0.3265	-0.4231	85.3070	-0.0050	-25.6585	85.7134	-0.2994	-43.1361	87.4412	-0.4933	-35.0050	89.1525	-0.3926
Previous Place: palatal	143.8232	36.2377	3.9689	118.7022	34.8607	3.4050	87.0322	34.9723	2.4886	51.6673	34.4926	1.4979	41.8791	34.6441	1.2088	32.2955	35.2035	0.9174	29.1285	35.9959	0.8092
Previous Manner: diphthong	48.2125	103.6145	0.4653	65.7295	99.7429	0.6590	77.6682	99.6524	0.7794	95.4262	98.2924	0.9708	85.6169	98.8414	0.8662	66.1290	100.4630	0.6582	62.1822	102.1930	0.6085
Previous Manner: flap	153.8991	91.5290	1.6814	115.0205	88.0352	1.3065	82.2543	87.9569	0.9352	58.5107	86.7419	0.6745	61.5684	87.1450	0.7065	68.8070	88.7599	0.7752	89.4965	90.5357	0.9885
Previous Manner: fricative	-79.3822	58.7580	-1.3510	-70.0690	56.5949	-1.2381	-81.3970	56.7231	-1.4350	-63.2249	55.9487	-1.1301	-51.5016	56.1727	-0.9168	-63.0198	57.1940	-1.1019	-64.2207	58.5354	-1.0971
Previous Manner: lax	159.5324	93.3640	1.7087	146.6622	90.0961	1.6278	127.6646	89.4436	1.4273	129.7420	88.2043	1.4709	152.5572	88.6623	1.7207	159.4487	90.5947	1.7600	176.8828	92.0962	1.9206
Previous Manner: nasal	133.1135	46.4186	2.8677	116.3186	44.6308	2.6062	95.0038	44.7055	2.1251	58.8760	44.0957	1.3352	37.5564	44.2984	0.8478	19.5785	45.0539	0.4346	15.9169	46.0406	0.3457
Previous Manner: stop	-46.7126	36.3555	-1.2849	-29.6261	34.9001	-0.8489	-12.5708	34.9883	-0.3593	-3.9520	34.5101	-0.1145	-3.2429	34.6663	-0.0935	-16.5549	35.2407	-0.4698	-24.8610	36.0041	-0.6905
Next Voicing: voiceless	10.5945	31.9124	0.3320	12.0703	30.6273	0.3941	21.0061	30.5855	0.6868	31.9593	30.1672	1.0594	22.9057	30.2938	0.7561	22.7683	30.9186	0.7364	32.5646	31.6259	1.0297
Next Place: dental	-15.2181	54.6837	-0.2783	-35.5462	52.5555	-0.6764	-48.0961	52.3637	-0.9185	-33.6851	51.6408	-0.6523	-61.8880	51.8554	-1.1935	-56.5667	53.0043	-1.0672	-39.5188	54.1825	-0.7294
Next Place: diphthong	92.5825	87.1247	1.0626	71.5863	83.5865	0.8564	111.4559	83.2997	1.3380	146.9423	82.1671	1.7883	127.2650	82.5543	1.5416	126.0823	84.2951	1.4957	133.2758	86.0209	1.5493
Next Place: glottal	25.2693	29.8346	0.8470	20.0551	28.6986	0.6988	21.5401	28.6002	0.7531	30.1520	28.2064	1.0690	22.2686	28.3366	0.7859	29.0399	28.9245	1.0040	47.1816	29.5093	1.5989
Next Place: labial	-63.0965	27.5755	-2.2881	-51.6863	26.4495	-1.9541	-51.0706	26.4321	-1.9321	-41.5913	26.0727	-1.5952	-42.2640	26.1808	-1.6143	-36.2024	26.7168	-1.3550	-38.5087	27.3433	-1.4083
Next Place: labio-dental	24.6439	58.7845	0.4192	-13.6446	56.3986	-0.2419	-43.2581	56.3689	-0.7674	-48.1663	55.6006	-0.8663	-82.7674	55.8543	-1.4818	-72.8838	56.9176	-1.2805	-64.6604	58.1331	-1.1123
Next Place: lax	35.9445	83.3196	0.4314	20.3971	79.9279	0.2552	34.2179	79.6163	0.4298	52.0318	78.5347	0.6625	26.7695	78.9154	0.3392	20.7729	80.5810	0.2578	24.1855	82.1816	0.2943
Next Place: palatal	-73.8235	32.6089	-2.2639	-45.6002	31.4070	-1.4519	-35.8280	31.3731	-1.1420	-14.9308	30.9369	-0.4826	-4.4616	31.0649	-0.1436	4.2126	31.6777	0.1330	6.4116	32.3881	0.1980
Next Place: palato-alveolar	-1.3698	52.7983	-0.0259	-0.0334	50.6595	-0.0007	-3.9802	50.5382	-0.0788	5.0498	49.8389	0.1013	-5.0956	50.0234	-0.1019	-2.4951	51.1416	-0.0488	9.2796	52.3878	0.1771
Next Place: tense	62.5382	93.5602	0.6684	76.1932	89.8012	0.8485	103.9819	89.4877	1.1620	134.7419	88.2718	1.5264	113.7245	88.6931	1.2822	104.7068	90.5520	1.1563	98.7732	92.3854	1.0691
Next Manner: approximate	116.0981	88.4394	1.3127	91.1662	84.8685	1.0742	94.5875	84.5642	1.1185	101.7855	83.4210	1.2201	67.8219	83.8445	0.8089	56.4658	85.5554	0.6600	57.0533	87.1967	0.6543
Next Manner: flap	113.0888	87.9817	1.2854	91.4744	84.4146	1.0836	102.2499	84.1380	1.2153	117.2248	82.9965	1.4124	86.5481	83.4044	1.0377	82.8735	85.1098	0.9737	87.9369	86.7895	1.0132
Next Manner: fricative	36.5903	74.9229	0.4884	41.1867	71.9511	0.5724	57.3896	71.6152	0.8014	67.2331	70.6523	0.9516	67.9666	71.0552	0.9565	67.3866	72.4560	0.9300	59.2772	73.6263	0.8051
Next Manner: nasal	77.3112	86.3345	0.8955	70.3369	82.8164	0.8493	87.1148	82.5400	1.0554	110.4161	81.4250	1.3560	80.0676	81.8323	0.9784	72.1275	83.5050	0.8638	77.4222	85.1389	0.9094
Next Manner: stop	68.6809	78.8502	0.8710	55.4718	75.6869	0.7329	66.7480	75.3917	0.8853	69.7934	74.3709	0.9385	43.0211	74.7586	0.5755	35.7384	76.2672	0.4686	26.9182	77.6623	0.3466
Duration (log) x Frequency (log)	-0.0356	0.0693	-0.5132	-0.0631	0.0680	-0.9284	-0.0884	0.0668	-1.3246	-0.0940	0.0658	-1.4288	-0.1194	0.0661	-1.8061	-0.1052	0.0680	-1.5481	-0.0764	0.0691	-1.1055

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	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	670.1065	235.0111	2.8514	606.1563	229.9860	2.6356	569.7290	223.9502	2.5440	566.2692	220.9681	2.5627	524.9912	221.3762	2.3715	486.7344	223.9289	2.1736	426.9173	222.8832	1.9154
Tense: past	-120.4399	82.1447	-1.4662	-111.1722	80.1809	-1.3865	-94.6644	77.9834	-1.2139	-85.2783	76.8793	-1.1092	-77.7140	76.8548	-1.0112	-58.5846	77.3889	-0.7570	-36.7005	77.2665	-0.4750
NDL Cue Strength	286.3523	190.9442	1.4997	249.5496	186.3146	1.3394	177.3552	181.1003	0.9793	69.5339	178.6814	0.3891	-32.4235	179.1187	-0.1810	-101.9675	180.6907	-0.5643	-171.9185	180.3473	-0.9533
Duration (log)	0.6687	0.9086	0.7359	0.7122	0.8992	0.7921	0.6649	0.8771	0.7581	0.3501	0.8696	0.4026	-0.3085	0.8751	-0.3525	-1.2183	0.9079	-1.3419	-2.0558	0.8713	-2.3595
Frequency (log)	-79.0763	36.3788	-2.1737	-72.5243	35.4924	-2.0434	-65.8632	34.5587	-1.9058	-60.9877	34.0366	-1.7918	-56.4948	33.8945	-1.6668	-54.0982	34.0957	-1.5867	-43.9456	33.9284	-1.2952
Previous Voicing: voiceless	139.6985	84.0568	1.6620	170.8028	81.9836	2.0834	190.3575	79.7055	2.3883	190.2250	78.6373	2.4190	175.1068	78.8286	2.2214	177.1168	79.5250	2.2272	166.5904	79.3765	2.0987
Previous Place: dental	23.4186	218.3583	0.1072	17.3447	213.4112	0.0813	-11.6717	207.6899	-0.0562	-26.8913	204.6212	-0.1314	13.2374	203.8975	0.0649	58.1001	204.6888	0.2838	98.1780	204.0175	0.4812
Previous Place: diphthong	180.1107	161.3690	1.1161	159.7358	157.5402	1.0139	150.0098	153.2124	0.9791	133.1764	151.2685	0.8804	113.0710	152.1524	0.7431	96.2245	153.8377	0.6255	47.9822	153.9203	0.3117
Previous Place: glottal	211.9305	153.1529	1.3838	188.9217	149.5749	1.2631	174.9624	145.7736	1.2002	204.4606	143.3369	1.4264	218.9350	141.8295	1.5436	247.3680	141.8560	1.7438	257.5305	140.8202	1.8288
Previous Place: labial	380.1401	77.7311	4.8905	330.1756	76.0892	4.3393	284.3701	74.1131	3.8370	238.2572	73.0145	3.2631	220.2148	72.6858	3.0297	196.5225	73.0102	2.6917	178.1097	72.6972	2.4500
Previous Place: labio-dental	207.6254	168.8399	1.2297	201.0749	165.5693	1.2144	187.2777	161.3980	1.1603	173.8701	158.9383	1.0939	128.3855	157.8983	0.8131	123.4703	158.3456	0.7798	93.0845	157.4702	0.5911
Previous Place: lax	2.9301	196.1721	0.0149	27.7954	191.4147	0.1452	11.2746	185.9421	0.0606	-17.3207	183.6324	-0.0943	-41.0202	185.1350	-0.2216	-71.4445	188.2468	-0.3795	-97.1707	188.4356	-0.5157
Previous Place: palatal	67.4806	80.6928	0.8363	63.0660	78.7257	0.8011	55.8748	76.6108	0.7293	53.9289	75.5069	0.7142	51.0506	75.3607	0.6774	44.2788	75.8405	0.5838	17.8683	75.4737	0.2367

Previous Manner: diphthong	163.2828	222.1153	0.7351	120.9766	216.4806	0.5588	119.7896	210.4124	0.5693	137.3067	207.6684	0.6612	141.8259	208.9611	0.6787	149.2672	211.6137	0.7054	178.7316	212.2719	0.8420
Previous Manner: flap	300.5728	199.5345	1.5064	324.0167	194.5010	1.6659	354.4159	188.9602	1.8756	347.1146	186.4964	1.8612	316.2983	187.6166	1.6859	280.8270	190.1868	1.4766	212.0357	190.4647	1.1133
Previous Manner: fricative	-368.5981	131.4751	-2.8036	-367.7278	128.4232	-2.8634	-361.9469	124.9673	-2.8963	-355.9755	123.1705	-2.8901	-331.9300	122.9271	-2.7002	-334.8074	123.6610	-2.7075	-316.7593	122.9527	-2.5763
Previous Manner: lax	58.6268	201.6319	0.2908	24.9763	197.1219	0.1267	41.4316	191.4466	0.2164	90.4212	189.3229	0.4776	155.9149	191.7425	0.8131	236.4755	196.3224	1.2045	207.9099	196.1486	1.0600
Previous Manner: nasal	132.9296	102.1984	1.3007	137.7951	99.7116	1.3819	145.8917	97.0079	1.5039	144.4054	95.6694	1.5094	140.8178	95.7354	1.4709	134.8105	96.5524	1.3962	97.9563	96.1877	1.0184
Previous Manner: stop	-164.8959	80.2801	-2.0540	-183.7562	78.2364	-2.3487	-181.2691	76.0577	-2.3833	-160.4899	74.9841	-2.1403	-128.0760	75.0757	-1.7060	-105.2208	75.7102	-1.3898	-72.6263	75.7240	-0.9591
Next Voicing: voiceless	-52.0518	70.1660	-0.7418	-50.6449	68.4885	-0.7395	-57.2848	66.5549	-0.8607	-55.9085	65.6995	-0.8510	-61.4126	66.0048	-0.9304	-57.7890	66.7733	-0.8654	-62.4120	66.6919	-0.9358
Next Place: dental	-102.8910	120.3245	-0.8551	-112.4608	117.5272	-0.9569	-128.4880	114.1639	-1.1255	-146.4046	112.7771	-1.2982	-158.6056	113.5663	-1.3966	-155.9064	115.2990	-1.3522	-165.4011	115.0516	-1.4376
Next Place: diphthong	-10.0381	188.4986	-0.0533	22.2047	184.1311	0.1206	43.5812	178.9238	0.2436	54.8594	176.7942	0.3103	92.5065	178.4116	0.5185	132.2896	181.2932	0.7297	155.8069	181.4479	0.8587
Next Place: glottal	15.5266	64.9840	0.2389	9.1244	63.4520	0.1438	-4.7131	61.6426	-0.0765	-15.6552	60.8931	-0.2571	-20.2622	61.3764	-0.3301	-25.6740	62.3650	-0.4117	-29.6481	62.3325	-0.4756
Next Place: labial	-26.3132	60.1861	-0.4372	-0.1078	58.7201	-0.0018	21.9208	57.0742	0.3841	36.6233	56.3360	0.6501	58.4459	56.5814	1.0330	78.5031	57.1460	1.3737	105.8439	57.0995	1.8537
Next Place: labio-dental	92.2943	128.9002	0.7160	117.4558	125.7621	0.9340	113.4416	122.2223	0.9282	121.1303	120.6148	1.0043	127.2220	121.1738	1.0499	121.7682	122.6079	0.9932	112.0402	122.6858	0.9132
Next Place: lax	-0.5588	180.2861	-0.0031	19.9728	176.1939	0.1134	16.8809	171.2044	0.0986	11.7950	169.2048	0.0697	46.8861	170.9040	0.2743	80.3506	173.9076	0.4620	112.7607	174.0660	0.6478
Next Place: palatal	-204.6338	72.1250	-2.8372	-196.0038	70.3851	-2.7847	-194.2443	68.4285	-2.8386	-204.2408	67.5213	-3.0248	-192.3509	67.6877	-2.8417	-209.7777	68.4369	-3.0653	-208.5543	68.1793	-3.0589
Next Place: palato-alveolar	-47.3027	116.1481	-0.4073	-31.4243	113.2637	-0.2774	-43.6151	110.0151	-0.3964	-70.8919	108.6164	-0.6527	-84.3335	109.1854	-0.7724	-79.6641	110.4955	-0.7210	-85.6537	110.3926	-0.7759
Next Place: tense	-189.5559	201.8491	-0.9391	-170.8069	197.1754	-0.8663	-151.7325	191.6587	-0.7917	-133.1556	189.3678	-0.7032	-99.0210	191.0865	-0.5182	-23.4419	194.1900	-0.1207	25.4443	194.2761	0.1310
Next Manner: approximate	67.6048	190.4480	0.3550	76.0518	186.1360	0.4086	66.3470	180.9268	0.3667	70.5325	178.8015	0.3945	94.8555	180.5705	0.5253	136.5541	183.6825	0.7434	173.8857	183.8470	0.9458
Next Manner: flap	60.9625	190.6231	0.3198	96.2105	186.2810	0.5165	103.9604	181.0444	0.5742	86.5245	178.8848	0.4837	129.3490	180.4933	0.7166	163.4894	183.4926	0.8910	176.8360	183.5976	0.9632
Next Manner: fricative	-12.5162	159.3923	-0.0785	9.7029	155.8519	0.0623	28.0649	151.4834	0.1853	37.0358	149.7694	0.2473	77.1587	151.7014	0.5086	106.0207	154.8371	0.6847	142.7822	155.3457	0.9191
Next Manner: nasal	29.9227	186.7795	0.1602	36.1577	182.5825	0.1980	17.7626	177.4738	0.1001	-9.7228	175.3692	-0.0554	1.9818	176.9749	0.0112	22.4951	179.9178	0.1250	39.4549	179.9980	0.2192
Next Manner: stop	144.9368	169.4928	0.8551	161.0892	165.6469	0.9725	153.5231	160.9868	0.9536	141.7302	159.1106	0.8908	168.1902	160.8142	1.0459	192.8417	163.7839	1.1774	206.7835	164.0531	1.2605
Duration (log) x Frequency (log)	-0.1927	0.1598	-1.2055	-0.1914	0.1580	-1.2115	-0.1733	0.1541	-1.1247	-0.1048	0.1527	-0.6864	0.0235	0.1542	0.1525	0.1893	0.1601	1.1826	0.3369	0.1546	2.1787

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Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	148.8994	197.1390	0.7553	146.0667	189.5685	0.7705	105.3105	183.9096	0.5726	87.2125	191.9009	0.4545	137.8475	212.6139	0.6483	239.0186	217.7081	1.0979	309.0211	229.6731	1.3455
Tense: past	0.0912	58.2323	0.0016	1.3068	55.1622	0.0237	13.8598	53.5196	0.2590	18.6063	57.3600	0.3244	19.3553	68.6528	0.2819	14.1364	71.2779	0.1983	-5.8354	75.1839	-0.0776
NDL Cue Strength	-100.7546	368.1493	-0.2737	-64.3724	356.0248	-0.1808	-26.3052	346.4329	-0.0759	-30.3279	361.5429	-0.0839	-124.2891	392.5600	-0.3166	-298.5866	399.2780	-0.7478	-356.4386	421.7487	-0.8451
Duration (log)	0.0339	0.5880	0.0577	-0.2762	0.5484	-0.5036	-0.2246	0.5307	-0.4231	-0.0119	0.5513	-0.0217	0.0773	0.5890	0.1312	0.0295	0.6061	0.0487	0.0486	0.6284	0.0773
Frequency (log)	6.8419	13.3956	0.5108	-0.3099	12.6090	-0.0246	0.1885	12.2529	0.0154	1.2564	12.9454	0.0971	-0.4448	14.5234	-0.0306	-4.1424	15.0168	-0.2759	-8.2036	15.6665	-0.5236
Previous Voicing: voiceless	85.0341	130.3836	0.6522	115.9609	125.0747	0.9271	128.0815	121.6118	1.0532	116.3520	127.5857	0.9120	69.6256	143.8195	0.4841	25.5860	147.7796	0.1731	-2.0087	155.5991	-0.0129
Previous Place: dental	-65.6758	71.7407	-0.9155	-54.5399	68.7139	-0.7937	-61.2985	66.5316	-0.9213	-62.2015	70.3642	-0.8840	-48.6349	79.5440	-0.6114	-41.4948	81.3774	-0.5099	-11.5296	86.3815	-0.1335
Previous Place: glottal	19.4515	92.1489	0.2111	21.8949	89.3856	0.2449	19.2611	86.3958	0.2229	33.6658	88.6709	0.3797	60.3100	93.2660	0.6466	96.4037	94.3935	1.0213	109.5741	101.0914	1.0839
Previous Place: palatal	-8.4253	118.4328	-0.0711	-7.0246	113.9566	-0.0616	-0.8635	110.8753	-0.0078	-10.9873	116.7238	-0.0941	-41.0224	129.6273	-0.3165	-95.7747	132.3154	-0.7238	-117.7872	139.8641	-0.8422
Previous Manner: approximate	-80.2070	125.4969	-0.6391	-61.9040	121.3449	-0.5101	-45.8851	118.0702	-0.3886	-52.3297	123.2438	-0.4246	-91.6114	134.0449	-0.6834	-156.1548	136.3990	-1.1448	-184.6525	144.1211	-1.2812
Previous Manner: fricative	-58.8557	75.9666	-0.7748	-85.0567	74.0298	-1.1490	-74.0696	71.1929	-1.0404	-72.5281	71.8717	-1.0091	-79.0914	73.2847	-1.0792	-101.9806	73.7614	-1.3826	-133.4939	79.3545	-1.6822
Next Voicing: voiceless	4.3042	24.7111	0.1742	6.4060	23.8562	0.2685	0.9894	22.9648	0.0431	4.5115	23.0841	0.1954	7.2643	23.2287	0.3127	14.9392	23.4491	0.6371	33.2648	25.1381	1.3233
Next Place: dental	53.0569	54.9941	0.9648	66.5551	53.6326	1.2409	58.1699	51.5191	1.1291	57.4510	51.8633	1.1077	47.4606	52.7309	0.9001	55.7793	53.0820	1.0508	78.2316	57.1249	1.3695
Next Place: diphthong	14.3270	56.9691	0.2515	30.7976	55.9364	0.5506	41.4773	53.8690	0.7700	48.5644	53.8308	0.9022	32.5705	53.6078	0.6076	-11.7215	53.6790	-0.2184	-59.6442	58.4690	-1.0201
Next Place: glottal	38.1608	43.7299	0.8726	51.0719	43.0186	1.1872	49.5955	41.2704	1.2017	54.7322	41.3340	1.3241	49.2829	41.6169	1.1842	46.7055	41.6998	1.1200	48.5246	45.2275	1.0729
Next Place: labial	4.9401	48.2965	0.1023	2.5143	47.4153	0.0530	1.4258	45.7045	0.0312	2.0150	45.7625	0.0440	-13.4426	45.7169	-0.2940	-25.4213	45.7806	-0.5553	-27.9410	49.7910	-0.5612
Next Place: labio-dental	73.1979	53.4930	1.3684	84.3121	52.6587	1.6011	75.9545	50.5131	1.5037	63.9963	50.8931	1.2575	57.2682	52.1271	1.0986	68.9172	52.3400	1.3167	82.3534	56.5103	1.4573
Next Place: lax	30.8766	52.0596	0.5931	37.5121	51.1109	0.7339	35.8522	49.3015	0.7272	43.6062	49.4146	0.8825	33.2584	49.4441	0.6726	16.0789	49.5411	0.3246	3.3087	53.8633	0.0614
Next Place: palatal	-7.8595	53.7870	-0.1461	-3.3598	52.6609	-0.0638	1.4913	50.8534	0.0293	-1.9290	51.2318	-0.0377	-14.1843	51.8090	-0.2738	-15.0385	52.0363	-0.2890	-21.5685	56.3816	-0.3825
Next Place: palato-alveolar	-21.7156	57.3594	-0.3786	-25.3389	56.7465	-0.4465	-30.6538	54.5772	-0.5617	-21.6830	54.4323	-0.3983	-8.1042	53.9830	-0.1501	-6.9997	53.8512	-0.1300	-4.1080	58.2328	-0.0705
Next Place: tense	26.1479	56.1470	0.4657	13.9368	55.2283	0.2523	11.7917	53.1701	0.2218	31.7647	53.1597	0.5975	33.4241	53.0612	0.6299	6.6623	53.1166	0.1254	-19.6682	57.8054	-0.3402
Next Manner: flap	-4.7020	41.4839	-0.1133	13.3891	40.7454	0.3286	15.8471	39.2857	0.4034	36.0630	39.4179	0.9149	39.8159	39.6290	1.0047	31.8769	39.7266	0.8024	30.9172	42.8524	0.7215
Next Manner: fricative	-28.0010	71.2496	-0.3930	-33.0077	69.8909	-0.4723	-18.8305	67.1198	-0.2806	-6.5352	67.2889	-0.0971	-6.1279	67.6588	-0.0906	-28.4365	67.8445	-0.4191	-52.5296	73.6110	-0.7136
Next Manner: nasal	9.7399	47.6722	0.2043	20.2144	46.9659	0.4304	24.2350	45.2024	0.5361	33.6975	45.1082	0.7470	28.0827	44.8250	0.6265	18.0855	44.8317	0.4034	12.1466	48.9087	0.2484
Next Manner: stop	3.0820	32.1535	0.0959	14.3348	31.6331	0.4532	20.3048	30.4447	0.6669	35.7618	30.2973	1.1804	57.0851	29.9359	1.9069	62.8773	29.9558	2.0990	63.8345	32.6007	1.9581
Duration (log) x Frequency (log)	-0.0766	0.1351	-0.5674	0.0050	0.1257	0.0399	0.0107	0.1217	0.0878	-0.0279	0.1265	-0.2209	-0.0378	0.1350	-0.2796	-0.0221	0.1391	-0.1586	-0.0254	0.1442	-0.1760

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Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	-195.2039	557.9446	-0.3499	66.1729	552.3775	0.1198	319.3573	528.3115	0.6045	245.1761	540.9009	0.4533	270.2663	565.3752	0.4780	244.7602	595.8872	0.4107	221.1954	597.4812	0.3702
Tense: past	73.8260	183.4699	0.4024	-23.1686	174.1577	-0.1330	-48.0364	155.4111	-0.3091	-7.5144	157.2403	-0.0478	-9.8764	164.1584	-0.0602	-67.9708	173.6969	-0.3913	-152.3915	174.9080	-0.8713
NDL Cue Strength	1261.9663	1025.4764	1.2306	557.6714	1026.9763	0.5430	58.9631	993.9147	0.0593	-71.0240	1012.2298	-0.0702	39.4190	1046.9883	0.0376	236.4454	1104.8661	0.2140	543.0319	1112.0818	0.4883
Duration (log)	-1.9267	1.4641	-1.3160	-1.2733	1.4772	-0.8620	-0.4147	1.4420	-0.2876	1.7417	1.5160	1.1488	1.8659	1.6029	1.1641	1.5393	1.6700	0.9218	0.3032	1.6777	0.1807

Frequency (log)	-15.7013	37.9641	-0.4136	-7.9799	36.7744	-0.2170	-9.7898	34.5023	-0.2837	19.5330	35.8459	0.5449	17.7571	38.0084	0.4672	-2.6507	39.8036	-0.0666	-35.4950	40.0955	-0.8853
Previous Voicing: voiceless	630.4596	380.3160	1.6577	389.1718	370.8504	1.0494	209.5645	349.4410	0.5997	169.2302	356.1666	0.4751	132.6027	370.0829	0.3583	-8.8156	390.9663	-0.0225	-98.1069	395.3597	-0.2481
Previous Place: dental	-121.7599	210.1587	-0.5794	-101.8009	206.8905	-0.4921	-82.5322	193.5567	-0.4264	-64.0284	198.2815	-0.3229	5.5512	207.7777	0.0267	44.4719	218.4806	0.2036	51.4413	216.9263	0.2371
Previous Place: glottal	-216.6698	251.2167	-0.8625	-142.0491	256.2478	-0.5543	-63.2002	249.0338	-0.2538	-43.9694	256.7424	-0.1713	-41.8056	270.5192	-0.1545	-43.6421	286.2930	-0.1524	-66.3665	285.2695	-0.2326
Previous Place: palatal	374.4012	340.0585	1.1010	197.0631	336.9998	0.5848	122.2294	318.9181	0.3833	111.9304	323.8930	0.3456	90.2298	336.1994	0.2684	120.7935	354.8099	0.3404	197.5913	356.2148	0.5547
Previous Manner: approximate	588.1858	350.3966	1.6786	378.8741	350.5712	1.0807	234.7387	338.4465	0.6936	179.4123	344.4402	0.5209	186.6493	356.2978	0.5239	217.5735	376.0020	0.5786	283.0560	378.2272	0.7484
Previous Manner: fricative	-285.9389	194.2578	-1.4720	-281.6560	202.3823	-1.3917	-262.5442	201.8599	-1.3006	-249.7000	210.6755	-1.1852	-214.4303	224.1456	-0.9567	-57.3687	235.0307	-0.2441	104.5429	230.1304	0.4543
Next Voicing: voiceless	-40.9181	61.0545	-0.6702	-17.9132	63.9038	-0.2803	-16.1549	63.1739	-0.2557	-12.4457	66.5087	-0.1871	-26.4603	71.5491	-0.3698	-69.2957	75.0617	-0.9232	-87.0544	73.9573	-1.1771
Next Place: dental	126.3579	139.7983	0.9039	210.0222	145.4682	1.4438	224.6273	146.6809	1.5314	253.6422	154.0551	1.6464	180.5270	164.2497	1.0991	46.5467	171.8591	0.2708	-52.5830	168.0210	-0.3130
Next Place: diphthong	42.5681	145.3735	0.2928	141.3703	153.6979	0.9198	129.9994	150.5300	0.8636	32.9731	155.2676	0.2124	-44.1897	166.3181	-0.2657	42.1182	175.9201	0.2394	316.5200	172.3046	1.8370
Next Place: glottal	177.9440	112.1188	1.5871	211.5654	117.4875	1.8007	195.5495	119.1295	1.6415	203.9581	124.8630	1.6335	201.9201	133.2372	1.5155	127.5314	139.7681	0.9125	86.5261	136.2479	0.6351
Next Place: labial	-87.9195	124.1866	-0.7080	-31.8153	130.9988	-0.2429	-77.8428	128.9551	-0.6036	-132.2562	133.3217	-0.9920	-131.5267	142.5835	-0.9225	1.8239	150.9554	0.0121	199.0369	148.5076	1.3402
Next Place: labio-dental	109.5197	139.1140	0.7873	129.3659	144.8182	0.8933	97.7925	147.3812	0.6635	130.5725	153.9960	0.8479	126.7861	163.2635	0.7766	108.9839	171.0508	0.6371	145.9982	166.4195	0.8773
Next Place: lax	-53.8956	134.2107	-0.4016	7.7751	141.3246	0.0550	-47.0128	138.5921	-0.3392	-78.5138	142.9086	-0.5494	-116.0788	152.5220	-0.7611	-15.2846	161.5739	-0.0946	137.5245	159.0470	0.8647
Next Place: palatal	-199.4684	139.9726	-1.4251	-143.6663	146.1953	-0.9827	-101.0995	142.5477	-0.7092	-68.7226	146.9672	-0.4676	-94.6959	156.3548	-0.6056	-106.6798	165.4459	-0.6448	-55.5818	163.7805	-0.3394
Next Place: palato-alveolar	-48.3803	144.3384	-0.3352	-18.9795	153.5187	-0.1236	-5.1169	158.3455	-0.0323	33.2942	165.6084	0.2010	43.4966	176.1050	0.2470	24.7515	185.0457	0.1338	-25.7425	179.5995	-0.1433
Next Place: tense	-13.4232	143.8250	-0.0933	63.7039	151.8144	0.4196	6.4264	149.8610	0.0429	-56.7909	154.8614	-0.3667	-16.0942	165.5015	-0.0972	107.4835	174.9708	0.6143	239.0748	171.4377	1.3945
Next Manner: flap	-8.4092	105.9066	-0.0794	79.2787	111.2229	0.7128	54.1776	111.1998	0.4872	8.9386	115.5490	0.0774	-60.7233	123.0203	-0.4936	-31.9712	129.7760	-0.2464	11.6108	128.2737	0.0905
Next Manner: fricative	-196.9531	181.8127	-1.0833	-167.0244	191.3874	-0.8727	-212.9046	191.2931	-1.1130	-314.7136	199.4015	-1.5783	-381.6168	212.9661	-1.7919	-237.2181	223.9612	-1.0592	-68.2085	218.3429	-0.3124
Next Manner: nasal	-15.0402	122.2829	-0.1230	63.6707	129.5318	0.4915	32.1068	128.0130	0.2508	-10.9029	132.6287	-0.0822	-117.5529	142.1498	-0.8270	-144.3134	150.5827	-0.9584	-126.3129	147.6410	-0.8555
Next Manner: stop	6.7818	81.8357	0.0829	54.4522	86.4862	0.6296	38.7959	86.1723	0.4502	-8.9790	89.9066	-0.0999	-79.9491	96.6358	-0.8273	-16.1211	102.2535	-0.1577	16.2877	100.8526	0.1615
Duration (log) x Frequency (log)	0.4696	0.3363	1.3966	0.2470	0.3377	0.7315	0.0345	0.3248	0.1062	-0.4445	0.3416	-1.3014	-0.4004	0.3623	-1.1053	-0.2030	0.3779	-0.5372	0.1638	0.3828	0.4279

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Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	-470.9558	765.6208	-0.6151	-108.3909	722.4783	-0.1500	228.1007	600.1658	0.3801	220.4504	583.6228	0.3777	71.4483	598.5056	0.1194	25.2815	617.7132	0.0409	-151.6066	584.8895	-0.2592
Tense: past	158.4524	182.8253	0.8667	73.5937	172.3563	0.4270	-3.4350	142.9089	-0.0240	-0.9794	139.0816	-0.0070	35.9789	142.7757	0.2520	50.4032	147.8375	0.3409	122.7175	141.0974	0.8697
NDL Cue Strength	-184.1897	336.5221	-0.5473	-46.4742	317.0457	-0.1466	30.3841	263.6300	0.1153	14.4659	256.7473	0.0563	-47.0328	263.6767	-0.1784	-62.4880	273.6350	-0.2284	-156.4648	261.5509	-0.5982
Duration (log)	1.5695	9.4435	0.1662	-2.9895	8.9141	-0.3354	-4.8746	7.3359	-0.6645	-3.9492	7.1174	-0.5549	-1.2047	7.2956	-0.1651	-0.6909	7.4985	-0.0921	-1.3125	6.9395	-0.1891
Frequency (log)	103.6187	133.0179	0.7790	43.5134	125.3962	0.3470	-20.3499	104.7060	-0.1944	-22.4995	101.8624	-0.2209	-1.9628	104.4715	-0.0188	0.6544	108.1175	0.0061	24.2959	103.8266	0.2340
Previous Voicing: voiceless	19.0898	206.8775	0.0923	-41.8341	195.4446	-0.2140	-36.9911	160.5591	-0.2304	-5.8630	156.4275	-0.0375	56.6709	160.6955	0.3527	88.4712	165.9801	0.5330	138.0482	155.2565	0.8892
Previous Place: dental	160.7014	243.3678	0.6603	208.8414	229.7485	0.9090	143.6268	190.3612	0.7545	113.1331	184.9777	0.6116	65.1454	189.6788	0.3435	45.3279	196.2662	0.2310	118.5680	189.6835	0.6251
Next Voicing: voiceless	23.4318	31.6062	0.7414	15.5550	29.6768	0.5241	3.0582	24.9868	0.1224	-2.5267	24.2684	-0.1041	-7.6136	24.8500	-0.3064	-12.0449	25.8202	-0.4665	-11.7518	25.1756	-0.4668
Duration (log) x Frequency (log)	-0.4286	1.9710	-0.2174	0.4870	1.8604	0.2618	0.8972	1.5325	0.5855	0.7019	1.4868	0.4721	0.1133	1.5241	0.0743	0.0439	1.5658	0.0280	0.2040	1.4487	0.1408

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	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	-779.9798	1101.5891	-0.7080	-587.5467	1036.7282	-0.5667	-95.4353	1054.5489	-0.0905	346.8741	1137.8799	0.3048	776.6687	1251.5344	0.6206	1005.4476	1243.0331	0.8089	878.5179	1372.8498	0.6399
Tense: past	42.1899	315.8388	0.1336	18.1298	256.8228	0.0706	-85.8337	255.4316	-0.3360	-128.0056	278.0717	-0.4603	-152.5067	302.3141	-0.5045	-191.5487	293.1300	-0.6535	-90.6610	324.4101	-0.2795
NDL Cue Strength	-286.5439	586.6438	-0.4884	-284.2354	470.9806	-0.6035	-54.5773	470.5418	-0.1160	14.0195	514.5186	0.0272	42.6826	555.9415	0.0768	146.6748	536.1436	0.2736	23.4153	593.2254	0.0395
Duration (log)	13.2068	15.3242	0.8618	10.7262	12.9075	0.8310	3.1588	13.0352	0.2423	-0.8506	14.1355	-0.0602	-4.8748	15.4035	-0.3165	-10.2590	15.1379	-0.6777	-12.6508	16.7389	-0.7558
Frequency (log)	241.3375	187.8988	1.2844	204.9049	179.1664	1.1437	119.1627	182.1416	0.6542	25.2717	196.7598	0.1284	-63.9431	216.7536	-0.2950	-92.7604	216.3289	-0.4288	-70.8341	238.8109	-0.2966
Previous Voicing: voiceless	-155.1173	380.2044	-0.4080	-178.7793	297.9379	-0.6001	-319.9539	295.3808	-1.0832	-330.2462	321.4986	-1.0272	-294.8618	347.8041	-0.8478	-389.0089	331.5333	-1.1734	-367.1875	367.4754	-0.9992
Previous Place: dental	-14.8797	400.4743	-0.0372	13.7807	336.8499	0.0409	140.4485	332.6169	0.4223	116.0220	358.7209	0.3234	88.0090	397.6350	0.2213	149.8938	397.8526	0.3768	243.0930	439.9387	0.5526
Next Voicing: voiceless	26.0962	39.0818	0.6677	40.5327	41.1953	0.9839	54.8336	42.1592	1.3006	71.4877	45.1289	1.5841	66.6798	50.7961	1.3127	69.5191	51.9842	1.3373	70.1801	57.4573	1.2214
Duration (log) x Frequency (log)	-2.6994	3.1842	-0.8477	-2.0996	2.6911	-0.7802	-0.4116	2.7218	-0.1512	0.4932	2.9521	0.1671	1.2782	3.2142	0.3977	2.3639	3.1565	0.7489	2.7800	3.4896	0.7967

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	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	73.4068	92.7952	0.7911	47.4764	92.5951	0.5127	22.5629	91.7380	0.2459	-11.4160	94.4450	-0.1209	44.3690	94.0155	0.4719	122.4767	94.7975	1.2920	110.6526	96.2239	1.1499
Tense: past	10.8341	15.5684	0.6959	3.8599	15.5167	0.2488	2.9288	15.3838	0.1904	13.4445	15.8400	0.8488	20.7308	15.8029	1.3118	34.7293	16.0229	2.1675	52.2933	16.2268	3.2227
NDL Cue Strength	-87.3873	80.3417	-1.0877	-63.0877	80.0205	-0.7884	-33.8847	79.2399	-0.4276	-25.7444	81.5195	-0.3158	-60.9927	81.1834	-0.7513	-44.1525	82.1933	-0.5372	-8.6988	83.2696	-0.1045
Duration (log)	-0.2231	0.1893	-1.1784	-0.1282	0.1907	-0.6723	0.0448	0.1946	0.2301	0.2013	0.2000	1.0068	0.3317	0.1934	1.7149	0.2824	0.1916	1.4737	0.2692	0.1970	1.3668
Frequency (log)	5.2446	10.1741	0.5155	5.8940	10.1282	0.5819	7.8478	10.0540	0.7806	11.9339	10.3564	1.1523	8.5161	10.2990	0.8269	1.4893	10.3903	0.1433	4.3875	10.4984	0.4179
Previous Voicing: voiceless	-7.9739	67.7070	-0.1178	4.3836	67.6658	0.0648	16.9399	67.0972	0.2525	36.4193	69.0659	0.5273	-38.1394	68.6609	-0.5555	-92.6268	69.0015	-1.3424	-80.4207	70.0793	-1.1476
Previous Place: dental	-1.8515	94.2655	-0.0196	6.9105	94.1385	0.0734	-22.1900	93.2736	-0.2379	17.1934	95.9552	0.1792	-8.5244	95.4752	-0.0893	-77.4076	96.2294	-0.8044	-128.7605	97.7661	-1.3170
Previous Place: diphthong	-17.0110	53.0384	-0.3207	-7.5820	53.1426	-0.1427	14.9043	52.8214	0.2822	31.8075	54.3726	0.5850	6.4384	53.8887	0.1195	-11.7195	53.8968	-0.2174	-14.8769	54.9068	-0.2709
Previous Place: glottal	41.3154	79.5428	0.5194	34.5076	79.6037	0.4335	-9.6842	78.9847	-0.1226	17.3282	81.2893	0.2132	-30.5405	80.6455	-0.3787	-104.7495	80.8025	-1.2964	-176.3535	82.2207	-2.1449

Previous Place: labial	56.3699	43.3665	1.2998	64.3044	43.0567	1.4935	62.2456	42.6530	1.4593	83.9182	43.9077	1.9112	76.0608	43.8214	1.7357	42.8628	44.5971	0.9611	27.0309	45.0057	0.6006
Previous Place: lax	3.0129	52.0347	0.0579	9.2655	52.1161	0.1778	20.3755	51.7721	0.3936	35.2244	53.2878	0.6610	31.9281	52.8212	0.6045	13.3712	52.8439	0.2530	3.7901	53.8125	0.0704
Previous Place: palatal	39.5299	41.8112	0.9454	31.8042	41.6922	0.7628	22.6106	41.2871	0.5476	8.9428	42.4788	0.2105	35.5245	42.2503	0.8408	52.4950	42.5872	1.2326	18.6075	43.1836	0.4309
Previous Place: palato-alveolar	15.0789	60.5402	0.2491	-2.8451	60.2761	-0.0472	-33.9167	59.9827	-0.5654	-53.8213	61.6370	-0.8732	-11.5639	60.9471	-0.1897	21.6639	61.5782	0.3518	59.6812	62.4251	0.9560
Previous Place: tense	-8.0110	59.1586	-0.1354	-15.4732	59.2269	-0.2613	-13.8217	58.8136	-0.2350	10.5796	60.5366	0.1748	-1.0826	60.0325	-0.0180	-18.3006	60.1003	-0.3045	-32.6639	61.1893	-0.5338
Previous Manner: approximate	-34.1405	60.7995	-0.5615	-28.3212	60.8024	-0.4658	-18.4411	60.2897	-0.3059	10.3702	62.0591	0.1671	-36.1396	61.7249	-0.5855	-71.1827	62.0508	-1.1472	-51.6423	63.0690	-0.8188
Previous Manner: flap	10.1325	68.1288	0.1487	-17.9497	68.1300	-0.2635	-29.1261	67.5704	-0.4310	8.6123	69.5519	0.1238	4.6484	69.1061	0.0673	-15.6153	69.3927	-0.2250	-47.2745	70.5340	-0.6702
Previous Manner: fricative	-19.6810	88.7147	-0.2218	-40.1142	88.6976	-0.4523	-7.9133	88.0083	-0.0899	-25.9640	90.5637	-0.2867	49.7409	89.8501	0.5536	151.1019	90.1499	1.6761	219.4915	91.6775	2.3942
Previous Manner: lax	0.3616	28.8027	0.0126	-0.9684	28.8439	-0.0336	-8.5649	28.6698	-0.2987	-8.9125	29.5110	-0.3020	-36.2224	29.2529	-1.2382	-35.8114	29.2718	-1.2234	-29.5093	29.8228	-0.9895
Previous Manner: nasal	1.1177	45.9372	0.0243	3.2861	46.0437	0.0714	11.7498	45.7733	0.2567	32.3468	47.1159	0.6865	14.2049	46.6895	0.3042	-4.1596	46.6815	-0.0891	-14.1457	47.5623	-0.2974
Next Voicing: voiceless	9.5555	10.6855	0.8943	6.0805	10.6719	0.5698	9.3433	10.6010	0.8814	6.0414	10.9061	0.5539	11.3528	10.8053	1.0507	18.2448	10.8452	1.6823	11.6014	11.0212	1.0526
Next Place: dental	-4.5651	16.6549	-0.2741	-3.9401	16.6508	-0.2366	-2.8455	16.5343	-0.1721	-4.7256	17.0147	-0.2777	0.1980	16.8663	0.0117	4.7633	16.8994	0.2819	-13.7714	17.1953	-0.8009
Next Place: diphthong	27.1150	36.2071	0.7489	47.7947	36.1525	1.3220	47.8942	35.8078	1.3375	35.5414	36.8444	0.9646	39.2161	36.5600	1.0726	21.2090	36.6630	0.5785	6.5038	37.2655	0.1745
Next Place: glottal	23.2972	12.8519	1.8127	28.9670	12.8755	2.2498	34.2965	12.8189	2.6755	41.6819	13.1883	3.1605	48.6377	13.0456	3.7283	53.9611	13.0427	4.1373	52.9854	13.2985	3.9843
Next Place: labial	10.6530	9.5750	1.1126	5.4235	9.5724	0.5666	4.4779	9.5061	0.4711	6.8560	9.7804	0.7010	9.3887	9.6960	0.9683	10.5039	9.7203	1.0806	6.3549	9.8889	0.6426
Next Place: labio-dental	9.3704	16.8103	0.5574	26.2925	16.7965	1.5654	33.0668	16.6653	1.9842	40.2444	17.1464	2.3471	34.5312	16.9953	2.0318	15.5653	17.0340	0.9138	-15.3287	17.3260	-0.8847
Next Place: lax	9.0977	35.8435	0.2538	24.7512	35.7850	0.6917	21.1061	35.4376	0.5956	4.5735	36.4624	0.1254	2.9247	36.1842	0.0808	-18.7755	36.2923	-0.5173	-40.7980	36.8864	-1.1060
Next Place: palatal	8.3970	12.0382	0.6975	8.7906	12.0407	0.7301	10.3073	11.9686	0.8612	11.7412	12.3225	0.9528	21.4126	12.2242	1.7517	16.2837	12.2566	1.3286	10.7338	12.4551	0.8618
Next Place: palato-alveolar	24.5248	24.5063	1.0008	50.4276	24.5444	2.0545	36.7379	24.4140	1.5048	18.2137	25.1263	0.7249	-5.3244	24.8661	-0.2141	-34.4417	24.8229	-1.3875	-31.9091	25.2976	-1.2613
Next Place: tense	17.6506	38.0105	0.4644	39.1938	37.9838	1.0319	24.9914	37.6752	0.6633	7.2942	38.7639	0.1882	8.9794	38.4211	0.2337	-3.8810	38.4774	-0.1009	-3.3584	39.1405	-0.0858
Next Manner: approximate	-9.8931	36.5539	-0.2706	9.1127	36.5051	0.2496	6.0561	36.1663	0.1675	-12.7373	37.2176	-0.3422	-16.4474	36.9344	-0.4453	-33.3388	37.0386	-0.9001	-41.9741	37.6473	-1.1149
Next Manner: flap	-17.1226	40.9210	-0.4184	-6.6031	40.8389	-0.1617	-6.8217	40.4435	-0.1687	-27.9012	41.6155	-0.6705	-31.2769	41.3330	-0.7567	-53.9855	41.5246	-1.3001	-64.2615	42.1723	-1.5238
Next Manner: fricative	-6.3028	35.0697	-0.1797	5.7522	35.0068	0.1643	-1.4231	34.6628	-0.0411	-18.0858	35.6711	-0.5070	-24.3607	35.4148	-0.6879	-43.4671	35.5365	-1.2232	-38.6498	36.1034	-1.0705
Next Manner: nasal	0.7934	37.5894	0.0211	17.6764	37.5369	0.4709	21.7413	37.1844	0.5847	5.1339	38.2641	0.1342	0.9781	37.9780	0.0258	-26.0202	38.0948	-0.6830	-37.1935	38.7224	-0.9605
Next Manner: stop	-13.8430	36.6055	-0.3782	2.4465	36.5539	0.0669	-4.0122	36.2125	-0.1108	-26.6130	37.2677	-0.7141	-34.1924	36.9902	-0.9244	-52.4173	37.1007	-1.4128	-59.6168	37.7049	-1.5811
Duration (log) x Frequency (log)	0.0356	0.0259	1.3731	0.0230	0.0261	0.8829	-0.0036	0.0264	-0.1345	-0.0317	0.0271	-1.1684	-0.0527	0.0264	-1.9955	-0.0426	0.0262	-1.6243	-0.0349	0.0269	-1.3010

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	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	767.4483	199.0648	3.8553	876.7873	208.1942	4.2114	1008.5054	221.7954	4.5470	1062.1992	232.5141	4.5683	1077.0096	240.8000	4.4726	1055.2318	247.5464	4.2628	1025.1420	253.1615	4.0494
Tense: past	-64.3528	33.9712	-1.8943	-79.4596	35.3259	-2.2493	-98.4072	37.6036	-2.6170	-87.1590	39.3854	-2.2130	-65.7365	40.7779	-1.6121	-43.5420	42.1117	-1.0340	-38.0529	43.3056	-0.8787
NDL Cue Strength	234.0751	174.1152	1.3444	120.1407	180.8987	0.6641	13.4910	192.5788	0.0701	-9.6695	201.8063	-0.0479	4.7226	209.0088	0.0226	125.2749	215.6735	0.5809	224.0651	221.5843	1.0112
Duration (log)	0.0701	0.4167	0.1683	-0.5170	0.4411	-1.1720	-0.7201	0.4722	-1.5250	-0.7919	0.4960	-1.5965	-0.5657	0.5115	-1.1060	-0.1825	0.5244	-0.3480	-0.0266	0.5381	-0.0494
Frequency (log)	-72.1063	21.9131	-3.2906	-82.9444	22.7247	-3.6500	-90.9424	24.1972	-3.7584	-91.9231	25.3607	-3.6246	-85.6651	26.2663	-3.2614	-81.5433	27.1573	-3.0026	-75.8889	27.9815	-2.7121
Previous Voicing: voiceless	-205.2523	143.6966	-1.4284	-203.2593	150.7033	-1.3487	-211.6819	160.7551	-1.3168	-255.4438	168.6937	-1.5142	-328.7694	174.7069	-1.8818	-329.6261	179.3350	-1.8380	-276.9847	183.1641	-1.5122
Previous Place: dental	-405.5979	203.3130	-1.9949	-358.8534	212.1281	-1.6917	-346.4465	225.8474	-1.5340	-361.8864	236.7365	-1.5286	-374.9325	245.2293	-1.5289	-348.2488	252.1446	-1.3811	-298.1856	257.8812	-1.1563
Previous Place: diphthong	140.1416	112.1327	1.2498	130.1996	117.9531	1.1038	70.0832	125.8485	0.5569	1.2202	132.1074	0.0092	-86.3852	136.7700	-0.6316	-118.6599	139.9497	-0.8479	-140.7154	142.4647	-0.9877
Previous Place: glottal	224.7326	168.0657	1.3372	196.5353	176.5272	1.1133	124.1721	188.3030	0.6594	70.2941	197.6468	0.3557	29.3799	204.6805	0.1435	72.8468	209.5533	0.3476	132.9512	213.3672	0.6231
Previous Place: labial	42.1680	96.0088	0.4392	75.7859	98.6021	0.7686	60.6184	104.6850	0.5791	66.0169	109.5104	0.6028	70.5786	113.4229	0.6223	69.0005	117.7405	0.5860	84.4735	121.8700	0.6931
Previous Place: lax	-238.6242	109.8775	-2.1717	-222.7272	115.5554	-1.9274	-205.4857	123.2996	-1.6666	-214.7323	129.4401	-1.6589	-271.7126	134.0282	-2.0273	-273.1713	137.1995	-1.9911	-265.4000	139.7086	-1.8997
Previous Place: palatal	-16.6866	89.1310	-0.1872	2.7695	93.2083	0.0297	31.5709	99.3938	0.3176	31.6991	104.2686	0.3040	17.9545	108.0132	0.1662	15.2379	111.1661	0.1371	4.8966	113.8509	0.0430
Previous Place: palato-alveolar	-313.8229	132.6215	-2.3663	-183.5524	137.0457	-1.3394	-124.5282	145.7715	-0.8543	-69.9308	152.7105	-0.4579	-40.1903	158.1172	-0.2542	-121.4974	163.7202	-0.7421	-198.1461	169.1280	-1.1716
Previous Place: tense	-232.4853	124.9888	-1.8600	-171.5820	131.4293	-1.3055	-142.5215	140.2211	-1.0164	-155.0126	147.1886	-1.0532	-203.1409	152.4026	-1.3329	-193.1519	155.9867	-1.2383	-209.7187	158.8066	-1.3206
Previous Manner: approximate	-168.5045	129.4056	-1.3021	-181.4565	135.7670	-1.3365	-243.3951	144.7819	-1.6811	-284.6043	151.8997	-1.8736	-322.5879	157.3041	-2.0507	-301.1661	161.3544	-1.8665	-259.0805	164.6282	-1.5737
Previous Manner: flap	-297.6419	144.5793	-2.0587	-304.4386	151.5904	-2.0083	-356.6893	161.6787	-2.2062	-383.7345	169.6736	-2.2616	-389.7898	175.7007	-2.2185	-309.9178	180.1856	-1.7200	-189.2537	183.8590	-1.0293
Previous Manner: fricative	206.6716	188.3550	1.0972	163.1080	197.4041	0.8263	139.2954	210.5052	0.6617	188.0297	220.8930	0.8512	260.9873	228.7550	1.1409	254.2893	234.5795	1.0840	183.6896	239.3239	0.7675
Previous Manner: lax	76.5378	60.8029	1.2588	60.0859	64.0978	0.9374	18.6558	68.4000	0.2727	17.3908	71.7954	0.2422	48.7743	74.3230	0.6562	49.9520	76.0167	0.6571	22.4027	77.3453	0.2896
Previous Manner: nasal	-188.1197	97.1226	-1.9369	-180.7925	102.1687	-1.7695	-200.0164	109.0145	-1.8348	-216.9369	114.4429	-1.8956	-256.2187	118.4881	-2.1624	-246.6521	121.2613	-2.0341	-222.7132	123.4534	-1.8040
Next Voicing: voiceless	33.2609	22.6918	1.4658	17.1174	23.8109	0.7189	22.9749	25.4069	0.9043	45.8241	26.6644	1.7185	76.4515	27.6104	2.7689	79.9570	28.3705	2.8183	89.7742	29.0209	3.0934
Next Place: dental	49.9656	35.1241	1.4225	31.3909	37.0371	0.8476	34.6603	39.5494	0.8764	55.4615	41.5204	1.3358	91.6530	42.9929	2.1318	89.7105	44.0744	2.0354	99.9549	44.9537	2.2235
Next Place: diphthong	79.4218	76.0870	1.0438	58.7161	80.0105	0.7339	60.6904	85.3905	0.7107	83.6412	89.6458	0.9330	96.6252	92.8606	1.0405	70.0772	95.1687	0.7363	33.0433	96.9943	0.3407
Next Place: glottal	38.9970	27.1124	1.4383	55.4290	28.6977	1.9315	73.2805	30.6562	2.3904	91.5203	32.1885	2.8433	119.6932	33.3186	3.5924	138.2447	34.0909	4.0552	162.5376	34.7019	4.6838
Next Place: labial	44.3882	20.2169	2.1956	42.5315	21.3141	1.9955	53.0048	22.7568	2.3292	81.9977	23.8898	3.4323	121.5871	24.7393	4.9147	180.3363	25.3648	7.1097	243.0673	25.8699	9.3957
Next Place: labio-dental	29.1938	35.4274	0.8240	41.4609	37.2997	1.1116	53.0810	39.8168	1.3331	66.8344	41.8005	1.5989	93.2013	43.2900	2.1530	124.5611	44.3785	2.8068	186.6785	45.2557	4.1250
Next Place: lax	86.4152	75.3436	1.1469	78.4959	79.1992	0.9911	75.0658	84.5198	0.8881	92.6147	88.7301	1.0438	105.3395	91.9134	1.1461	75.8802	94.2001	0.8055	35.2127	96.0077	0.3668
Next Place: palatal	10.5850	25.4579	0.4158	-18.1464	26.8069	-0.6769	-38.4769	28.6268	-1.3441	-58.7843	30.0530	-1.9560	-77.1074	31.1185	-2.4779	-82.5649	31.9549	-2.5838	-94.0997	32.6591	-2.8813
Next Place: palato-alveolar	2.5895	51.1808	0.0506	-48.9421	54.3833	-0.8999	-26.1420	58.1551	-0.4495	-22.9601	61.0928	-0.3758	-27.4491	63.2587	-0.4339	-73.0691	64.7538	-1.1284	-148.6929	65.9281	-2.2554
Next Place: tense	78.5803	79.7587	0.9852	79.8176	84.1098	0.9490	86.9596	89.8418	0.9679	121.0852	94.3510	1.2833	147.0193	97.7228	1.5045	137.1712	100.1072	1.3702	99.6437	101.9824	0.9771
Next Manner: approximate	98.1322	76.8651	1.2767	99.0198	80.8266	1.2251	101.2713	86.2629	1.1740	113.0231	90.5602	1.2480	114.8227	93.8024	1.2241	65.1976	96.1295	0.6782	16.3923	97.9727	0.1673

Next Manner: flap	50.6062	86.4042	0.5857	3.9525	90.6759	0.0436	-26.5576	96.7391	-0.2745	-30.5693	101.5326	-0.3011	-60.6533	105.1729	-0.5767	-129.4651	107.9165	-1.1997	-194.5444	110.1416	-1.7663
Next Manner: fricative	12.7931	73.7741	0.1734	6.0503	77.4847	0.0781	-19.5217	82.6821	-0.2361	-48.1376	86.7966	-0.5546	-101.6077	89.9099	-1.1301	-159.3050	92.1753	-1.7283	-247.6676	93.9807	-2.6353
Next Manner: nasal	46.3593	79.1109	0.5860	32.0186	83.1881	0.3849	11.6126	88.7769	0.1308	8.6283	93.1924	0.0926	-6.0897	96.5290	-0.0631	-65.1556	98.9305	-0.6586	-137.4222	100.8282	-1.3629
Next Manner: stop	33.7778	76.9849	0.4388	40.6956	80.9316	0.5028	40.2228	86.3725	0.4657	27.4747	90.6738	0.3030	-7.3196	93.9196	-0.0779	-76.7806	96.2546	-0.7977	-139.8342	98.1073	-1.4253
Duration (log) x Frequency (log)	-0.0498	0.0566	-0.8806	0.0833	0.0596	1.3976	0.1551	0.0637	2.4350	0.2005	0.0668	3.0016	0.1998	0.0691	2.8926	0.1760	0.0711	2.4755	0.1621	0.0731	2.2165

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	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	12.4108	135.0068	0.0919	51.3274	123.7496	0.4148	97.8626	125.4756	0.7799	113.9655	139.0352	0.8197	157.8366	150.1558	1.0512	211.9425	159.2822	1.3306	239.3011	170.2892	1.4053
Tense: past	65.0110	74.5882	0.8716	77.3097	66.5490	1.1617	111.4323	66.3971	1.6783	80.0246	73.2334	1.0927	48.2055	78.2410	0.6161	72.2173	81.1131	0.8903	91.3851	85.3437	1.0708
NDL Cue Strength	-132.0978	443.8339	-0.2976	-139.3838	363.2770	-0.3837	30.7470	344.0306	0.0894	186.7572	385.9546	0.4839	234.7151	422.9053	0.5550	278.2348	459.3455	0.6057	380.0525	495.7850	0.7666
Duration (log)	0.3382	1.0096	0.3350	0.1626	0.9333	0.1742	-0.1344	0.9505	-0.1414	-0.2094	1.0519	-0.1991	-0.4848	1.1375	-0.4262	-1.0723	1.2096	-0.8864	-1.5468	1.2925	-1.1967
Frequency (log)	20.1626	38.6255	0.5220	14.8124	34.5410	0.4288	1.3475	34.1180	0.0395	-5.8680	37.9115	-0.1548	-14.8175	41.1913	-0.3597	-25.4527	44.2522	-0.5752	-32.4759	47.6297	-0.6818
Previous Voicing: voiceless	-57.5173	118.4309	-0.4857	-112.7657	105.8342	-1.0655	-176.8987	107.5208	-1.6453	-158.0301	118.4668	-1.3340	-139.8749	127.1386	-1.1002	-176.9210	133.2598	-1.3276	-187.4715	141.4882	-1.3250
Previous Place: glottal	53.8914	129.3198	0.4167	31.8182	119.8245	0.2655	98.7243	121.7707	0.8107	105.0987	133.9833	0.7844	69.6808	144.1443	0.4834	85.9798	152.4061	0.5641	132.7168	162.6765	0.8158
Previous Place: labial	-38.9088	90.8772	-0.4281	-84.9593	85.9519	-0.9885	-153.6560	90.4901	-1.6980	-142.2509	99.9330	-1.4235	-131.6347	106.9008	-1.2314	-167.9206	111.2376	-1.5096	-185.8037	117.7140	-1.5784
Previous Place: labio-dental	51.7037	109.8070	0.4709	54.6232	99.9592	0.5465	114.9320	101.8999	1.1279	121.1044	113.1166	1.0706	100.8890	122.1144	0.8262	129.9877	128.9845	1.0078	177.6181	137.2464	1.2942
Previous Place: palatal	-270.9709	261.2273	-1.0373	-258.6623	235.6737	-1.0975	-403.3250	237.9250	-1.6952	-373.9767	264.8603	-1.4120	-354.2258	288.1631	-1.2293	-356.2132	309.6485	-1.1504	-378.8905	332.5250	-1.1394
Previous Manner: fricative	-32.4656	100.3478	-0.3235	8.5437	88.3451	0.0967	24.7728	86.7682	0.2855	20.0287	95.7228	0.2092	27.6403	103.5460	0.2669	46.2059	110.0881	0.4197	31.6243	117.9247	0.2682
Next Voicing: voiceless	-75.8950	117.0650	-0.6483	-85.7798	122.1516	-0.7022	-104.3075	128.2195	-0.8135	-44.5543	137.4761	-0.3241	-34.8922	143.1675	-0.2437	6.1520	143.8922	0.0428	55.6813	150.3986	0.3702
Next Place: dental	-48.8683	121.3552	-0.4027	-69.2963	125.9959	-0.5500	-95.9164	132.1890	-0.7256	-32.8561	141.9145	-0.2315	-20.8430	148.0637	-0.1408	15.3380	149.2889	0.1027	56.2627	156.2276	0.3601
Next Place: glottal	50.0824	41.5648	1.2049	71.3964	40.5798	1.7594	71.9920	43.4068	1.6585	80.7722	47.6454	1.6953	92.9167	49.9906	1.8587	95.4944	49.4189	1.9323	81.8318	50.8021	1.6108
Next Place: labial	47.7904	66.6633	0.7169	35.9846	63.5830	0.5659	0.1247	68.9442	0.0018	-13.8628	76.7975	-0.1805	-42.1380	82.5965	-0.5102	-80.8117	85.4677	-0.9455	-94.3382	89.3374	-1.0560
Next Place: lax	16.0259	35.4740	0.4518	10.3918	34.8425	0.2983	2.0566	37.4679	0.0549	2.1721	41.1794	0.0527	-3.9855	43.3065	-0.0920	-4.9537	42.7363	-0.1159	5.3150	43.6261	0.1218
Next Place: tense	-1.8335	49.1673	-0.0373	-10.7690	46.5372	-0.2314	-21.7543	50.5715	-0.4302	-11.6895	56.5057	-0.2069	-16.2545	61.3399	-0.2650	-39.6585	65.1302	-0.6089	4.3736	69.3292	0.0631
Next Manner: fricative	37.9311	116.9526	0.3243	43.6825	121.1955	0.3604	63.0254	127.0235	0.4962	1.1710	136.3850	0.0086	-23.4763	142.5367	-0.1647	-72.5053	144.5220	-0.5017	-123.4361	151.7931	-0.8132
Next Manner: nasal	-78.5926	65.3489	-1.2027	-48.4172	61.9260	-0.7819	-4.6265	67.2719	-0.0688	23.1785	75.1998	0.3082	51.6213	81.6001	0.6326	89.7585	86.4210	1.0386	96.8897	91.6231	1.0575
Next Manner: stop	53.1653	77.9881	0.6817	66.5468	73.0928	0.9104	89.2510	79.7492	1.1191	38.0934	89.5467	0.4254	19.1259	97.8456	0.1955	-3.4120	105.0456	-0.0325	-31.4918	112.2826	-0.2805
Duration (log) x Frequency (log)	-0.0041	0.2478	-0.0167	0.0609	0.2322	0.2623	0.1280	0.2361	0.5421	0.1370	0.2607	0.5255	0.1913	0.2812	0.6802	0.2939	0.2974	0.9883	0.3623	0.3166	1.1442

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	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	539.3649	216.4544	2.4918	609.8595	194.1492	3.1412	507.9988	185.2912	2.7416	387.8676	190.7867	2.0330	334.7850	192.8704	1.7358	224.6598	195.4060	1.1497	79.8155	210.0132	0.3800
Tense: past	-22.2510	132.1177	-0.1684	-23.8933	111.2564	-0.2148	-12.7950	104.3651	-0.1226	-39.5689	112.7559	-0.3509	-51.0669	105.1713	-0.4856	-140.6604	103.1976	-1.3630	-178.4801	109.6627	-1.6275
NDL Cue Strength	-1954.8375	780.5669	-2.5044	-1798.6581	665.2576	-2.7037	-1959.6867	619.5131	-3.1633	-1906.4020	670.8249	-2.8419	-2561.3062	619.0145	-4.1377	-2860.9854	587.0297	-4.8737	-3171.7669	644.8106	-4.9189
Duration (log)	0.8781	1.5300	0.5739	0.6694	1.4160	0.4727	1.0582	1.3608	0.7776	1.6831	1.3777	1.2217	1.8665	1.4220	1.3125	2.8234	1.4444	1.9548	3.8307	1.5394	2.4885
Frequency (log)	52.8774	63.2056	0.8366	33.5635	54.7803	0.6127	64.0184	51.5883	1.2409	95.9121	54.2633	1.7675	139.6261	52.8451	2.6422	169.0814	52.0993	3.2454	211.9693	57.2791	3.7006
Previous Voicing: voiceless	-5.9456	208.4401	-0.0285	-1.9884	188.0677	-0.0106	41.4348	181.0106	0.2289	104.7361	191.3022	0.5475	61.1825	188.2727	0.3250	171.0128	191.1641	0.8946	220.8873	205.0486	1.0772
Previous Place: glottal	-93.6977	214.1720	-0.4375	-96.8464	184.8609	-0.5239	-147.0786	174.7507	-0.8416	-163.6630	183.1251	-0.8937	-357.4202	181.2012	-1.9725	-484.8116	181.8477	-2.6660	-555.3207	199.5067	-2.7835
Previous Place: labial	283.6848	131.7716	2.1529	226.9475	122.0660	1.8592	212.1649	117.3006	1.8087	221.6684	117.3076	1.8896	209.3686	123.4213	1.6964	282.1364	131.3948	2.1472	340.1765	139.7724	2.4338
Previous Place: labio-dental	-166.5235	177.5575	-0.9379	-184.8640	150.5110	-1.2282	-206.3063	140.6803	-1.4665	-222.8376	147.4166	-1.5116	-373.6425	143.9423	-2.5958	-498.5024	144.3219	-3.4541	-562.0071	156.4716	-3.5918
Previous Place: palatal	147.6426	433.7706	0.3404	251.2193	363.1895	0.6917	486.0519	337.4789	1.4402	516.6292	358.8941	1.4395	800.5976	342.9372	2.3345	1067.3790	335.5015	3.1814	1354.7770	366.3953	3.6976
Previous Manner: fricative	218.4376	193.4285	1.1293	224.7332	167.9535	1.3381	213.3225	160.8776	1.3260	173.4043	171.6758	1.0101	328.2333	169.2212	1.9397	341.1132	165.9574	2.0554	369.8459	183.0399	2.0206
Next Voicing: voiceless	-359.2524	159.8598	-2.2473	-438.3954	149.3477	-2.9354	-417.6652	143.1387	-2.9179	-412.4245	142.5777	-2.8926	-368.9362	150.3315	-2.4542	-369.6346	163.4646	-2.2613	-279.6980	177.0049	-1.5802
Next Place: dental	-304.2248	168.1042	-1.8097	-396.1206	155.3466	-2.5499	-350.7606	148.3028	-2.3652	-344.2667	148.4235	-2.3195	-292.9081	155.2228	-1.8870	-295.2445	168.1348	-1.7560	-192.2979	182.3364	-1.0546
Next Place: glottal	38.6589	65.9541	0.5861	61.7704	58.5145	1.0556	93.9035	55.4658	1.6930	91.8437	55.1804	1.6644	103.3961	59.0296	1.7516	99.2368	65.0602	1.5253	86.1609	70.6801	1.2190
Next Place: labial	-138.9497	92.4810	-1.5025	-224.2285	85.8245	-2.6126	-211.7320	82.0867	-2.5794	-197.0721	80.6448	-2.4437	-191.2621	86.7423	-2.2049	-111.4034	95.5115	-1.1664	65.4697	100.7152	0.6500
Next Place: lax	9.8135	47.8276	0.2052	3.1558	44.8651	0.0703	14.7781	42.7087	0.3460	19.9587	41.4819	0.4811	-1.5785	45.0592	-0.0350	15.4238	50.8179	0.3035	28.7744	54.1655	0.5312
Next Place: tense	-25.7189	66.2487	-0.3882	-28.9552	62.6588	-0.4621	-15.9802	60.2977	-0.2650	-15.6159	58.7935	-0.2656	-27.6592	63.8308	-0.4333	6.5656	70.6983	0.0929	39.0411	75.3667	0.5180
Next Manner: fricative	316.4066	164.4679	1.9238	402.9979	151.7105	2.6564	386.6957	145.0985	2.6651	381.0463	145.5378	2.6182	304.0922	152.1336	1.9988	309.5284	164.0229	1.8871	235.8518	178.1119	1.3242
Next Manner: nasal	209.6728	91.3583	2.2951	301.7465	84.6745	3.5636	284.0130	81.3005	3.4934	258.1831	80.0682	3.2245	230.4449	86.1512	2.6749	178.7228	94.2030	1.8972	45.1115	99.4720	0.4535
Next Manner: stop	242.9620	109.0072	2.2289	319.2728	102.4399	3.1167	331.6994	99.2016	3.3437	319.9471	97.3045	3.2881	291.8298	105.7977	2.7584	248.7986	115.6360	2.1516	131.0670	123.3520	1.0625
Duration (log) x Frequency (log)	-0.1055	0.3699	-0.2852	-0.0469	0.3398	-0.1381	-0.1612	0.3253	-0.4955	-0.3279	0.3294	-0.9952	-0.4197	0.3392	-1.2374	-0.6150	0.3439	-1.7882	-0.8904	0.3704	-2.4037

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	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	22.6468	260.6896	0.0869	170.1988	236.7885	0.7188	302.9078	234.7860	1.2901	544.0192	249.3986	2.1813	606.5846	265.5354	2.2844	599.7269	253.5430	2.3654	532.7441	268.4402	1.9846
Tense: past	-39.3278	41.0207	-0.9587	-49.7451	40.4995	-1.2283	-9.4960	40.9174	-0.2321	23.8974	42.8024	0.5583	46.9047	44.7257	1.0487	43.1922	44.4662	0.9713	-8.6948	47.4123	-0.1834

NDL Cue Strength	-68.7504	144.5378	-0.4757	-11.2545	136.7958	-0.0823	35.0698	137.2083	0.2556	171.5472	144.2663	1.1891	205.5520	153.0051	1.3434	212.4310	150.0764	1.4155	206.1591	159.9849	1.2886
Duration (log)	-0.4793	0.6859	-0.6988	-1.0754	0.6293	-1.7090	-1.3635	0.6143	-2.2197	-1.5911	0.6459	-2.4633	-1.6876	0.6404	-2.6352	-1.4958	0.5891	-2.5390	-0.9096	0.6120	-1.4862
Frequency (log)	64.7709	78.0979	0.8294	35.9456	72.1085	0.4985	0.4556	71.9006	0.0063	-76.3160	76.1013	-1.0028	-93.0692	81.1463	-1.1469	-84.3675	78.4774	-1.0751	-76.9563	83.4300	-0.9224
Previous Voicing: voiceless	32.3588	18.8578	1.7159	32.5265	19.8125	1.6417	14.4643	20.2260	0.7151	-1.4507	20.8046	-0.0697	-18.8120	21.1512	-0.8894	-28.2720	21.7013	-1.3028	-31.7233	23.2751	-1.3630
Previous Place: diphthong	-320.5379	230.7488	-1.3891	-322.3167	214.2792	-1.5042	-297.9966	214.2231	-1.3911	-146.0696	226.5898	-0.6446	-117.3472	242.8819	-0.4831	-156.3478	236.1802	-0.6620	-87.7713	251.7219	-0.3487
Previous Place: labial	-228.4132	132.3924	-1.7253	-218.9404	116.8482	-1.8737	-230.6507	115.7283	-1.9930	-53.0572	124.5771	-0.4259	-64.0373	136.7318	-0.4683	-108.1362	130.1039	-0.8312	-34.9603	138.6851	-0.2521
Previous Place: labio-dental	-109.8458	59.0521	-1.8601	-101.0930	54.4158	-1.8578	-53.5333	54.1822	-0.9880	-3.7086	57.0311	-0.0650	35.8730	61.4533	0.5837	28.8969	59.4613	0.4860	-52.5768	63.3353	-0.8301
Previous Place: palatal	-325.4177	226.9535	-1.4339	-336.6209	209.7572	-1.6048	-288.0732	209.5342	-1.3748	-131.0735	222.0493	-0.5903	-107.3707	238.4955	-0.4502	-157.3640	231.4037	-0.6800	-97.7828	246.6170	-0.3965
Previous Place: palato-alveolar	49.3783	94.8917	0.5204	35.6760	87.3392	0.4085	27.3264	87.1529	0.3135	-43.0724	92.5506	-0.4654	-38.6957	99.9826	-0.3870	-20.4487	96.7608	-0.2113	-47.1797	103.1948	-0.4572
Previous Place: tense	-375.5102	232.4434	-1.6155	-332.2984	216.2171	-1.5369	-297.2432	216.2287	-1.3747	-163.7682	228.6004	-0.7164	-146.3609	244.8298	-0.5978	-184.2570	238.2742	-0.7733	-118.9553	253.9955	-0.4683
Previous Manner: fricative	-128.1784	129.8245	-0.9873	-121.4935	118.3522	-1.0265	-111.4578	117.8504	-0.9458	-57.1963	124.9533	-0.4577	-68.4519	135.6180	-0.5047	-104.0373	130.9876	-0.7943	-29.6822	139.7432	-0.2124
Previous Manner: nasal	-387.5304	328.3469	-1.1802	-330.2670	306.9932	-1.0758	-192.8515	307.2872	-0.6276	110.8445	324.6226	0.3415	169.2640	346.5405	0.4884	118.5753	337.8512	0.3510	155.3656	360.1305	0.4314
Previous Manner: stop	-25.9678	27.6974	-0.9376	-8.1542	29.2444	-0.2788	-9.5653	29.8658	-0.3203	-6.0571	30.6520	-0.1976	-11.0969	31.0767	-0.3571	-8.0908	31.9274	-0.2534	-3.4148	34.1823	-0.0999
Next Voicing: voiceless	21.3964	12.9733	1.6493	9.5807	13.6720	0.7008	9.3022	13.9504	0.6668	10.5015	14.3039	0.7342	6.9976	14.4933	0.4828	8.2293	14.8608	0.5538	7.2153	15.8662	0.4548
Next Place: dental	-37.6614	71.7123	-0.5252	38.1888	74.6445	0.5116	56.2407	75.5846	0.7441	36.2504	76.9651	0.4710	9.9615	77.1248	0.1292	0.6915	78.2797	0.0088	20.4587	82.5890	0.2477
Next Place: diphthong	-14.3424	35.9813	-0.3986	-15.9551	37.6664	-0.4236	-17.5506	38.3750	-0.4573	-14.1467	39.4527	-0.3586	-3.0876	40.0484	-0.0771	7.4888	40.9244	0.1830	32.2402	43.7454	0.7370
Next Place: glottal	23.0629	13.2602	1.7393	12.5780	13.9916	0.8990	15.4624	14.2843	1.0825	23.6623	14.6553	1.6146	27.3704	14.8456	1.8437	35.6816	15.2179	2.3447	46.7069	16.2229	2.8791
Next Place: labial	1.5841	15.6457	0.1012	-2.1414	16.4944	-0.1298	2.2522	16.8347	0.1338	1.8804	17.2682	0.1089	0.3968	17.4947	0.0227	-1.6439	17.9336	-0.0917	-2.0266	19.1370	-0.1059
Next Place: labio-dental	13.3815	46.4615	0.2880	-11.5870	49.0251	-0.2363	-24.7658	50.0708	-0.4946	-21.8116	51.4910	-0.4236	-17.9102	52.2088	-0.3430	-14.0872	53.5622	-0.2630	-8.7833	57.3247	-0.1532
Next Place: lax	18.6340	29.2215	0.6377	-2.8942	30.3945	-0.0952	-19.9949	30.9257	-0.6465	-16.9615	31.8704	-0.5322	-7.6028	32.3983	-0.2347	6.1913	32.9844	0.1877	32.2863	35.2329	0.9164
Next Place: palatal	2.6687	26.4533	0.1009	-11.0919	27.7523	-0.3997	-21.7201	28.2414	-0.7691	-18.2529	28.9011	-0.6316	-30.9029	29.2015	-1.0583	-74.5037	29.8437	-2.4965	-54.7236	31.8111	-1.7203
Next Manner: flap	16.2451	27.6302	0.5879	9.3710	28.8217	0.3251	4.6380	29.3432	0.1581	6.0278	30.2225	0.1994	8.8736	30.6955	0.2891	17.9781	31.2930	0.5745	35.2737	33.4288	1.0552
Next Manner: fricative	-17.6813	43.3791	-0.4076	-30.8619	45.5320	-0.6778	-48.9245	46.4150	-1.0541	-59.6362	47.6576	-1.2513	-43.0131	48.3190	-0.8902	-35.2123	49.4258	-0.7124	-22.7178	52.7471	-0.4307
Next Manner: nasal	71.2255	34.4211	2.0692	55.2782	36.0720	1.5324	36.9386	36.7689	1.0046	44.0525	37.7687	1.1664	51.3279	38.3567	1.3382	59.8169	39.2545	1.5238	73.6288	41.9930	1.7534
Next Manner: stop	-3.6505	29.0122	-0.1258	0.0952	30.3268	0.0031	-7.0684	30.8888	-0.2288	-9.0678	31.7791	-0.2853	-6.1866	32.2593	-0.1918	-4.9527	32.9242	-0.1504	6.0125	35.1625	0.1710
Duration (log) x Frequency (log)	0.1390	0.1061	1.3092	0.2998	0.0976	3.0706	0.3726	0.0954	3.9059	0.4056	0.1001	4.0504	0.4033	0.0993	4.0610	0.3523	0.0917	3.8428	0.2292	0.0952	2.4076

a F2

	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	727.2815	367.0705	1.9813	674.1983	356.0186	1.8937	794.6801	407.1016	1.9520	936.2309	435.0366	2.1521	1240.5667	388.5145	3.1931	1135.6946	374.2470	3.0346	834.6695	388.7989	2.1468
Tense: past	-163.2647	67.1360	-2.4319	-148.9479	62.0616	-2.4000	-131.7808	63.3927	-2.0788	-93.3811	65.5344	-1.4249	-70.0511	62.8673	-1.1143	-49.5500	64.0137	-0.7741	1.3213	68.4416	0.0193
NDL Cue Strength	414.3953	224.6595	1.8445	327.8488	206.5066	1.5876	239.9626	220.2187	1.0897	181.0908	233.0225	0.7771	304.9492	215.5788	1.4146	272.8727	215.4422	1.2666	150.2770	227.2569	0.6613
Duration (log)	2.8150	0.8090	3.4796	1.7303	1.0439	1.6576	0.5706	1.2225	0.4667	0.0308	1.2483	0.0247	-0.2843	1.1006	-0.2583	-0.0307	1.0327	-0.0297	0.1718	1.1307	0.1519
Frequency (log)	-207.8775	115.5936	-1.7983	-186.7777	108.3835	-1.7233	-205.7899	119.9947	-1.7150	-245.8076	127.8503	-1.9226	-342.6093	115.9694	-2.9543	-329.9415	113.6980	-2.9019	-268.3745	118.6256	-2.2624
Previous Voicing: voiceless	-33.7445	33.7975	-0.9984	-6.6797	31.7645	-0.2103	21.6500	29.8878	0.7244	42.2182	29.8740	1.4132	45.7773	29.8593	1.5331	55.0225	31.6170	1.7403	74.2017	35.1738	2.1096
Previous Place: diphthong	598.7933	349.5939	1.7128	510.2908	319.1056	1.5991	557.6439	347.8092	1.6033	688.2888	371.5006	1.8527	975.2967	339.9930	2.8686	1086.7296	336.4985	3.2295	1130.2504	349.5684	3.2333
Previous Place: labial	567.9128	187.1870	3.0339	497.9037	168.2813	2.9588	427.9088	196.4776	2.1779	221.4797	216.0746	1.0250	180.5150	190.7433	0.9464	225.7187	182.8068	1.2347	355.3822	182.9410	1.9426
Previous Place: labio-dental	-72.8973	87.6238	-0.8319	-117.8240	80.0583	-1.4717	-162.0178	87.2400	-1.8571	-121.8605	92.0795	-1.3234	-68.2395	85.2072	-0.8009	-15.1603	85.5613	-0.1772	10.4208	88.9670	0.1171
Previous Place: palatal	582.9001	341.6308	1.7062	459.0391	311.6114	1.4731	514.0640	341.8464	1.5038	674.7534	366.0321	1.8434	957.0363	333.8893	2.8663	1045.8767	329.4385	3.1747	1082.2152	341.1510	3.1722
Previous Place: palato-alveolar	-672.5987	142.0192	-4.7360	-495.8618	128.2900	-3.8652	-405.8656	141.3724	-2.8709	-382.7277	151.2158	-2.5310	-458.8704	138.5127	-3.3128	-450.8931	137.1954	-3.2865	-420.7870	140.7339	-2.9899
Previous Place: tense	588.3614	353.1069	1.6662	520.6089	322.4931	1.6143	582.2183	350.5458	1.6609	709.7082	374.0208	1.8975	953.8116	342.7624	2.7827	996.3093	339.6989	2.9329	998.6505	353.4275	2.8256
Previous Manner: fricative	491.3053	192.1617	2.5567	499.3473	172.4610	2.8954	538.9032	191.2654	2.8176	562.5850	206.1487	2.7290	654.5180	187.3110	3.4943	714.2762	184.9976	3.8610	783.0199	189.3599	4.1351
Previous Manner: nasal	909.7609	501.6345	1.8136	818.3134	460.6753	1.7763	916.9387	498.3094	1.8401	1145.7697	530.0563	2.1616	1580.7493	486.8507	3.2469	1655.4296	483.0165	3.4273	1637.2975	504.4350	3.2458
Previous Manner: stop	19.0728	49.9129	0.3821	45.2811	46.9346	0.9648	52.9050	44.1658	1.1979	50.4771	44.1214	1.1440	47.6654	44.0388	1.0824	64.5528	46.4009	1.3912	68.6435	51.5656	1.3312
Next Voicing: voiceless	-14.4958	23.1048	-0.6274	-12.3586	21.8724	-0.5650	-9.5985	20.6724	-0.4643	-19.9569	20.6612	-0.9659	-14.5251	20.5922	-0.7054	-12.9359	21.6781	-0.5967	-12.0338	24.0877	-0.4996
Next Place: dental	-58.1699	119.7404	-0.4858	-30.4613	118.9481	-0.2561	18.4991	117.1965	0.1578	16.8345	117.5522	0.1432	32.1749	114.4068	0.2812	43.9056	118.0587	0.3719	96.5325	131.5523	0.7338
Next Place: diphthong	51.4351	63.5089	0.8099	48.9370	60.4147	0.8100	3.2631	57.6039	0.0566	-35.4619	57.6243	-0.6154	-67.1682	57.1183	-1.1759	-131.2755	59.8385	-2.1938	-209.1449	66.3269	-3.1532
Next Place: glottal	-20.5770	23.5900	-0.8723	-0.2000	22.2904	-0.0090	6.9333	21.0850	0.3288	9.3147	21.1245	0.4409	26.0086	21.0742	1.2341	42.6323	22.1594	1.9239	56.6771	24.5981	2.3041
Next Place: labial	-32.5672	27.8590	-1.1690	-6.5031	26.3043	-0.2472	-10.6925	24.8933	-0.4295	27.4412	24.9217	1.1011	52.0602	24.8470	2.0952	77.0931	26.1253	2.9509	117.6985	29.0058	4.0578
Next Place: labio-dental	114.7896	83.4889	1.3749	107.4076	78.7883	1.3632	101.2197	74.4944	1.3588	71.3327	74.5779	0.9565	137.6936	74.1780	1.8563	212.0586	77.8469	2.7240	273.2218	86.3787	3.1631
Next Place: lax	104.0387	51.0092	2.0396	101.9544	48.6660	2.0950	33.6274	46.8032	0.7185	-25.9995	46.9334	-0.5540	-61.5270	46.3545	-1.3273	-102.2136	48.3675	-2.1133	-174.8293	53.5448	-3.2651
Next Place: palatal	34.3710	46.2615	0.7430	38.5197	44.7458	0.8609	51.8544	42.5922	1.2175	58.2659	42.4464	1.3727	39.3112	42.0302	0.9353	59.3681	44.0866	1.3466	105.4702	49.0629	2.1497
Next Manner: flap	63.1751	48.4613	1.3036	64.6252	46.2402	1.3976	4.9171	44.3528	0.1109	-43.5626	44.4368	-0.9803	-81.3172	43.9137	-1.8517	-133.6937	45.8228	-2.9176	-208.0625	50.7513	-4.0996
Next Manner: fricative	126.9770	76.6610	1.6563	90.6963	72.9303	1.2436	0.4083	69.3091	0.0059	-50.6369	69.3317	-0.7304	-141.4830	68.8750	-2.0542	-234.5356	72.2836	-3.2447	-344.5155	80.2564	-4.2927
Next Manner: nasal	56.4318	61.1352	0.9231	58.8070	57.7375	1.0185	17.6034	54.8011	0.3212	-53.0751	54.8116	-0.9683	-102.8994	54.5017	-1.8880	-168.8530	57.3051	-2.9466	-267.0051	63.6217	-4.1968
Next Manner: stop	77.5543	51.0434	1.5194	74.1752	48.5847	1.5267	14.0657	46.4620	0.3027	-28.6084	46.5398	-0.6147	-76.1885	46.0823	-1.6533	-137.7190	48.1719	-2.8589	-222.0189	53.3931	-4.1582
Duration (log) x Frequency (log)	-0.4413	0.1263	-3.4930	-0.2224	0.1617	-1.3756	0.0315	0.1884	0.1672	0.1555	0.1922	0.8093	0.1996	0.1699	1.1744	0.1268	0.1602	0.7920	0.0494	0.1754	0.2817

Table A.13: Coefficients for the F1 and F2 global (all vowels pooled) LMER models of formant deviance from vowel onset.

	F1			F2		
Predictor	Estimate	std.Error	t.value	Estimate	std.Error	t.value
(Intercept)	-60.3277	27.1073	-2.2255	183.8443	60.7904	3.0242
Tense: past	-8.7889	2.4983	-3.5180	24.9237	5.4280	4.5917
Percent: 30	-9.5582	10.0868	-0.9476	-95.3896	21.8949	-4.3567
Percent: 40	8.7738	10.0868	0.8698	-164.3852	21.8949	-7.5079
Percent: 50	36.6516	10.0868	3.6336	-211.0620	21.8949	-9.6398
Percent: 60	61.9945	10.0868	6.1461	-246.8289	21.8949	-11.2734
Percent: 70	86.2746	10.0868	8.5532	-255.1690	21.8949	-11.6543
Percent: 80	108.1120	10.0868	10.7182	-207.1662	21.8949	-9.4619
NDL Cue Strength	-26.0884	5.7085	-4.5701	8.3677	12.3979	0.6749
Vowel: a	30.7875	2.4581	12.5248	27.1492	5.3391	5.0849
Vowel: æ	16.1865	3.8502	4.2041	66.8724	8.3784	7.9815
Vowel: ɔ	13.4642	3.3119	4.0655	35.7741	7.1997	4.9688
Vowel: ɛ	3.0858	2.0574	1.4999	24.3122	4.4681	5.4413
Vowel: ɪ	-23.5196	2.0074	-11.7163	44.3914	4.3594	10.1829
Vowel: i	-51.6467	2.1697	-23.8034	111.6534	4.7128	23.6914
Vowel: o	-21.0531	1.7442	-12.0701	35.9628	3.7878	9.4944
Vowel: ʊ	-19.3965	3.7261	-5.2056	36.8355	8.0976	4.5489
Vowel: u	-50.2501	2.5671	-19.5749	28.4480	5.5784	5.0997
Duration (log)	20.7207	5.2872	3.9190	-59.8977	11.8658	-5.0479
Frequency (log)	-58.5587	11.5120	-5.0867	-293.0058	26.3273	-11.1293
Previous Voicing: voiceless	-15.7020	2.5432	-6.1742	-12.1867	5.5233	-2.2064
Previous Place: dental	-22.7336	9.4161	-2.4143	36.5773	20.4782	1.7862
Previous Place: diphthong	3.9222	11.5211	0.3404	-0.7684	25.0680	-0.0307
Previous Place: glottal	13.9388	4.4459	3.1352	50.9637	9.6868	5.2611
Previous Place: labial	7.0776	2.5547	2.7705	58.4090	5.5608	10.5036
Previous Place: labio-dental	-27.9528	4.4046	-6.3462	6.6740	9.5891	0.6960
Previous Place: lax	-11.5736	11.5638	-1.0009	73.4326	25.1635	2.9182
Previous Place: palatal	3.3317	2.9577	1.1264	49.2760	6.4279	7.6660
Previous Place: palato-alveolar	3.5537	5.0007	0.7106	47.6947	10.8918	4.3790
Previous Place: tense	-1.3258	9.5736	-0.1385	12.2316	20.8609	0.5863
Previous Manner: approximate	-17.7404	8.1374	-2.1801	76.2812	17.7552	4.2963
Previous Manner: diphthong	-49.3063	11.5253	-4.2781	-88.5137	25.0305	-3.5362
Previous Manner: flap	6.2253	14.2199	0.4378	37.5253	30.9580	1.2121
Previous Manner: fricative	22.6637	7.3109	3.1000	-6.6932	15.9701	-0.4191
Previous Manner: lax	15.3760	9.0504	1.6989	-34.0611	19.6488	-1.7335
Previous Manner: nasal	10.4072	8.0273	1.2965	74.8735	17.5166	4.2744
Previous Manner: stop	10.0335	7.9726	1.2585	69.9992	17.4016	4.0226
Next Voicing: voiceless	-3.5275	1.5109	-2.3348	-18.2677	3.2808	-5.5680
Next Place: dental	-7.2143	3.0892	-2.3353	-60.8007	6.7079	-9.0641
Next Place: diphthong	35.7948	9.1642	3.9059	-50.0716	19.8979	-2.5164
Next Place: glottal	5.4222	1.6595	3.2674	-15.1567	3.6038	-4.2057
Next Place: labial	8.0867	1.7091	4.7315	33.7936	3.7122	9.1033
Next Place: labio-dental	-3.2305	3.3371	-0.9681	-29.7822	7.2475	-4.1093
Next Place: lax	35.7628	18.7680	1.9055	-71.1671	40.7355	-1.7471
Next Place: palatal	12.0064	2.0617	5.8236	-14.9944	4.4875	-3.3414
Next Place: palato-alveolar	14.9064	6.1614	2.4193	-69.5119	13.3774	-5.1962
Next Place: tense	19.6003	9.5804	2.0459	17.7506	20.8033	0.8533
Next Manner: approximate	11.0507	9.0490	1.2212	-12.7308	19.6474	-0.6480
Next Manner: flap	22.6619	9.0545	2.5028	-41.2334	19.6606	-2.0973
Next Manner: fricative	16.9542	8.7683	1.9336	-20.8732	19.0392	-1.0963
Next Manner: lax	-12.9341	16.5176	-0.7831	33.2881	35.8474	0.9286
Next Manner: nasal	23.4982	9.1406	2.5707	-24.5324	19.8470	-1.2361
Next Manner: stop	17.5997	8.9029	1.9768	-34.8832	19.3314	-1.8045
Tense: past x Percent: 30	9.9964	2.9405	3.3996	-1.9290	6.3828	-0.3022
Tense: past x Percent: 40	19.1579	2.9405	6.5152	-10.4789	6.3828	-1.6417
Tense: past x Percent: 50	26.4371	2.9405	8.9907	-28.6004	6.3828	-4.4808
Tense: past x Percent: 60	28.6169	2.9405	9.7320	-49.0144	6.3828	-7.6791
Tense: past x Percent: 70	28.0819	2.9405	9.5500	-67.9520	6.3828	-10.6461
Tense: past x Percent: 80	23.5311	2.9405	8.0024	-81.1054	6.3828	-12.7068
Percent: 30 x NDL Cue Strength	13.3262	6.1728	2.1589	14.5606	13.3989	1.0867
Percent: 40 x NDL Cue Strength	26.5509	6.1728	4.3013	27.0531	13.3989	2.0191
Percent: 50 x NDL Cue Strength	32.0063	6.1728	5.1851	36.2152	13.3989	2.7028
Percent: 60 x NDL Cue Strength	30.8832	6.1728	5.0031	35.4277	13.3989	2.6441
Percent: 70 x NDL Cue Strength	23.8186	6.1728	3.8587	25.4561	13.3989	1.8999
Percent: 80 x NDL Cue Strength	12.4952	6.1728	2.0242	14.1628	13.3989	1.0570
Duration (log) x Frequency (log)	14.1029	2.4568	5.7404	72.3020	5.3769	13.4468
Percent: 30 x Duration (log)	5.3382	2.2945	2.3266	31.5601	4.9805	6.3367
Percent: 40 x Duration (log)	3.0944	2.2945	1.3486	57.4536	4.9805	11.5357
Percent: 50 x Duration (log)	-1.7451	2.2945	-0.7606	79.1766	4.9805	15.8973
Percent: 60 x Duration (log)	-6.2621	2.2945	-2.7292	97.6121	4.9805	19.5989
Percent: 70 x Duration (log)	-10.6691	2.2945	-4.6499	108.9096	4.9805	21.8672
Percent: 80 x Duration (log)	-14.4487	2.2945	-6.2972	105.7603	4.9805	21.2349

Table A.14: Coefficients for the F1 and F2 by vowel LMER models of formant deviance from vowel onset.

i F1	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	18.6042	28.4173	0.6547	49.4197	35.0779	1.4089	58.7814	37.6185	1.5626	49.5072	39.4005	1.2565	51.4935	39.9387	1.2893	77.0783	40.6163	1.8977	80.8275	44.5500	1.8143
Tense: past	-5.1343	10.9484	-0.4690	-13.0426	13.6041	-0.9587	-23.9195	14.5568	-1.6432	-28.8185	15.2378	-1.8912	-27.4879	15.4700	-1.7769	-30.0335	15.8008	-1.9008	-25.7330	17.3879	-1.4799
NDL Cue Strength	30.6000	44.7066	0.6845	56.8783	55.5744	1.0235	21.2879	59.6136	0.3571	7.9437	62.4298	0.1272	20.7856	63.4294	0.3277	30.7246	64.7578	0.4745	26.3248	71.1741	0.3699
Duration (log)	-0.0456	0.1203	-0.3794	-0.0422	0.1428	-0.2953	0.0807	0.1498	0.5390	0.1781	0.1591	1.1194	0.1550	0.1589	0.9755	0.0524	0.1597	0.3283	-0.0019	0.1744	-0.0107
Frequency (log)	-7.1773	4.5886	-1.5641	-11.9381	5.6494	-2.1132	-9.4112	6.0445	-1.5570	-6.1214	6.3187	-0.9688	-5.0652	6.3935	-0.7922	-6.9112	6.4903	-1.0649	-9.7883	7.1345	-1.3720
Previous Voicing: voiceless	2.4486	15.2638	0.1604	1.2644	18.9539	0.0667	-2.6460	20.3840	-0.1298	1.9520	21.3925	0.0912	11.5951	21.7557	0.5330	19.1600	22.1800	0.8638	25.1515	24.3398	1.0333
Previous Place: diphthong	-7.0599	16.8747	-0.4184	-16.2814	20.4232	-0.7972	-19.0627	21.7863	-0.8750	-19.5432	23.0045	-0.8495	-40.6420	23.2120	-1.7509	-75.8482	23.4224	-3.2383	-69.3828	25.6131	-2.7089
Previous Place: labial	-3.6107	8.9868	-0.4018	-8.5889	11.1995	-0.7669	-6.2049	11.9666	-0.5185	-6.2210	12.5425	-0.4960	-3.6056	12.7459	-0.2829	-1.8626	13.0575	-0.1426	0.7309	14.3986	0.0508
Previous Place: labio-dental	-7.6969	18.7969	-0.4095	-12.8955	23.4470	-0.5500	-22.4173	25.1594	-0.8910	-24.6252	26.3567	-0.9343	-23.3415	26.8081	-0.8707	-30.1161	27.4027	-1.0990	-47.3994	30.2001	-1.5695
Previous Place: lax	-2.4026	10.6920	-0.2247	-18.0935	13.2561	-1.3649	-24.2684	14.2032	-1.7087	-32.6353	14.9100	-2.1888	-34.0054	15.1425	-2.2457	-42.7162	15.4668	-2.7618	-45.0256	16.9913	-2.6499
Previous Place: palatal	13.3405	18.4611	0.7226	11.0250	22.8421	0.4827	17.4622	24.6206	0.7093	15.3848	25.8641	0.5948	15.2565	26.2932	0.5802	14.5210	26.7294	0.5433	17.6037	29.2250	0.6024
Previous Place: palato-alveolar	-19.8531	26.2078	-0.7575	-22.1057	32.5134	-0.6799	-19.5348	35.0815	-0.5568	-17.6188	36.7131	-0.4799	-24.0058	37.3027	-0.6435	-33.3288	37.9222	-0.8789	-32.4220	41.4747	-0.7817
Previous Place: tense	14.4356	13.3832	1.0786	4.5129	16.4818	0.2738	3.2087	17.7993	0.1803	-6.6417	18.7556	-0.3541	-6.2617	19.0722	-0.3283	-23.1507	19.3235	-1.1981	-34.3643	21.0906	-1.6294
Previous Manner: fricative	-3.5353	23.2094	-0.1523	-12.3162	28.8552	-0.4268	-5.7670	31.0272	-0.1859	-16.5518	32.5372	-0.5087	-36.3917	33.0884	-1.0998	-54.5023	33.7449	-1.6151	-51.3289	37.0670	-1.3848
Previous Manner: nasal	-4.2824	10.6233	-0.4031	-15.6641	13.2395	-1.1831	-30.5304	14.1378	-2.1595	-38.0514	14.7876	-2.5732	-44.9703	15.0216	-2.9937	-57.1870	15.3941	-3.7149	-60.4257	16.9910	-3.5563
Previous Manner: stop	-6.0459	16.1122	-0.3752	-20.3427	19.9663	-1.0189	-34.9686	21.5223	-1.6248	-45.6922	22.6010	-2.0217	-59.4294	22.9925	-2.5847	-79.1139	23.3913	-3.3822	-83.2695	25.6434	-3.2472
Next Voicing: voiceless	-0.7038	5.0812	-0.1385	1.1944	6.2790	0.1902	2.6355	6.7775	0.3889	7.5734	7.1068	1.0656	10.3937	7.2210	1.4394	13.8384	7.3235	1.8896	15.8505	8.0012	1.9810
Next Place: dental	5.3191	7.9641	0.6679	10.4842	9.8651	1.0628	12.5034	10.6488	1.1742	15.7134	11.1504	1.4092	18.3090	11.3313	1.6158	26.0224	11.5107	2.2607	26.6647	12.5849	2.1188
Next Place: diphthong	36.1470	23.2723	1.5532	41.7295	28.8268	1.4476	40.3570	31.1166	1.2970	54.2024	32.6241	1.6614	65.2438	33.1503	1.9681	71.2724	33.7018	2.1148	105.7987	36.7955	2.8753
Next Place: glottal	0.6293	6.1400	0.1025	3.2801	7.5870	0.4323	4.6031	8.1920	0.5619	7.8485	8.5872	0.9140	10.5534	8.7231	1.2098	19.4561	8.8446	2.1998	21.4401	9.6578	2.2200
Next Place: labial	-9.3782	5.5337	-1.6947	-8.4944	6.8353	-1.2427	-7.6734	7.3601	-1.0426	-8.0696	7.6993	-1.0481	-14.3050	7.8092	-1.8318	-18.5487	7.9260	-2.3402	-20.4605	8.6767	-2.3581
Next Place: labio-dental	-9.1860	11.5850	-0.7929	-5.6606	14.0787	-0.4021	-1.7549	15.0259	-0.1168	4.1129	15.7742	0.2607	6.1556	15.9108	0.3869	19.7628	16.0930	1.2280	26.4281	17.5614	1.5049
Next Place: lax	22.4573	28.6419	0.7841	31.6279	35.4404	0.8924	22.8110	38.2060	0.5971	26.8301	40.0462	0.6700	27.7769	40.6783	0.6828	54.2448	41.3608	1.3115	99.3329	45.2350	2.1959
Next Place: palatal	-0.8100	6.2493	-0.1296	3.1716	7.7356	0.4100	8.3716	8.2911	1.0097	7.5652	8.6748	0.8721	5.5785	8.7991	0.6340	2.0929	8.9595	0.2336	-2.9197	9.8426	-0.2966
Next Place: palato-alveolar	33.0117	15.8355	2.0847	28.4366	19.5587	1.4539	21.2929	21.1705	1.0058	15.1773	22.1927	0.6839	10.1610	22.5564	0.4505	11.2251	22.8628	0.4910	15.7332	24.9081	0.6316
Next Place: tense	22.3881	23.3172	0.9602	29.4026	28.8840	1.0180	30.5315	31.1997	0.9786	43.0932	32.7052	1.3176	43.8446	33.2414	1.3190	51.3829	33.7824	1.5210	78.2643	36.8833	2.1219
Next Manner: approximate	30.9251	22.5459	1.3716	37.1391	27.9313	1.3297	34.3463	30.1542	1.1390	39.7036	31.5953	1.2566	42.5595	32.1071	1.3255	41.6488	32.6381	1.2761	52.3056	35.6618	1.4667
Next Manner: flap	23.3499	22.4198	1.0415	28.7259	27.7672	1.0345	20.3594	29.9574	0.6796	24.9860	31.3898	0.7960	23.5259	31.8918	0.7377	19.4975	32.4260	0.6013	30.4801	35.4482	0.8598
Next Manner: fricative	19.8297	21.5597	0.9198	20.0714	26.7253	0.7510	14.3946	28.8682	0.4986	15.5644	30.2494	0.5145	11.9367	30.7472	0.3882	0.2794	31.2520	0.0089	6.2794	34.1367	0.1839
Next Manner: lax	4.6610	18.6264	0.2502	3.1971	23.0040	0.1390	8.8478	24.7595	0.3573	10.7562	25.9389	0.4147	9.3226	26.3257	0.3541	-17.4286	26.7574	-0.6514	-48.2160	29.2979	-1.6457
Next Manner: nasal	35.5209	22.7649	1.5603	39.9539	28.2058	1.4165	36.5296	30.4516	1.1996	43.3330	31.9143	1.3578	43.6675	32.4333	1.3464	43.1484	32.9731	1.3086	53.6845	36.0141	1.4907
Next Manner: stop	23.2138	21.9940	1.0555	27.7437	27.2457	1.0183	21.3856	29.4012	0.7274	23.2745	30.8144	0.7553	23.5590	31.3108	0.7524	20.0518	31.8389	0.6298	30.3656	34.7923	0.8728
Duration (log) x Frequency (log)	0.0263	0.0203	1.2957	0.0219	0.0242	0.9079	-0.0031	0.0255	-0.1213	-0.0205	0.0271	-0.7568	-0.0189	0.0271	-0.6959	-0.0076	0.0272	-0.2777	0.0021	0.0296	0.0706

i F2	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	196.0233	72.4687	2.7049	232.8070	115.4597	2.0163	320.3189	136.2839	2.3504	357.5990	153.8207	2.3248	417.5353	165.0851	2.5292	483.1519	172.8585	2.7951	428.4432	183.8885	2.3299
Tense: past	-24.4363	28.8863	-0.8459	-41.3428	45.3458	-0.9117	-56.2345	53.2865	-1.0553	-42.8781	60.1447	-0.7129	-57.4384	64.7970	-0.8864	-65.4906	67.9321	-0.9641	-59.3526	72.6586	-0.8169
NDL Cue Strength	252.6645	116.3063	2.1724	366.0810	181.5957	2.0159	406.8697	213.7895	1.9031	468.5656	241.7904	1.9379	577.9625	261.3233	2.2117	514.8744	273.8458	1.8802	409.7907	292.0191	1.4033
Duration (log)	0.5891	0.3198	1.8421	0.4370	0.5139	0.8505	0.3612	0.6200	0.5825	-0.2463	0.7076	-0.3481	-0.5783	0.7530	-0.7681	-0.7156	0.7921	-0.9033	-0.0955	0.8555	-0.1116
Frequency (log)	-12.5244	12.0532	-1.0391	-20.8129	19.3624	-1.0749	-30.2262	22.7742	-1.3272	-48.1183	25.6413	-1.8766	-67.6903	27.3923	-2.4711	-75.6265	28.7133	-2.6339	-67.3398	30.6825	-2.1947
Previous Voicing: voiceless	44.2751	39.3420	1.1254	-9.1906	61.0904	-0.1504	11.1934	71.9126	0.1557	24.8591	81.3265	0.3057	74.4703	88.0306	0.8460	70.6140	92.3358	0.7648	75.5975	98.7323	0.7657
Previous Place: diphthong	-274.5874	42.5066	-6.4599	-455.4522	66.2850	-6.8711	-570.3105	78.9541	-7.2233	-611.7670	89.7334	-6.8176	-694.3306	96.6876	-7.1812	-726.4507	101.6581	-7.1460	-762.3016	109.7498	-6.9458
Previous Place: labial	47.8934	24.5819	1.9483	147.2073	38.5284	3.8207	193.6053	45.2929	4.2745	208.9384	51.1498	4.0848	189.0289	55.1778	3.4258	177.2921	57.8611	3.0641	183.8866	61.7727	2.9768
Previous Place: labio-dental	105.2677	50.8828	2.0688	186.8233	79.6505	2.3455	191.2421	93.7340	2.0403	213.8969	105.9516	2.0188	216.2598	114.4420	1.8897	170.2133	119.9242	1.4193	92.3528	127.7205	0.7231
Previous Place: lax	-166.2208	27.7851	-5.9824	-298.0834	43.3018	-6.8839	-381.8091	51.0837	-7.4742	-418.3295	57.8337	-7.2333	-483.6062	62.5092	-7.7366	-521.7427	65.5706	-7.9570	-498.6783	70.1229	-7.1115
Previous Place: palatal	35.1815	47.1030	0.7469	56.6782	73.1235	0.7751	67.2002	86.2011	0.7796	85.0223	97.5711	0.8714	129.7618	105.6266	1.2285	111.9847	110.7635	1.0110	202.6981	118.3394	1.7129
Previous Place: palato-alveolar	-41.7625	60.9425	-0.6853	-81.8057	92.3924	-0.8854	-108.9105	108.9870	-0.9993	-121.8272	123.5324	-0.9862	-141.6019	134.5710	-1.0522	-166.2745	141.1239	-1.1782	-135.2129	152.0122	-0.8895
Previous Place: tense	-251.8305	35.3079	-7.1324	-434.8682	54.7626	-7.9410	-519.6889	64.4653	-8.0615	-534.7493	72.9109	-7.3343	-592.4423	78.9118	-7.5076	-605.3032	82.8296	-7.3078	-589.6890	88.7854	-6.6417
Previous Manner: fricative	-219.1861	59.1240	-3.7072	-287.4713	91.3548	-3.1468	-370.6394	107.7498	-3.4398	-416.1843	122.0090	-3.4111	-518.1132	132.2454	-3.9178	-499.4969	138.7032	-3.6012	-461.6921	148.5407	-3.1082
Previous Manner: nasal	-62.1312	29.1496	-2.1315	-108.2272	46.0497	-2.3502	-188.4512	54.1722	-3.4787	-218.5457	61.1866	-3.5718	-248.3928	65.9142	-3.7684	-279.0753	69.0592	-4.0411	-312.4465	73.3705	-4.2585
Previous Manner: stop	-141.3359	41.8157	-3.3800	-216.5654	65.0157	-3.3310	-309.0954	76.5151	-4.0397	-361.3152	86.5055	-4.1768	-456.4782	93.5543	-4.8793	-471.7957	98.1530	-4.8067	-500.2642	105.0353	-4.7628
Next Voicing: voiceless	27.0816	12.5946	2.1503	64.9313	19.3428	3.3569	73.1844	22.8249	3.2063	86.0905	25.8680	3.3281	86.5928	28.0423	3.0879	99.0612	29.4139	3.3678	102.9992	31.5904	3.2605
Next Place: dental	28.3513	19.2168	1.4753	71.8521	29.3402	2.4489	68.4297	34.6177	1.9767	67.0616	39.2433	1.7089	58.8022	42.6401	1.3790	64.5895	44.7205	1.4443	64.9612	48.0766	1.3512
Next Place: diphthong	-82.7590	56.5611	-1.4632	7.4695	86.3475	0.0865	27.7038	102.1001	0.2713	117.4994	116.0043	1.0129	197.9188	126.2318	1.5679	218.8774	132.3615	1.6536	272.0770	141.7213	1.9198
Next Place: glottal	9.2373	14.8652	0.6214	28.1693	22.7213	1.2398	23.5405	26.8480	0.8768	33.4498	30.4701	1.0978	54.9901	33.0927	1.6617	81.1765	34.7110	2.3386	97.9614	37.2866	2.6273

Next Place: labial	-20.7765	13.2100	-1.5728	-30.9181	20.2027	-1.5304	-44.0480	23.8676	-1.8455	-57.3857	27.0528	-2.1213	-71.8739	29.3391	-2.4498	-85.7227	30.7881	-2.7843	-78.4621	33.2296	-2.3612
Next Place: labio-dental	-29.6220	28.3205	-1.0460	-24.8883	43.9596	-0.5662	-29.1719	52.4800	-0.5559	-30.2589	59.8017	-0.5060	-31.7573	64.5348	-0.4921	24.1669	67.7570	0.3567	22.5429	72.8395	0.3095
Next Place: lax	-103.7261	68.5761	-1.5126	-16.3185	104.5643	-0.1561	-39.3488	123.6860	-0.3181	8.4992	140.4582	0.0605	15.1241	152.8129	0.0990	125.2091	160.2832	0.7812	327.0234	172.1087	1.9001
Next Place: palatal	-18.4201	15.6665	-1.1758	-28.1606	24.2424	-1.1616	-38.7448	28.5824	-1.3555	-28.1069	32.3299	-0.8694	-7.9062	34.9324	-0.2263	9.5378	36.6562	0.2602	39.7847	39.4744	1.0079
Next Place: palato-alveolar	9.5997	37.8112	0.2539	41.6748	57.3911	0.7262	45.6086	67.9893	0.6708	114.1791	77.3924	1.4753	176.2331	84.3049	2.0904	208.6905	88.4587	2.3592	268.0045	94.9402	2.8229
Next Place: tense	-97.1106	56.5697	-1.7167	-6.9094	86.3267	-0.0800	20.3949	102.0488	0.1999	106.8358	115.9351	0.9215	172.5588	126.1749	1.3676	169.7710	132.3080	1.2832	225.2485	141.6818	1.5898
Next Manner: approximate	-69.8544	54.7290	-1.2764	38.9248	83.5809	0.4657	81.7841	98.7710	0.8280	188.3447	112.1740	1.6790	276.2366	122.0228	2.2638	305.9537	127.9654	2.3909	362.2849	137.1123	2.6422
Next Manner: flap	-68.0619	54.5855	-1.2469	20.0508	83.5013	0.2401	52.5921	98.6780	0.5330	141.1057	112.0729	1.2591	228.6160	121.8879	1.8756	244.4732	127.8218	1.9126	265.1489	136.8521	1.9375
Next Manner: fricative	-108.8774	52.5815	-2.0706	-62.3184	80.4207	-0.7749	-40.2320	94.9712	-0.4236	41.5820	107.8248	0.3856	115.2497	117.2719	0.9828	115.7942	122.9631	0.9417	148.2502	131.5852	1.1266
Next Manner: lax	22.4245	43.5034	0.5155	29.9971	66.1509	0.4535	77.9625	78.2924	0.9958	121.2945	88.8594	1.3650	192.5818	96.6361	1.9929	104.6650	101.3938	1.0323	-52.0810	109.3786	-0.4762
Next Manner: nasal	-68.4487	55.2513	-1.2389	28.5333	84.3787	0.3382	72.4706	99.7456	0.7266	177.9192	113.3031	1.5703	269.0667	123.2846	2.1825	285.7628	129.2724	2.2105	319.8987	138.4178	2.3111
Next Manner: stop	-82.6708	53.7399	-1.5383	-6.5811	82.2447	-0.0800	22.9643	97.2071	0.2362	104.6520	110.4136	0.9478	185.6614	120.0700	1.5463	197.5803	125.9085	1.5692	234.1799	134.7329	1.7381
Duration (log) x Frequency (log)	0.0512	0.0534	0.9590	0.1387	0.0852	1.6276	0.1924	0.1022	1.8827	0.3145	0.1161	2.7082	0.3633	0.1240	2.9310	0.3551	0.1304	2.7235	0.1884	0.1410	1.3363

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	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	2.6553	27.5503	0.0964	20.2809	35.9706	0.5638	35.3233	44.6887	0.7904	33.9178	50.1688	0.6761	27.5745	54.6143	0.5049	20.5825	57.9976	0.3549	31.2025	60.6105	0.5148
Tense: past	3.7227	6.3399	0.5872	-0.3020	8.1624	-0.0370	-1.1564	10.0006	-0.1156	2.8097	11.0860	0.2534	8.9741	12.1067	0.7413	11.6830	12.8821	0.9069	20.2939	13.4904	1.5043
NDL Cue Strength	-1.3000	12.0418	-0.1080	3.5283	15.4783	0.2279	5.9224	18.8800	0.3137	1.2771	20.8956	0.0611	1.3364	22.8331	0.0585	0.6997	24.3107	0.0288	1.6962	25.4687	0.0666
Duration (log)	0.2322	0.1457	1.5935	0.2914	0.2021	1.4415	0.2327	0.2524	0.9217	0.2695	0.2896	0.9308	0.1539	0.3179	0.4841	0.1548	0.3413	0.4536	0.0608	0.3560	0.1708
Frequency (log)	-0.3243	2.5038	-0.1295	-3.0047	3.3202	-0.9050	-6.2542	4.2470	-1.4726	-5.9567	4.8454	-1.2293	-6.1305	5.2529	-1.1671	-5.4819	5.5554	-0.9868	-5.3989	5.7903	-0.9324
Previous Voicing: voiceless	-2.9117	5.0126	-0.5809	-6.9576	6.4802	-1.0737	-8.2630	7.8568	-1.0517	-9.1425	8.7019	-1.0506	-6.4980	9.5197	-0.6826	-3.7304	10.1494	-0.3675	-0.1873	10.6364	-0.0176
Previous Place: glottal	5.6716	13.5472	0.4187	22.2629	17.6434	1.2618	35.6627	22.3966	1.5923	33.7777	25.1226	1.3445	36.3940	27.2940	1.3334	37.6271	28.8897	1.3024	33.6786	30.1721	1.1162
Previous Place: labial	42.7171	13.4187	3.1834	39.4076	17.7856	2.2157	37.7421	23.0202	1.6395	44.0598	26.0455	1.6916	54.3577	28.2317	1.9254	60.9366	29.8161	2.0438	74.3032	31.0797	2.3907
Previous Place: labio-dental	-15.3790	22.9464	-0.6702	-14.1887	29.2952	-0.4843	-15.6906	35.0537	-0.4476	-27.8963	38.5291	-0.7240	-37.3351	42.2115	-0.8845	-44.5399	45.0501	-0.9887	-48.4900	47.2641	-1.0259
Previous Place: lax	-14.7891	29.0798	-0.5086	-8.3451	37.4447	-0.2229	2.4600	45.6118	0.0539	7.6488	50.4552	0.1516	26.7687	55.1088	0.4857	34.4385	58.6595	0.5871	26.0169	61.4453	0.4234
Previous Place: palatal	10.1695	9.0995	1.1176	18.4546	11.8422	1.5584	20.3149	14.6216	1.3894	15.3445	16.2654	0.9434	19.7631	17.7610	1.1127	24.2654	18.8945	1.2843	29.6248	19.7767	1.4980
Previous Place: palato-alveolar	-12.6868	17.3381	-0.7317	-18.7210	22.1685	-0.8445	-18.6557	26.6694	-0.6995	-18.9560	29.3658	-0.6455	-19.1480	32.0897	-0.5967	-23.5447	34.1903	-0.6886	-31.0570	35.8418	-0.8665
Previous Place: tense	-20.6468	29.0528	-0.7107	-33.6801	37.5077	-0.8980	-17.4991	45.8210	-0.3819	-3.1508	50.7677	-0.0621	5.8035	55.4272	0.1047	6.8937	58.9787	0.1169	4.0230	61.7586	0.0651
Previous Manner: approximate	-28.9376	28.5432	-1.0138	-36.7651	36.8133	-0.9987	-27.9410	44.8293	-0.6233	-11.3141	49.5729	-0.2282	0.0533	54.1356	0.0010	-1.7073	57.6241	-0.0296	-20.2578	60.3580	-0.3356
Previous Manner: flap	-36.7097	36.5858	-1.0034	-48.4004	47.0370	-1.0290	-42.4569	56.9453	-0.7456	-41.1143	62.9102	-0.6535	-41.3138	68.7919	-0.6006	-45.1021	73.2960	-0.6153	-53.1614	76.8117	-0.6921
Previous Manner: fricative	-10.3326	25.4915	-0.4053	-9.9106	32.8944	-0.3013	-0.2823	40.2055	-0.0070	9.8055	44.5132	0.2203	18.0711	48.5913	0.3719	20.8320	51.6982	0.4030	11.1657	54.1348	0.2063
Previous Manner: nasal	-10.4523	29.2441	-0.3574	1.1030	37.8180	0.0292	29.6877	46.2328	0.6421	40.0720	51.2506	0.7819	42.7090	55.9574	0.7632	39.6041	59.5435	0.6651	24.5516	62.3435	0.3938
Previous Manner: stop	-26.7581	26.9378	-0.9933	-34.5039	34.7391	-0.9932	-23.2882	42.3724	-0.5496	-8.0619	46.9172	-0.1718	-0.7357	51.2338	-0.0144	-0.1531	54.5237	-0.0028	-10.7281	57.0991	-0.1879
Next Voicing: voiceless	4.8402	3.4304	1.4110	5.5787	4.4135	1.2640	2.9178	5.3338	0.5470	-2.2763	5.8941	-0.3862	-6.4119	6.4512	-0.9939	-9.8182	6.8808	-1.4269	-12.9647	7.2130	-1.7974
Next Place: dental	0.4239	10.0475	0.0422	-6.2131	12.8818	-0.4823	-13.8710	15.4534	-0.8976	-20.7553	17.0236	-1.2192	-25.6567	18.6482	-1.3758	-30.6969	19.9074	-1.5420	-27.0080	20.8784	-1.2936
Next Place: diphthong	6.9135	9.8726	0.7003	14.9133	12.6556	1.1784	17.0905	15.1862	1.1254	14.7258	16.7292	0.8802	16.7921	18.3263	0.9163	23.7326	19.5593	1.2134	40.6327	20.5142	1.9807
Next Place: glottal	4.6989	3.7025	1.2691	3.3769	4.7628	0.7090	0.1749	5.7550	0.0304	-3.8314	6.3582	-0.6026	-3.7863	6.9584	-0.5441	-0.1562	7.4215	-0.0210	4.6533	7.7796	0.5981
Next Place: labial	9.6967	5.5409	1.7500	8.1344	7.1268	1.1414	6.9137	8.5747	0.8063	12.3061	9.4387	1.3038	13.8253	10.3170	1.3400	13.5268	10.9964	1.2301	10.1968	11.5286	0.8845
Next Place: labio-dental	8.1274	9.3323	0.8709	0.5090	11.9786	0.0425	-2.8052	14.4778	-0.1938	0.9556	15.9845	0.0598	3.1421	17.4867	0.1797	6.2047	18.6393	0.3329	4.7768	19.5372	0.2445
Next Place: lax	6.0603	5.6127	1.0797	6.6310	7.2157	0.9190	10.3264	8.6739	1.1905	12.9789	9.5687	1.3564	19.4852	10.4841	1.8586	27.2981	11.1933	2.4388	38.6070	11.7387	3.2889
Next Place: palatal	14.5082	7.4754	1.9408	19.9319	9.7419	2.0460	16.5173	12.0593	1.3697	9.1502	13.4102	0.6823	9.5426	14.6322	0.6522	15.4426	15.5546	0.9928	19.7860	16.2765	1.2156
Next Place: palato-alveolar	-8.9578	16.1344	-0.5552	-16.7482	20.6196	-0.8122	-16.9018	24.6523	-0.6856	-19.4582	27.0834	-0.7185	-19.1740	29.6727	-0.6462	-21.2177	31.6742	-0.6699	-21.9785	33.2322	-0.6614
Next Place: tense	-12.3610	23.1131	-0.5348	-26.6724	29.4639	-0.9053	-36.3131	35.2125	-1.0313	-43.2212	38.6785	-1.1174	-41.0824	42.3822	-0.9693	-15.1475	45.2432	-0.3348	41.1697	47.4714	0.8673
Next Manner: approximate	10.1218	8.2709	1.2238	9.3390	10.6173	0.8796	18.0335	12.7439	1.4151	19.8465	14.0300	1.4146	12.3995	15.3619	0.8072	6.6265	16.3922	0.4042	4.7694	17.1914	0.2774
Next Manner: flap	7.7122	3.5984	2.1432	10.3433	4.6251	2.2363	12.0280	5.5915	2.1511	10.4749	6.1770	1.6958	10.4646	6.7607	1.5479	12.4419	7.2105	1.7255	13.5279	7.5587	1.7897
Next Manner: fricative	-0.3315	6.9402	-0.0478	2.5950	8.8790	0.2923	3.5037	10.6174	0.3300	0.8856	11.6757	0.0758	2.0247	12.7936	0.1583	3.0638	13.6621	0.2243	4.2329	14.3320	0.2953
Next Manner: nasal	7.3755	6.4665	1.1406	8.7369	8.3436	1.0471	7.4795	10.1193	0.7391	-0.2129	11.1717	-0.0191	-0.9305	12.2023	-0.0763	0.3474	12.9939	0.0267	6.8299	13.6147	0.5017
Duration (log) x Frequency (log)	0.0360	0.0225	1.5995	0.0623	0.0309	2.0142	0.0914	0.0386	2.3653	0.0979	0.0441	2.2188	0.1255	0.0484	2.5941	0.1283	0.0518	2.4787	0.1298	0.0541	2.4007

ı F2

	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	-3.6358	59.2522	-0.0614	-57.4384	79.6188	-0.7214	-87.5774	98.4018	-0.8900	-107.3816	115.6668	-0.9284	-82.8114	130.4672	-0.6347	-41.7397	147.9964	-0.2820	-10.5677	166.2772	-0.0636
Tense: past	-16.1901	13.5309	-1.1965	-18.9132	18.0535	-1.0476	-22.5679	22.1182	-1.0203	-41.3632	25.8796	-1.5983	-62.3576	29.2103	-2.1348	-69.4109	33.1229	-2.0956	-77.8791	37.3384	-2.0858
NDL Cue Strength	12.4890	25.7047	0.4859	17.2252	34.2936	0.5023	25.4751	41.9155	0.6078	7.3047	48.9378	0.1493	26.3452	55.2146	0.4771	28.9731	62.5860	0.4629	35.5349	70.5478	0.5037
Duration (log)	0.2379	0.3369	0.7060	0.6982	0.4588	1.5218	0.8517	0.5715	1.4904	1.2397	0.6627	1.8706	1.6594	0.7342	2.2601	2.0687	0.8230	2.5134	2.6791	0.9009	2.9740
Frequency (log)	-3.2020	5.4928	-0.5829	-2.0316	7.4000	-0.2745	-2.9779	9.2316	-0.3226	0.7130	10.9897	0.0649	-1.3693	12.3967	-0.1105	0.4815	14.1002	0.0341	7.0874	15.7831	0.4490
Previous Voicing: voiceless	-16.3634	10.8114	-1.5135	-26.3461	14.5015	-1.8168	-31.1057	17.6924	-1.7581	-42.6532	20.5982	-2.0707	-54.1561	23.2100	-2.3333	-56.4662	26.2928	-2.1476	-51.7134	29.5722	-1.7487

Previous Place: glottal	7.4637	29.0778	0.2567	29.6701	38.9690	0.7614	69.2208	48.4404	1.4290	104.3934	57.6703	1.8102	142.8840	65.3146	2.1876	170.9413	74.3974	2.2977	193.7611	83.9573	2.3079
Previous Place: labial	87.9983	28.6672	3.0697	136.5974	38.5800	3.5406	200.8884	48.7422	4.1214	261.2225	58.6641	4.4528	263.5313	66.6064	3.9565	272.0801	75.9475	3.5825	268.7050	85.5721	3.1401
Previous Place: labio-dental	-6.9211	49.2389	-0.1406	-0.7269	65.6051	-0.0111	10.7659	79.5321	0.1354	51.9076	91.9158	0.5647	81.5985	103.4345	0.7889	87.3745	117.0118	0.7467	66.5452	132.0718	0.5039
Previous Place: lax	1.1219	61.9123	0.0181	25.4254	82.8731	0.3068	54.4322	101.6648	0.5354	74.7779	118.7525	0.6297	83.2751	134.0312	0.6213	52.7751	151.9367	0.3473	6.6312	171.4228	0.0387
Previous Place: palatal	5.8302	19.6091	0.2973	21.2143	26.2734	0.8074	44.9335	32.3277	1.3899	47.8905	37.9244	1.2628	63.7062	42.7951	1.4886	100.4145	48.5404	2.0687	128.7336	54.6349	2.3563
Previous Place: palato-alveolar	-19.6752	36.6169	-0.5373	-9.8236	49.0178	-0.2004	12.2967	59.8618	0.2054	4.3548	69.5613	0.0626	-11.2030	78.4960	-0.1427	-27.2287	88.9097	-0.3063	-63.1952	100.3708	-0.6296
Previous Place: tense	33.3147	61.9013	0.5382	83.6453	82.9833	1.0080	128.3374	102.0182	1.2580	164.9006	119.2960	1.3823	180.8928	134.6391	1.3435	161.1823	152.6372	1.0560	88.1665	172.1477	0.5122
Previous Manner: approximate	26.2904	60.6625	0.4334	71.0999	81.3674	0.8738	118.8786	100.0273	1.1885	156.8029	116.9134	1.3412	162.2042	131.9973	1.2288	108.6796	149.6366	0.7263	33.1406	168.8392	0.1963
Previous Manner: flap	12.3158	78.3590	0.1572	85.2207	104.7774	0.8133	124.6048	127.9807	0.9736	141.8613	148.8470	0.9531	149.8058	167.7445	0.8931	63.0769	189.9801	0.3320	-45.1686	214.2961	-0.2108
Previous Manner: fricative	11.2352	54.1548	0.2075	56.4531	72.5928	0.7777	89.1797	89.3614	0.9980	109.8297	104.5830	1.0502	105.7811	118.0808	0.8958	57.6341	133.8843	0.4305	-18.4752	151.0792	-0.1223
Previous Manner: nasal	-11.1211	62.4994	-0.1779	30.6447	83.8385	0.3655	65.6623	103.1419	0.6366	84.6533	120.6141	0.7019	84.3560	136.0812	0.6199	40.5807	154.2671	0.2631	-45.9208	173.9959	-0.2639
Previous Manner: stop	10.5154	57.4112	0.1832	52.3383	76.9256	0.6804	85.2746	94.5233	0.9022	126.4829	110.4257	1.1454	138.9049	124.5955	1.1148	83.5075	141.2231	0.5913	2.7977	159.3432	0.0176
Next Voicing: voiceless	6.1904	7.3776	0.8391	11.1532	9.8614	1.1310	12.5482	12.0047	1.0453	-0.8373	13.9415	-0.0601	-13.6944	15.6982	-0.8724	-23.8068	17.7703	-1.3397	-31.9781	20.0045	-1.5986
Next Place: dental	-25.2112	21.6201	-1.1661	-49.1494	28.8730	-1.7023	-66.0198	35.0585	-1.8831	-104.8192	40.5391	-2.5856	-136.4422	45.5861	-2.9931	-154.8100	51.5522	-3.0030	-143.6744	58.0818	-2.4737
Next Place: diphthong	9.0757	21.2722	0.4266	19.5765	28.3979	0.6894	13.6850	34.4813	0.3969	6.1761	39.8898	0.1548	0.3885	44.8706	0.0087	6.2943	50.7596	0.1240	34.2185	57.2168	0.5980
Next Place: glottal	4.0669	7.9568	0.5111	5.1945	10.6385	0.4883	-2.3933	12.9559	-0.1847	-22.0157	15.0476	-1.4631	-37.8056	16.9438	-2.2312	-46.7388	19.1802	-2.4368	-50.9803	21.5945	-2.3608
Next Place: labial	1.3349	11.8180	0.1130	-14.6743	15.8908	-0.9234	-19.9260	19.4466	-1.0247	-1.2847	22.6511	-0.0567	16.1045	25.5608	0.6300	43.9882	28.9673	1.5185	72.5823	32.6639	2.2221
Next Place: labio-dental	-22.8040	20.0326	-1.1383	-48.9880	26.7522	-1.8312	-66.4116	32.5924	-2.0376	-88.5162	37.8521	-2.3385	-101.6527	42.6264	-2.3847	-92.6798	48.2609	-1.9204	-62.8569	54.4137	-1.1552
Next Place: lax	15.0779	12.1189	1.2442	22.2745	16.1770	1.3769	21.2098	19.6421	1.0798	15.2247	22.7261	0.6699	4.2421	25.5500	0.1660	-4.9781	28.8919	-0.1723	-6.2894	32.5060	-0.1935
Next Place: palatal	-0.5244	16.0681	-0.0326	4.1902	21.5366	0.1946	12.0951	26.5850	0.4550	15.3361	31.2443	0.4908	11.5457	35.2811	0.3272	41.1100	40.0309	1.0270	62.4631	45.1111	1.3846
Next Place: palato-alveolar	-42.0414	34.6446	-1.2135	-63.1148	46.1844	-1.3666	-84.8128	55.9992	-1.5145	-90.3121	64.6868	-1.3961	-95.9499	72.7680	-1.3186	-106.5477	82.2955	-1.2947	-117.1472	92.8566	-1.2616
Next Place: tense	58.5892	49.4991	1.1836	53.9695	65.9010	0.8189	42.2284	79.8528	0.5288	18.2252	92.2202	0.1976	-4.4571	103.7494	-0.0430	-56.4477	117.3317	-0.4811	-168.3821	132.4120	-1.2717
Next Manner: approximate	-8.9170	17.7870	-0.5013	3.3972	23.7823	0.1428	9.5208	28.9337	0.3291	21.7181	33.5157	0.6480	35.4844	37.7237	0.9406	93.9230	42.6857	2.2003	148.1715	48.1190	3.0793
Next Manner: flap	4.6665	7.7312	0.6036	6.9554	10.3239	0.6737	7.2344	12.5655	0.5757	-3.2083	14.5944	-0.2198	-12.0381	16.4350	-0.7325	-13.6762	18.6057	-0.7351	-8.9279	20.9490	-0.4262
Next Manner: fricative	27.3688	14.9103	1.8356	58.5335	19.8994	2.9415	76.5452	24.1395	3.1710	96.7281	27.8695	3.4707	102.7319	31.3288	3.2792	104.9414	35.4160	2.9631	101.4972	39.9203	2.5425
Next Manner: nasal	6.1423	13.7700	0.4461	13.3863	18.5043	0.7234	8.3454	22.7163	0.3674	-9.7747	26.5328	-0.3684	-11.7695	29.9595	-0.3928	-11.6424	33.9654	-0.3428	6.3841	38.3024	0.1667
Duration (log) x Frequency (log)	0.0690	0.0520	1.3268	0.0534	0.0705	0.7570	0.0812	0.0875	0.9279	0.0573	0.1017	0.5636	0.0237	0.1130	0.2098	-0.0131	0.1270	-0.1030	-0.0711	0.1397	-0.5093

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Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	-55.8257	27.7957	-2.0084	-66.7636	38.2270	-1.7465	-68.8500	45.3280	-1.5189	-76.0781	49.9361	-1.5235	-73.8627	55.0104	-1.3427	-41.9303	57.4313	-0.7301	42.8766	60.4973	0.7087
Tense: past	11.8996	7.8442	1.5170	15.8671	10.5168	1.5087	19.3903	12.6392	1.5341	18.9894	14.1474	1.3423	15.8390	15.3407	1.0325	0.9082	15.9811	0.0568	-27.1089	16.5595	-1.6371
NDL Cue Strength	-6.4848	17.4584	-0.3714	-11.8460	23.2604	-0.5093	-12.1588	28.1451	-0.4320	-24.3890	31.6867	-0.7697	-36.6083	34.0836	-1.0741	-22.7400	35.3841	-0.6427	22.7217	36.3808	0.6246
Duration (log)	0.7191	0.2076	3.4632	1.0069	0.2749	3.6624	0.9041	0.3329	2.7161	0.7889	0.3722	2.1192	0.3409	0.4013	0.8496	0.0823	0.4143	0.1986	0.0059	0.4277	0.0138
Frequency (log)	5.0403	5.0476	0.9985	8.3317	6.8870	1.2098	8.0638	8.2199	0.9810	8.2414	9.1191	0.9038	7.4405	10.0350	0.7415	1.4493	10.4849	0.1382	-12.3447	10.9910	-1.1232
Previous Voicing: voiceless	-8.0450	13.8473	-0.5810	-21.5611	18.3374	-1.1758	-35.6408	22.0870	-1.6137	-39.7587	24.8437	-1.6004	-46.0484	26.7362	-1.7223	-55.0507	27.8131	-1.9793	-67.3417	28.5916	-2.3553
Previous Place: glottal	30.8931	24.3482	1.2688	35.6274	32.9146	1.0824	48.4675	39.2361	1.2353	71.0107	43.6301	1.6276	111.5332	47.5889	2.3437	140.0760	49.6158	2.8232	159.7889	51.5889	3.0973
Previous Place: labial	11.7690	11.5808	1.0163	9.8446	15.7515	0.6250	17.5990	18.8550	0.9334	29.6894	20.9658	1.4161	46.4587	22.9495	2.0244	51.7655	23.9408	2.1622	39.8071	24.9958	1.5925
Previous Place: labio-dental	-15.6829	22.4221	-0.6994	-21.1946	30.4684	-0.6956	-3.6937	36.3046	-0.1017	20.2874	40.3080	0.5033	50.8787	44.1721	1.1518	75.3066	46.0957	1.6337	70.6373	48.1086	1.4683
Previous Place: lax	11.5733	23.8046	0.4862	8.1948	31.3907	0.2611	7.8301	38.0653	0.2057	-3.0513	42.9210	-0.0711	-23.4936	46.1165	-0.5094	-24.7535	47.8822	-0.5170	-14.8989	49.1991	-0.3028
Previous Place: palatal	-18.0930	17.5236	-1.0325	-20.6624	23.2786	-0.8876	-22.4184	28.1182	-0.7973	-18.2247	31.6478	-0.5759	-30.4189	34.0721	-0.8928	-35.5862	35.4305	-1.0044	-40.2747	36.4836	-1.1039
Previous Place: tense	-20.2009	35.9928	-0.5612	-38.0923	47.7437	-0.7979	-44.2128	57.9971	-0.7623	-40.0564	65.6863	-0.6098	-46.4466	70.4155	-0.6596	-46.4495	73.2421	-0.6342	-25.1756	75.2300	-0.3346
Previous Manner: fricative	20.6110	20.3740	1.0116	40.6442	27.0945	1.5001	55.0279	32.5778	1.6891	58.3039	36.5771	1.5940	63.3494	39.3718	1.6090	58.5624	40.9334	1.4307	43.5776	42.1554	1.0337
Previous Manner: nasal	11.5818	11.6042	0.9981	26.4180	15.6869	1.6841	24.5280	18.8161	1.3036	17.2577	20.9857	0.8224	-1.3170	22.9029	-0.0575	-2.4104	23.8747	-0.1010	8.0955	24.8403	0.3259
Previous Manner: stop	17.3173	14.6463	1.1824	27.2036	19.4614	1.3978	40.8120	23.4964	1.7369	44.7396	26.4500	1.6915	49.0919	28.4639	1.7247	51.3894	29.6147	1.7353	59.3748	30.5150	1.9458
Next Voicing: voiceless	8.9359	8.9334	1.0003	13.0561	11.8079	1.1057	3.7582	14.3003	0.2628	-1.1738	16.1223	-0.0728	-8.4318	17.2811	-0.4879	-13.7148	17.9209	-0.7653	-32.1092	18.3794	-1.7470
Next Place: dental	12.2180	23.9840	0.5094	17.6406	31.6866	0.5567	6.3296	38.6397	0.1638	-13.8034	43.6929	-0.3159	-41.8987	47.0754	-0.8900	-65.5786	48.9667	-1.3392	-117.2571	50.3099	-2.3307
Next Place: diphthong	-2.6377	19.7345	-0.1337	-21.4611	26.1401	-0.8210	-9.6687	31.7073	-0.3049	13.2443	35.7939	0.3700	35.2199	38.6965	0.9102	56.3036	40.3475	1.3955	73.9894	41.5876	1.7791
Next Place: glottal	6.3914	9.0085	0.7095	8.0358	11.8980	0.6754	-2.3434	14.4000	-0.1627	-4.6848	16.2316	-0.2886	-3.6247	17.3965	-0.2084	-0.9887	18.0390	-0.0548	-12.5397	18.4953	-0.6780
Next Place: labial	3.3491	14.6583	0.2285	9.9765	19.3838	0.5147	20.1312	23.4143	0.8598	27.9820	26.3582	1.0616	42.2944	28.4729	1.4854	60.4260	29.6726	2.0364	79.6267	30.5595	2.6056
Next Place: labio-dental	29.4894	34.3667	0.8581	28.4492	45.6128	0.6237	5.2493	55.1461	0.0952	-14.4072	62.0947	-0.2320	-26.3833	66.7461	-0.3953	-49.1778	69.2683	-0.7100	-114.4416	71.1295	-1.6089
Next Place: lax	1.9582	14.9223	0.1312	-12.8903	19.9079	-0.6475	-6.5339	24.0957	-0.2712	15.4786	27.1364	0.5704	45.9686	29.2313	1.5726	64.2035	30.4053	2.1116	80.7127	31.3408	2.5753
Next Place: palatal	8.7444	18.9746	0.4608	25.9640	25.0085	1.0382	24.9435	30.3063	0.8230	31.0828	34.2148	0.9085	34.0107	36.7210	0.9262	16.2050	38.1635	0.4246	-18.7015	39.1486	-0.4777
Next Manner: flap	8.9732	11.6886	0.7677	-1.0374	15.6362	-0.0663	10.1412	18.8014	0.5394	26.9374	21.0614	1.2790	46.4634	22.8841	2.0304	62.0951	23.8600	2.6025	70.6860	24.6929	2.8626
Next Manner: fricative	-21.4695	23.2770	-0.9223	-22.3894	30.7973	-0.7270	5.7412	37.6364	0.1525	25.9750	42.5956	0.6098	55.3909	45.9523	1.2054	80.0743	47.8154	1.6747	119.4183	49.1428	2.4300
Next Manner: nasal	15.5593	13.5780	1.1459	11.0135	18.3424	0.6004	27.8358	21.9908	1.2658	39.1919	24.5173	1.5985	52.9458	26.7979	1.9757	55.4993	27.9507	1.9856	48.3216	29.0807	1.6616
Next Manner: stop	0.8750	13.2797	0.0659	-12.4297	17.6826	-0.7029	2.0587	21.2931	0.0967	17.4298	23.8867	0.7297	37.4213	25.8485	1.4477	53.0639	26.9038	1.9724	79.2045	27.7656	2.8526
Duration (log) x Frequency (log)	-0.0198	0.0330	-0.6009	-0.0237	0.0437	-0.5430	0.0137	0.0532	0.2577	0.0452	0.0599	0.7546	0.1247	0.0647	1.9261	0.1624	0.0671	2.4208	0.1479	0.0692	2.1377

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Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	-6.7180	35.8512	-0.1874	114.8177	49.2184	2.3328	211.7884	62.9711	3.3633	318.4365	75.7389	4.2044	382.5360	86.4657	4.4241	423.1470	95.2839	4.4409	447.2034	102.1333	4.3786
Tense: past	-29.1454	11.0929	-2.6274	-56.8061	15.3091	-3.7106	-77.9556	18.9970	-4.1036	-98.2100	21.8495	-4.4948	-123.7654	24.6023	-5.0307	-137.4435	27.5925	-4.9812	-137.6502	30.7178	-4.4811
NDL Cue Strength	50.0435	24.8249	2.0159	89.9105	34.6012	2.5985	121.8685	42.7722	2.8492	139.3497	48.8097	2.8550	158.5993	54.8630	2.8908	153.2426	61.6409	2.4861	123.2387	69.4027	1.7757
Duration (log)	1.6863	0.2527	6.6742	1.5004	0.3507	4.2779	1.3863	0.4348	3.1882	1.0924	0.5094	2.1443	0.8017	0.5754	1.3933	0.7620	0.6262	1.2169	0.7549	0.6927	1.0897
Frequency (log)	-0.6134	6.6512	-0.0922	-16.2364	9.1636	-1.7718	-27.1572	11.6957	-2.3220	-35.4425	13.9917	-2.5331	-41.8466	15.9249	-2.6278	-44.0651	17.5796	-2.5066	-43.6537	18.9653	-2.3018
Previous Voicing: voiceless	-17.0322	20.0065	-0.8513	-42.7157	27.6522	-1.5448	-76.2998	33.9165	-2.2496	-93.9633	38.4034	-2.4467	-109.4181	43.0287	-2.5429	-131.3852	48.4097	-2.7140	-160.9500	54.6548	-2.9448
Previous Place: glottal	35.4011	33.5869	1.0540	75.8654	46.1811	1.6428	128.4149	58.0170	2.2134	167.7469	67.8589	2.4720	252.2360	76.7724	3.2855	299.4460	85.4841	3.5029	320.5550	93.7694	3.4185
Previous Place: labial	31.2466	15.8663	1.9694	43.5644	21.8954	1.9897	52.6202	27.7104	1.8989	35.2483	32.7424	1.0765	35.4102	37.1859	0.9522	26.8864	41.3433	0.6503	10.6431	45.0095	0.2365
Previous Place: labio-dental	-43.8672	30.2955	-1.4480	-57.4010	41.6727	-1.3774	-60.4573	52.5119	-1.1513	-59.5319	62.2072	-0.9570	-36.5108	70.7155	-0.5163	-52.8514	78.0325	-0.6773	-86.7530	84.7413	-1.0237
Previous Place: lax	32.2897	33.6170	0.9605	9.8856	46.7051	0.2117	-28.0153	57.4642	-0.4875	-70.6849	65.1675	-1.0847	-105.1640	73.0019	-1.4406	-130.1510	82.2003	-1.5833	-143.9832	92.9598	-1.5489
Previous Place: palatal	-1.9386	25.1134	-0.0772	11.9216	34.7606	0.3430	30.3068	42.8487	0.7073	41.7040	48.6851	0.8566	48.0482	54.5880	0.8802	61.5318	61.5151	1.0003	85.1969	69.3409	1.2287
Previous Place: tense	19.7415	53.1631	0.3713	23.7217	74.1118	0.3201	17.5138	91.3260	0.1918	17.0670	103.0593	0.1656	35.4051	115.3617	0.3069	61.2292	131.0645	0.4672	93.7587	149.1866	0.6285
Previous Manner: fricative	-14.8858	29.2750	-0.5085	-26.3064	40.4676	-0.6501	-25.2210	49.7667	-0.5068	-32.7064	56.5420	-0.5784	-36.3128	63.4617	-0.5722	-7.4225	71.4585	-0.1039	42.4039	80.4752	0.5269
Previous Manner: nasal	-20.6862	16.0850	-1.2861	-34.8566	22.2062	-1.5697	-56.6251	27.8755	-2.0314	-59.5360	32.6446	-1.8238	-68.0006	36.9810	-1.8388	-65.4816	41.1843	-1.5900	-53.5272	45.1911	-1.1845
Previous Manner: stop	20.7239	21.2429	0.9756	19.3472	29.3888	0.6583	18.3222	36.1470	0.5069	21.1342	40.9351	0.5163	31.9844	45.8551	0.6975	49.6200	51.8271	0.9574	67.1870	58.5253	1.1480
Next Voicing: voiceless	-6.5941	12.6733	-0.5203	-21.2022	17.6365	-1.2022	-31.1198	21.6905	-1.4347	-28.3348	24.6095	-1.1514	-36.0767	27.5941	-1.3074	-39.5247	31.0472	-1.2731	-38.8707	35.1380	-1.1062
Next Place: dental	16.1325	34.6732	0.4653	10.0263	48.2131	0.2080	16.5632	59.5786	0.2780	79.3821	67.6967	1.1726	90.1214	75.8565	1.1881	99.9420	85.4424	1.1697	125.1379	96.4635	1.2973
Next Place: diphthong	-18.8247	28.6550	-0.6569	-33.4184	39.7192	-0.8414	-30.5745	49.0857	-0.6229	-65.4982	55.9265	-1.1711	-68.3411	62.7121	-1.0898	-48.8478	70.6696	-0.6912	-43.1407	79.5164	-0.5425
Next Place: glottal	-3.0447	12.7463	-0.2389	-14.9201	17.7298	-0.8415	-23.4648	21.7998	-1.0764	-20.6506	24.7302	-0.8350	-27.5594	27.7289	-0.9939	-29.2495	31.1982	-0.9375	-31.2301	35.3168	-0.8843
Next Place: labial	10.4270	21.1266	0.4936	39.9949	29.2276	1.3684	76.5203	35.9449	2.1288	119.0818	40.8412	2.9157	156.6143	45.7822	3.4209	186.6121	51.4205	3.6291	227.8885	57.8991	3.9360
Next Place: labio-dental	74.6941	48.7559	1.5320	47.6136	67.8180	0.7021	15.7696	83.7398	0.1883	71.7975	95.5635	0.7513	118.4022	107.4087	1.1024	237.8652	120.5428	1.9733	304.0214	135.7095	2.2402
Next Place: lax	5.3132	21.5265	0.2468	0.5484	29.9483	0.0183	-8.8352	37.0540	-0.2384	-24.9467	42.2164	-0.5909	-11.5372	47.4111	-0.2433	-12.2362	53.4899	-0.2288	-25.7779	60.2373	-0.4279
Next Place: palatal	-34.2451	27.5156	-1.2446	-43.6022	38.1619	-1.1426	-33.0277	46.7049	-0.7072	-39.7175	52.5960	-0.7551	-73.0101	58.8131	-1.2414	-119.9081	66.3612	-1.8069	-143.1919	75.3760	-1.8997
Next Manner: flap	-1.3522	16.5027	-0.0819	-6.0885	22.8029	-0.2670	-10.3943	28.3428	-0.3667	-31.1873	32.7497	-0.9523	-30.3436	36.9225	-0.8218	-41.8768	41.2073	-1.0162	-67.9003	45.7521	-1.4841
Next Manner: fricative	-15.0774	33.5657	-0.4492	-27.2141	46.7616	-0.5820	-26.9052	58.0003	-0.4639	-82.1148	66.1576	-1.2412	-91.1107	74.2071	-1.2278	-120.7683	83.4833	-1.4466	-156.8707	93.9989	-1.6689
Next Manner: nasal	12.8807	18.7976	0.6852	2.4350	25.9331	0.0939	-0.5108	32.5450	-0.0157	-42.0128	38.2490	-1.0984	-61.6625	43.3925	-1.4210	-68.7598	48.1145	-1.4291	-78.2867	52.6478	-1.4870
Next Manner: stop	-1.7565	18.6524	-0.0942	3.7675	25.8041	0.1460	3.8151	31.9665	0.1193	-25.4640	36.7495	-0.6929	-16.3252	41.3564	-0.3947	-26.7247	46.2254	-0.5781	-48.2906	51.6007	-0.9359
Duration (log) x Frequency (log)	-0.1626	0.0423	-3.8491	-0.0930	0.0588	-1.5802	-0.0506	0.0730	-0.6923	0.0110	0.0850	0.1292	0.0617	0.0958	0.6439	0.0710	0.1052	0.6752	0.0708	0.1170	0.6052

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Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	145.8745	325.1178	0.4487	81.2514	449.4500	0.1808	-481.0810	535.9399	-0.8976	-701.3513	642.0672	-1.0923	-656.6854	632.2347	-1.0387	-378.3014	651.8699	-0.5803	70.7587	634.8864	0.1115
Tense: past	-101.2602	156.3233	-0.6478	-118.5461	215.3093	-0.5506	95.6626	253.5106	0.3774	191.9615	305.9392	0.6274	149.3406	299.4446	0.4987	-2.2713	308.0536	-0.0074	-225.4349	298.6291	-0.7549
NDL Cue Strength	204.9350	277.2657	0.7391	154.5213	385.4753	0.4009	-202.4216	414.7219	-0.4881	-380.0530	512.6621	-0.7413	-394.1328	495.1982	-0.7959	-248.1813	506.9969	-0.4895	1.1185	486.8965	0.0023
Duration (log)	1.2213	0.5859	2.0846	1.6323	0.7913	2.0629	2.4580	1.1692	2.1023	2.4985	1.2472	2.0033	2.3800	1.2331	1.9301	2.1608	1.2964	1.6668	1.5686	1.3272	1.1819
Frequency (log)	-8.7838	56.2428	-0.1562	19.8562	77.7984	0.2552	131.7563	94.1747	1.3991	175.4708	111.5534	1.5730	170.0800	110.2002	1.5434	123.7972	113.9068	1.0868	54.2057	111.6173	0.4856
Previous Voicing: voiceless	-41.1120	89.7479	-0.4581	5.1525	125.7033	0.0410	148.8176	132.1212	1.1264	214.1702	158.2469	1.3534	214.8048	152.4498	1.4090	165.1609	156.1001	1.0580	91.4302	151.0093	0.6055
Previous Place: glottal	-89.4216	101.0088	-0.8853	-130.0449	135.9173	-0.9568	31.1243	177.5690	0.1753	105.1398	214.1969	0.4909	102.9444	213.1576	0.4829	20.7997	220.0179	0.0945	-121.6529	213.5756	-0.5696
Previous Place: labio-dental	63.1264	159.4229	0.3960	-14.2901	222.1913	-0.0643	-279.2865	237.0824	-1.1780	-390.3395	286.7546	-1.3612	-378.1691	277.6664	-1.3620	-304.1770	284.2982	-1.0699	-150.4311	274.0877	-0.5488
Next Voicing: voiceless	115.9411	47.4969	2.4410	131.4648	62.7065	2.0965	82.1335	67.7805	1.2118	93.9869	81.8479	1.1483	107.2256	81.4369	1.3167	111.7903	82.9803	1.3472	119.3350	78.5892	1.5185
Next Place: glottal	-9.5024	39.4651	-0.2408	-1.8521	51.2188	-0.0362	22.3472	63.7079	0.3508	31.9003	74.9275	0.4257	35.5676	76.0100	0.4679	43.7509	78.3532	0.5584	18.8749	76.1137	0.2480
Next Place: labio-dental	266.7177	44.7303	5.9628	246.3340	57.4182	4.2902	183.5059	65.0847	2.8195	176.4106	76.3574	2.3103	195.2700	75.5933	2.5832	173.8508	77.0055	2.2576	148.7574	73.6044	2.0210
Next Manner: stop	-11.1113	35.6029	-0.3121	-30.4706	45.9650	-0.6629	-73.1890	52.0585	-1.4059	-98.8138	62.1323	-1.5904	-110.3913	61.6448	-1.7908	-115.3881	62.7804	-1.8380	-105.8984	59.7877	-1.7712
Duration (log) x Frequency (log)	-0.2931	0.1831	-1.6011	-0.3942	0.2459	-1.6032	-0.6639	0.3567	-1.8613	-0.6913	0.3858	-1.7918	-0.5982	0.3822	-1.5650	-0.4643	0.4014	-1.1567	-0.3050	0.4093	-0.7450

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Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	567.6983	370.6707	1.5315	1081.7976	647.5066	1.6707	1490.7592	1000.7834	1.4896	2172.8202	1283.2704	1.6932	2406.7078	1416.2405	1.6994	3084.8123	1497.3144	2.0602	3639.8706	1472.8624	2.4713
Tense: past	-364.2946	178.7774	-2.0377	-645.7211	313.2485	-2.0614	-824.6989	483.1368	-1.7070	-1152.5639	619.1893	-1.8614	-1295.2161	681.2574	-1.9012	-1740.8302	720.0754	-2.4176	-2080.8053	708.0970	-2.9386
NDL Cue Strength	345.0756	309.7319	1.1141	660.4383	546.3304	1.2089	913.8631	844.8319	1.0817	1448.8293	1087.6411	1.3321	1628.3839	1204.5871	1.3518	2134.9344	1276.3676	1.6727	2733.0246	1241.0717	2.2021
Duration (log)	0.5160	0.9000	0.5733	0.7685	1.5405	0.4989	0.5686	2.3242	0.2446	0.7604	2.8571	0.2662	0.9198	2.9331	0.3136	1.5244	2.8756	0.5301	2.5647	2.8508	0.8997
Frequency (log)	-79.2118	64.6274	-1.2257	-148.5709	112.7691	-1.3175	-214.6435	174.2384	-1.2319	-327.2879	223.3721	-1.4652	-348.7305	246.3049	-1.4158	-400.2624	259.8140	-1.5406	-445.9570	255.8548	-1.7430
Previous Voicing: voiceless	-135.9616	105.0688	-1.2940	-287.7198	183.8940	-1.5646	-408.3238	285.7802	-1.4288	-591.7423	367.2567	-1.6113	-611.3634	406.1646	-1.5052	-711.2162	423.4887	-1.6794	-820.0978	407.9857	-2.0101
Previous Place: glottal	-281.4903	112.9022	-2.4932	-479.8363	195.8641	-2.4498	-588.3095	299.1724	-1.9665	-768.8580	382.6839	-2.0091	-875.1073	418.3076	-2.0920	-1228.2583	450.0292	-2.7293	-1457.9212	455.4775	-3.2009
Previous Place: labio-dental	184.5378	183.6073	1.0051	368.1888	321.8369	1.1440	516.8968	499.0361	1.0358	842.7447	641.3623	1.3140	910.3504	709.0682	1.2839	1103.1748	743.6879	1.4834	1292.8470	720.8585	1.7935
Next Voicing: voiceless	65.2614	48.5971	1.3429	67.4486	80.4529	0.8384	18.1654	123.2191	0.1474	-4.8274	161.8842	-0.0298	-41.0406	180.3566	-0.2276	-11.6255	199.3815	-0.0583	69.3594	202.9537	0.3417

Next Place: glottal	11.7309	39.7658	0.2950	36.4354	68.9282	0.5286	21.6993	105.7859	0.2051	25.4770	138.5504	0.1839	3.0264	153.8354	0.0197	-15.3523	170.1570	-0.0902	-34.8286	178.4678	-0.1952
Next Place: labio-dental	-2.4088	43.8881	-0.0549	-43.6540	72.5010	-0.6021	-19.3778	110.7098	-0.1750	-2.2713	146.6091	-0.0155	-14.5625	163.3980	-0.0891	7.8118	182.4124	0.0428	37.0172	188.9174	0.1959
Next Manner: stop	-11.7038	35.4496	-0.3302	-14.8326	59.7489	-0.2482	-5.0679	91.8439	-0.0552	14.7313	120.8126	0.1219	15.3274	134.6411	0.1138	14.3949	148.2665	0.0971	6.3911	152.7295	0.0418
Duration (log) x Frequency (log)	0.1740	0.2635	0.6602	0.2683	0.4714	0.5690	0.4449	0.7064	0.6298	0.5024	0.8780	0.5722	0.4163	0.9034	0.4608	0.0077	0.9051	0.0085	-0.5862	0.9119	-0.6429

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Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	-59.8692	48.9554	-1.2229	-99.6663	70.9696	-1.4044	-140.6498	88.0492	-1.5974	-148.3055	98.6761	-1.5030	-132.5125	104.2172	-1.2715	-76.4096	112.0253	-0.6821	-45.4584	118.1530	-0.3847
Tense: past	-2.3152	16.4142	-0.1411	11.1052	24.0465	0.4618	25.7838	29.8138	0.8648	31.4217	33.7057	0.9322	27.2171	35.7515	0.7613	23.6821	38.4918	0.6152	11.0067	40.6022	0.2711
NDL Cue Strength	15.8565	37.8935	0.4184	-12.5954	55.6589	-0.2263	-22.1944	68.7838	-0.3227	-41.4500	77.5042	-0.5348	-46.9297	82.4171	-0.5694	-58.3252	89.3289	-0.6529	-32.9726	94.4503	-0.3491
Duration (log)	0.5619	0.2206	2.5471	0.8107	0.3033	2.6730	1.0668	0.3854	2.7682	0.9815	0.4300	2.2824	0.9979	0.4396	2.2699	0.8207	0.4519	1.8160	0.6977	0.4738	1.4724
Frequency (log)	-1.8435	7.3689	-0.2502	3.0625	10.5854	0.2893	6.5332	13.1211	0.4979	9.2177	14.8106	0.6224	7.9594	15.6899	0.5073	4.6285	16.8622	0.2745	-0.4623	17.7823	-0.0260
Previous Voicing: voiceless	-2.7144	16.8430	-0.1612	-0.1872	24.6008	-0.0076	9.2608	30.3475	0.3052	19.6832	34.0373	0.5783	21.2576	36.2166	0.5870	27.3159	39.3590	0.6940	46.2224	41.6201	1.1106
Previous Place: dental	-51.1676	43.1642	-1.1854	-40.6957	63.0223	-0.6457	-35.2168	78.3390	-0.4495	2.2366	89.2060	0.0251	36.2935	94.5383	0.3839	67.9587	101.0818	0.6723	92.3795	106.5081	0.8673
Previous Place: diphthong	5.3969	33.1130	0.1630	-6.2764	48.4374	-0.1296	-13.3416	59.7256	-0.2234	-12.7305	66.6621	-0.1910	6.1242	70.8544	0.0864	22.6258	77.0035	0.2938	41.6030	81.3907	0.5112
Previous Place: glottal	-78.2519	29.6055	-2.6432	-88.1553	43.0208	-2.0491	-84.3552	53.7208	-1.5703	-60.7362	61.9614	-0.9802	-31.3966	65.5114	-0.4793	6.3560	69.0739	0.0920	24.2358	72.6795	0.3335
Previous Place: labial	5.5555	15.6267	0.3555	-4.2151	22.8831	-0.1842	-13.4077	28.4096	-0.4719	-11.3378	32.1373	-0.3528	-3.2808	34.0179	-0.0964	-4.3845	36.4211	-0.1204	2.5773	38.3476	0.0672
Previous Place: labio-dental	-44.6855	33.9766	-1.3152	-47.6401	49.6117	-0.9603	-46.1429	61.7943	-0.7467	-38.4498	70.0600	-0.5488	-35.1645	73.9254	-0.4757	-25.2386	78.6104	-0.3211	-16.4363	82.7278	-0.1987
Previous Place: lax	0.5115	41.4067	0.0124	-10.6414	60.6415	-0.1755	-8.7945	75.1900	-0.1170	-27.2484	84.0120	-0.3243	-42.7468	88.8216	-0.4813	-47.5419	95.9132	-0.4957	-23.1041	101.1029	-0.2285
Previous Place: palatal	3.9776	16.0322	0.2481	-0.4393	23.2351	-0.0189	-9.7347	28.7530	-0.3386	-19.3359	32.5084	-0.5948	-14.7821	34.5106	-0.4283	1.3371	37.1916	0.0360	17.8018	39.3102	0.4529
Previous Manner: diphthong	45.8228	46.5913	0.9835	55.0481	67.6709	0.8135	35.9701	83.4075	0.4313	38.8741	92.8084	0.4189	1.0278	98.6461	0.0104	-33.6876	107.2802	-0.3140	-47.8874	113.2236	-0.4229
Previous Manner: flap	43.1115	41.1557	1.0475	17.9860	60.2408	0.2986	14.9107	74.5122	0.2001	25.4371	83.5117	0.3046	55.4183	88.6759	0.6250	96.1241	96.1065	1.0002	125.1000	101.3822	1.2339
Previous Manner: fricative	43.9150	25.4015	1.7288	35.5803	37.3164	0.9535	18.2180	46.2387	0.3940	1.2767	52.6670	0.0242	-13.6447	55.9352	-0.2439	-38.6749	60.0769	-0.6438	-49.4459	63.5613	-0.7779
Previous Manner: lax	-4.3662	44.3782	-0.0984	-11.4948	64.6569	-0.1778	-14.1885	80.4480	-0.1764	5.4313	89.6170	0.0606	27.4684	94.2499	0.2914	64.2676	101.1913	0.6351	44.6828	106.5185	0.4195
Previous Manner: nasal	21.4964	20.7048	1.0382	24.6672	29.9308	0.8241	24.8275	37.0167	0.6707	19.5365	41.6041	0.4696	18.2326	44.1432	0.4130	27.9533	47.6893	0.5862	34.7061	50.3933	0.6887
Previous Manner: stop	8.5350	16.1714	0.5278	13.4539	23.6256	0.5695	15.5601	29.2331	0.5323	25.0305	32.9379	0.7599	25.7983	34.9853	0.7374	18.6390	37.8180	0.4929	8.3009	39.9039	0.2080
Next Voicing: voiceless	12.9514	14.2593	0.9083	20.2953	20.8990	0.9711	29.6867	25.8398	1.1489	22.2140	28.9850	0.7664	15.3842	30.7712	0.5000	22.2463	33.3590	0.6669	24.9418	35.2373	0.7078
Next Place: dental	25.6923	24.8936	1.0321	34.9747	36.4261	0.9602	52.2358	45.1037	1.1581	42.8516	50.5084	0.8484	29.4763	53.5174	0.5508	31.3459	57.9322	0.5411	32.5139	61.1533	0.5317
Next Place: diphthong	37.3565	39.6837	0.9414	55.0939	58.1416	0.9476	109.9604	71.8902	1.5296	125.8183	80.0753	1.5713	136.5227	84.8403	1.6092	113.1588	91.9891	1.2301	112.8838	97.0803	1.1628
Next Place: glottal	15.4915	13.5880	1.1401	22.1881	19.8559	1.1175	27.3529	24.5586	1.1138	22.8471	27.4427	0.8325	21.5487	29.0942	0.7407	35.2110	31.5246	1.1169	47.7600	33.2639	1.4358
Next Place: labial	0.9006	12.0793	0.0746	-8.3614	17.7071	-0.4722	-13.9084	21.8257	-0.6372	-30.0523	24.4494	-1.2292	-28.6610	26.0282	-1.1012	-30.1160	28.3365	-1.0628	-31.1905	29.9847	-1.0402
Next Place: labio-dental	-7.5867	26.4723	-0.2866	-6.4632	38.7486	-0.1668	2.4145	47.9100	0.0504	-0.5957	53.6580	-0.0111	-0.5128	56.9586	-0.0090	21.1295	61.7185	0.3424	22.9359	65.1298	0.3522
Next Place: lax	45.1276	38.3818	1.1758	70.2884	56.2440	1.2497	110.3660	69.6426	1.5847	119.5957	77.5169	1.5428	128.5484	81.9875	1.5679	99.8903	88.7112	1.1260	95.8805	93.5484	1.0249
Next Place: palatal	15.6974	14.7183	1.0665	7.0792	21.3535	0.3315	-9.4558	26.4336	-0.3577	-24.0403	29.6901	-0.8097	-34.3362	31.4776	-1.0908	-41.0768	34.0206	-1.2074	-36.7453	35.9220	-1.0229
Next Place: palato-alveolar	34.0757	23.6136	1.4431	34.0490	34.5214	0.9863	39.4644	42.6056	0.9263	41.8460	47.6260	0.8786	39.7534	50.6392	0.7850	43.7960	55.1471	0.7942	53.0641	58.2933	0.9103
Next Place: tense	59.3661	42.7485	1.3887	84.7988	62.3716	1.3596	118.3467	77.1039	1.5349	125.4425	85.7603	1.4627	126.8157	90.8165	1.3964	85.3524	98.4143	0.8673	71.2837	103.8813	0.6862
Next Manner: approximate	44.7081	40.5832	1.1016	74.9126	59.3852	1.2615	120.5544	73.4737	1.6408	146.7237	81.7332	1.7952	157.5813	86.4759	1.8223	124.8287	93.5812	1.3339	113.6523	98.7102	1.1514
Next Manner: flap	56.4104	40.4999	1.3929	80.1625	59.2183	1.3537	117.7902	73.3097	1.6067	134.8203	81.6155	1.6519	143.9389	86.3379	1.6672	124.0460	93.4038	1.3281	125.7329	98.5026	1.2764
Next Manner: fricative	31.1060	34.8847	0.8917	43.0725	51.1347	0.8423	63.1325	63.3869	0.9960	79.1031	70.3753	1.1240	94.9362	74.2658	1.2783	50.2570	80.0977	0.6274	42.3911	84.3519	0.5026
Next Manner: nasal	60.5419	39.6859	1.5255	91.0728	58.0568	1.5687	128.3942	71.8660	1.7866	140.9022	80.0082	1.7611	136.1327	84.6294	1.6086	99.1224	91.5242	1.0830	86.7019	96.5340	0.8981
Next Manner: stop	30.2261	36.4689	0.8288	49.8815	53.3496	0.9350	78.2519	66.0660	1.1844	99.1084	73.4395	1.3495	109.9291	77.6209	1.4162	78.3484	83.9132	0.9337	61.0774	88.4532	0.6905
Duration (log) x Frequency (log)	-0.0072	0.0385	-0.1863	-0.0245	0.0531	-0.4614	-0.0637	0.0671	-0.9504	-0.0563	0.0751	-0.7503	-0.0668	0.0773	-0.8639	-0.0459	0.0802	-0.5717	-0.0293	0.0842	-0.3478

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Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	-30.4627	51.0437	-0.5968	-48.7073	75.4232	-0.6458	-64.7263	99.0617	-0.6534	-68.8676	124.1632	-0.5547	26.8229	147.1748	0.1823	55.3423	167.9568	0.3295	96.6796	186.9367	0.5172
Tense: past	-3.8579	17.1173	-0.2254	-12.7473	25.7811	-0.4944	-14.3739	33.9724	-0.4231	-12.3964	42.5409	-0.2914	-35.7256	50.8597	-0.7024	-56.8857	58.1571	-0.9781	-78.5461	64.9243	-1.2098
NDL Cue Strength	40.1093	40.0371	1.0018	32.4111	60.4329	0.5363	22.8160	79.8483	0.2857	-9.3552	100.0160	-0.0935	18.9294	119.2167	0.1588	35.5986	136.4386	0.2609	56.4032	152.1612	0.3707
Duration (log)	1.2922	0.2362	5.4718	1.7308	0.3450	5.0176	2.0435	0.4555	4.4857	2.3240	0.5741	4.0480	2.3493	0.6444	3.6460	2.5560	0.7266	3.5176	2.7362	0.8056	3.3963
Frequency (log)	1.1665	7.6656	0.1522	0.2813	11.4598	0.0245	1.3762	15.1409	0.0909	8.9734	18.9716	0.4730	0.9352	22.5380	0.0415	-4.9850	25.7821	-0.1934	-9.2583	28.8085	-0.3214
Previous Voicing: voiceless	-5.0327	17.7189	-0.2840	-17.3159	26.5487	-0.6522	-26.5830	35.0562	-0.7583	-51.1068	43.9079	-1.1640	-57.2944	52.3638	-1.0942	-69.9573	59.9496	-1.1669	-77.4725	66.8183	-1.1594
Previous Place: dental	-61.7462	44.5357	-1.3864	-89.7547	67.0515	-1.3386	-93.4949	88.2277	-1.0597	-104.0013	110.5025	-0.9412	-141.4414	131.8738	-1.0726	-181.9467	150.6670	-1.2076	-195.0464	169.3373	-1.1518
Previous Place: diphthong	-0.4908	34.4130	-0.0143	7.6348	50.6037	0.1509	11.4602	66.4360	0.1725	-18.8976	83.1924	-0.2272	-32.2677	99.4620	-0.3244	-44.9083	113.7999	-0.3946	-49.8808	126.7716	-0.3935
Previous Place: glottal	11.2609	30.4380	0.3700	20.1310	45.9138	0.4385	39.5567	60.7254	0.6514	39.3097	76.0741	0.5167	66.1371	90.5053	0.7308	95.7610	103.6865	0.9236	124.2491	117.4255	1.0581
Previous Place: labial	40.0256	16.0198	2.4985	96.8675	23.9521	4.0442	132.6824	31.4292	4.2216	168.9534	39.3619	4.2923	206.8121	46.9986	4.4004	241.6142	53.6419	4.5042	270.4969	60.2214	4.4917
Previous Place: labio-dental	-31.3242	34.5710	-0.9061	-55.7740	51.4172	-1.0847	-53.4812	67.3865	-0.7936	-50.9214	84.4082	-0.6033	4.4189	100.6508	0.0439	55.0987	114.9233	0.4794	105.7631	129.1602	0.8189
Previous Place: lax	69.0474	43.2901	1.5950	58.5993	63.7329	0.9195	11.5941	83.3476	0.1391	-35.1023	104.3961	-0.3362	-36.6544	124.5677	-0.2943	-57.6852	142.0737	-0.4060	-61.1965	157.5848	-0.3883
Previous Place: palatal	21.2182	16.8224	1.2613	46.7726	25.2497	1.8524	74.3014	33.4212	2.2232	89.6928	41.8768	2.1418	112.4832	49.7348	2.2617	124.0604	56.9601	2.1780	128.7257	63.7636	2.0188

Previous Manner: diphthong	66.1693	48.0028	1.3784	103.2025	70.4693	1.4645	47.1057	92.4443	0.5096	-5.3614	115.7378	-0.0463	9.0670	138.6534	0.0654	42.1851	158.5335	0.2661	64.9853	176.0587	0.3691
Previous Manner: flap	-21.3676	43.1038	-0.4957	-0.9313	63.9375	-0.0146	17.1874	83.7991	0.2051	-9.6141	104.9322	-0.0916	-30.2607	125.5162	-0.2411	-49.9702	143.4049	-0.3485	-73.8922	159.3626	-0.4637
Previous Manner: fricative	8.5732	26.8913	0.3188	12.0951	40.6229	0.2977	9.6418	53.7986	0.1792	31.6177	67.3996	0.4691	24.7070	80.1401	0.3083	26.5639	91.8647	0.2892	33.7815	103.1120	0.3276
Previous Manner: lax	-70.5750	46.4129	-1.5206	-61.7941	67.4916	-0.9156	-33.9853	87.8519	-0.3868	-20.3680	110.1028	-0.1850	33.0539	130.6645	0.2530	107.7298	148.5850	0.7250	98.3427	164.2451	0.5988
Previous Manner: nasal	10.5199	21.6134	0.4867	25.2200	32.1096	0.7854	32.1808	42.3619	0.7597	15.0923	53.0759	0.2844	21.3308	63.1018	0.3380	29.8704	72.2239	0.4136	44.6788	80.7398	0.5534
Previous Manner: stop	-1.1796	16.8961	-0.0698	13.4852	25.3678	0.5316	24.3756	33.4219	0.7293	40.7816	41.8502	0.9745	43.9718	50.0470	0.8786	56.5946	57.2362	0.9888	77.2577	63.7557	1.2118
Next Voicing: voiceless	18.2481	15.0131	1.2155	20.0688	22.4778	0.8928	30.7068	29.6021	1.0373	40.2676	37.0774	1.0860	36.0125	44.2219	0.8144	33.2471	50.5431	0.6578	44.2819	56.2173	0.7877
Next Place: dental	7.6833	26.2696	0.2925	12.3420	39.2903	0.3141	42.1427	51.6710	0.8156	46.4112	64.7298	0.7170	25.5858	77.0779	0.3319	-2.8725	87.9791	-0.0326	2.8982	97.6504	0.0297
Next Place: diphthong	-12.8722	41.4247	-0.3107	-0.7646	61.0625	-0.0125	25.9305	79.8962	0.3246	29.9440	100.0708	0.2992	-14.3091	119.4290	-0.1198	-19.3231	136.2494	-0.1418	-62.0675	151.0244	-0.4110
Next Place: glottal	4.4332	14.2406	0.3113	3.5195	21.1102	0.1667	20.5095	27.6841	0.7408	27.7116	34.6758	0.7992	17.2917	41.3532	0.4181	-0.8430	47.1914	-0.0179	-4.0324	52.3756	-0.0770
Next Place: labial	16.8101	12.7186	1.3217	12.4883	18.9991	0.6573	3.9199	25.0572	0.1564	10.2188	31.3801	0.3256	22.1585	37.4672	0.5914	33.3167	42.8931	0.7767	41.9249	47.7895	0.8773
Next Place: labio-dental	0.8866	27.6002	0.0321	6.9775	41.0174	0.1701	31.4189	53.8414	0.5835	31.2132	67.4165	0.4630	13.0237	80.6653	0.1615	-4.9412	92.1799	-0.0536	6.4988	102.5328	0.0634
Next Place: lax	-5.7779	39.9904	-0.1445	17.0750	58.8324	0.2902	38.3777	76.8713	0.4992	33.9028	96.2996	0.3521	-8.0966	114.7596	-0.0706	-3.9082	130.7912	-0.0299	-26.4621	144.8438	-0.1827
Next Place: palatal	-13.7467	15.4653	-0.8889	-23.7183	23.1444	-1.0248	-35.9306	30.5160	-1.1774	-30.4629	38.2254	-0.7969	-32.3476	45.5370	-0.7104	-47.8841	52.0623	-0.9197	-55.8274	57.9514	-0.9633
Next Place: palato-alveolar	-10.0383	24.9452	-0.4024	-11.5761	37.4160	-0.3094	-3.9546	49.3179	-0.0802	-21.7106	61.7590	-0.3515	-51.1138	73.7884	-0.6927	-50.7325	84.3974	-0.6011	-71.0818	93.7457	-0.7582
Next Place: tense	3.1133	44.4872	0.0700	29.0055	65.0841	0.4457	54.9705	85.0367	0.6464	40.3757	106.5175	0.3791	-41.2760	127.0306	-0.3249	-47.5146	144.9536	-0.3278	-70.2997	160.7771	-0.4372
Next Manner: approximate	2.4121	42.1750	0.0572	33.1857	61.7428	0.5375	67.7492	80.6274	0.8403	62.4689	101.0037	0.6185	17.7074	120.3716	0.1471	28.1118	137.2316	0.2048	11.6113	152.0774	0.0764
Next Manner: flap	-9.3463	42.1360	-0.2218	11.0354	61.9824	0.1780	29.5431	81.0209	0.3646	18.4670	101.4981	0.1819	-24.3023	120.9479	-0.2009	-19.4102	137.8748	-0.1408	-47.1308	152.7835	-0.3085
Next Manner: fricative	-25.3970	35.9466	-0.7065	-6.1918	51.9197	-0.1193	-15.0209	67.3973	-0.2229	-37.1721	84.4242	-0.4403	-67.5612	100.7338	-0.6707	-38.3513	114.6478	-0.3345	-71.4827	126.8004	-0.5637
Next Manner: nasal	-6.0618	41.2489	-0.1470	20.4479	60.5548	0.3377	46.6776	79.1204	0.5900	37.7084	99.1175	0.3804	-7.3637	118.1054	-0.0623	4.3974	134.6432	0.0327	-9.0736	149.2704	-0.0608
Next Manner: stop	-24.6347	37.8311	-0.6512	0.5127	55.2659	0.0093	13.0655	72.0529	0.1813	-16.4646	90.2664	-0.1824	-60.0125	107.5549	-0.5580	-43.6715	122.5193	-0.3564	-76.0319	135.6276	-0.5606
Duration (log) x Frequency (log)	-0.1121	0.0412	-2.7190	-0.1532	0.0600	-2.5546	-0.1948	0.0788	-2.4710	-0.2321	0.0992	-2.3386	-0.2167	0.1125	-1.9257	-0.2283	0.1269	-1.7990	-0.2330	0.1404	-1.6600

u F1

	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	-170.5436	126.8090	-1.3449	-151.1366	137.5036	-1.0991	-101.0454	147.5822	-0.6847	-85.7556	154.9310	-0.5535	-142.3599	163.1161	-0.8728	-212.0445	166.9111	-1.2704	-241.0465	174.0389	-1.3850
Tense: past	26.6241	44.1591	0.6029	31.9394	43.5059	0.7341	15.3190	44.9185	0.3410	11.1257	46.6413	0.2385	19.9529	49.3540	0.4043	32.4430	50.7374	0.6394	46.4292	52.5759	0.8831
NDL Cue Strength	421.2372	225.5312	1.8678	443.4166	247.0744	1.7947	461.4770	265.7088	1.7368	486.5948	278.6469	1.7463	562.9637	295.0701	1.9079	637.8913	305.0790	2.0909	604.4140	317.6641	1.9027
Duration (log)	0.0698	0.3480	0.2007	0.3208	0.4041	0.7938	0.3387	0.4371	0.7750	0.2004	0.4679	0.4284	0.2282	0.4870	0.4687	0.0801	0.4761	0.1683	-0.3618	0.4961	-0.7293
Frequency (log)	0.3281	8.8174	0.0372	-2.3311	9.5257	-0.2447	-8.2430	10.2441	-0.8047	-10.7428	10.8445	-0.9906	-8.7683	11.2705	-0.7780	-6.9037	11.2518	-0.6136	-6.2997	11.7552	-0.5359
Previous Voicing: voiceless	96.1005	87.4028	1.0995	88.3184	91.6937	0.9632	65.2357	97.0706	0.6720	76.9777	101.4938	0.7584	106.3473	107.2146	0.9919	147.5975	110.2746	1.3385	205.5983	114.7048	1.7924
Previous Place: dental	-4.2838	48.4545	-0.0884	-15.6947	51.1168	-0.3070	-9.7247	54.4764	-0.1785	-9.2938	57.1525	-0.1626	-18.9192	60.2039	-0.3143	-33.3142	61.7085	-0.5399	-34.4366	64.2482	-0.5360
Previous Place: glottal	-52.7614	57.0335	-0.9251	-54.6031	64.9622	-0.8405	-34.8035	69.9482	-0.4976	-39.0027	73.5575	-0.5302	-59.7249	77.8182	-0.7675	-93.1383	80.2738	-1.1603	-109.9360	83.7146	-1.3132
Previous Place: palatal	128.1648	75.5423	1.6966	133.4171	81.3448	1.6401	132.9052	86.9087	1.5293	140.2648	90.9393	1.5424	160.2920	96.2006	1.6662	182.7001	99.3158	1.8396	173.8349	103.3262	1.6824
Previous Manner: approximate	131.0386	77.3497	1.6941	131.3515	84.4008	1.5563	127.2029	90.6672	1.4030	135.4547	95.0621	1.4249	159.2117	100.6859	1.5813	188.8665	104.0902	1.8145	184.4244	108.3487	1.7021
Previous Manner: fricative	21.2121	44.7989	0.4735	34.0899	52.7566	0.6462	36.8862	57.9714	0.6363	28.2137	61.5622	0.4583	26.2574	64.6054	0.4064	26.9155	65.5219	0.4108	-20.3006	68.5274	-0.2962
Next Voicing: voiceless	-15.3575	14.4750	-1.0610	-10.2229	17.3885	-0.5879	-10.4578	19.0371	-0.5493	-9.3497	20.3077	-0.4604	-13.2761	21.2529	-0.6247	-11.1434	21.3315	-0.5224	10.9372	22.2894	0.4907
Next Place: dental	-35.2759	32.6428	-1.0807	-32.6784	38.4901	-0.8490	-30.9343	42.4404	-0.7289	-22.4678	45.1463	-0.4977	-24.3247	47.1479	-0.5159	-23.8951	47.5463	-0.5026	3.7961	49.8457	0.0762
Next Place: diphthong	30.8493	33.1018	0.9320	10.2742	39.4096	0.2607	3.5463	43.1897	0.0821	7.4503	45.7977	0.1627	35.3169	48.4505	0.7289	76.3145	49.7627	1.5336	138.3982	51.8822	2.6675
Next Place: glottal	-31.5746	25.6743	-1.2298	-38.4247	30.5195	-1.2590	-36.5903	33.8492	-1.0810	-35.6232	35.9425	-0.9911	-37.8077	37.6098	-1.0053	-38.4529	38.2740	-1.0047	-17.2353	40.1716	-0.4290
Next Place: labial	-1.8685	28.0552	-0.0666	-1.8345	33.4433	-0.0549	-0.0835	36.6669	-0.0023	-1.7431	38.8350	-0.0449	13.7752	41.0681	0.3354	32.6797	42.3020	0.7725	52.0746	44.1532	1.1794
Next Place: labio-dental	-49.5313	32.0200	-1.5469	-55.3795	37.3192	-1.4839	-55.5832	41.2817	-1.3464	-50.5945	43.7702	-1.1559	-51.9205	45.7820	-1.1341	-51.7371	46.6415	-1.1093	-30.5364	48.9655	-0.6236
Next Place: lax	-10.1962	30.2548	-0.3370	-23.4229	35.7803	-0.6546	-22.6213	39.1448	-0.5779	-21.9769	41.4321	-0.5304	-0.0021	43.9063	0.0000	26.1208	45.3331	0.5762	57.4944	47.2649	1.2164
Next Place: palatal	-42.2738	31.8402	-1.3277	-37.7760	37.0344	-1.0200	-42.0157	40.3415	-1.0415	-35.1921	42.6535	-0.8251	-35.5073	45.1866	-0.7858	-28.0711	46.5676	-0.6028	-4.8662	48.5196	-0.1003
Next Place: palato-alveolar	-14.8928	32.0834	-0.4642	-11.6639	39.4273	-0.2958	-15.6363	44.0243	-0.3552	-17.5186	46.7588	-0.3747	-19.0797	48.9352	-0.3899	-22.2620	50.1051	-0.4443	-27.0270	52.6565	-0.5133
Next Place: tense	26.9904	32.6482	0.8267	18.1129	38.7820	0.4670	11.8017	42.5738	0.2772	-6.0712	45.1212	-0.1346	5.6736	47.6733	0.1190	43.2105	49.0260	0.8814	91.9217	51.1775	1.7961
Next Manner: flap	-12.9591	23.6126	-0.5488	-29.3835	28.3467	-1.0366	-31.3726	31.2924	-1.0026	-36.3212	33.2030	-1.0939	-14.4945	34.9434	-0.4148	7.0625	35.8599	0.1969	40.4108	37.5147	1.0772
Next Manner: fricative	33.3544	41.6569	0.8007	20.7746	49.5365	0.4194	15.5501	54.6271	0.2847	4.0433	57.9760	0.0697	22.7131	60.9779	0.3725	43.2314	62.2285	0.6947	37.0343	65.1041	0.5688
Next Manner: nasal	-20.4959	27.5992	-0.7426	-41.8121	33.0500	-1.2651	-51.5751	36.3197	-1.4200	-56.3253	38.4672	-1.4642	-42.3200	40.6717	-1.0405	-27.3334	42.0097	-0.6506	-4.5716	43.8825	-0.1042
Next Manner: stop	-1.3572	18.6841	-0.0726	-24.0878	22.5371	-1.0688	-30.6039	24.8261	-1.2327	-38.8822	26.3580	-1.4752	-21.0025	27.7209	-0.7576	-11.1689	28.4448	-0.3927	-6.3238	29.7761	-0.2124
Duration (log) x Frequency (log)	0.0335	0.0805	0.4165	-0.0196	0.0932	-0.2104	-0.0318	0.1004	-0.3166	-0.0086	0.1076	-0.0801	-0.0263	0.1121	-0.2349	0.0058	0.1092	0.0533	0.1011	0.1136	0.8903

u F2

	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	201.2092	142.4583	1.4124	93.6938	229.1602	0.4089	20.8349	331.1691	0.0629	-139.1285	456.9659	-0.3045	-393.0346	566.1458	-0.6942	-614.6282	627.4202	-0.9796	-768.3119	653.3530	-1.1760
Tense: past	-36.4167	46.3640	-0.7855	22.0076	72.7461	0.3025	15.5817	103.4868	0.1506	73.8602	146.3219	0.5048	127.8005	183.1952	0.6976	99.6893	204.3982	0.4877	129.1065	214.9399	0.6007
NDL Cue Strength	-307.2799	251.9443	-1.2196	-71.6383	412.7387	-0.1736	169.6274	597.9709	0.2837	583.7397	826.6786	0.7061	1186.5764	1025.8458	1.1567	1647.0513	1136.3409	1.4494	2161.8985	1181.6096	1.8296
Duration (log)	0.1405	0.4322	0.3251	0.6000	0.6786	0.8842	1.5360	0.9930	1.5468	1.9002	1.3222	1.4372	1.9911	1.5757	1.2636	2.3836	1.7604	1.3540	2.1862	1.8433	1.1860

Frequency (log)	-6.8512	10.0807	-0.6796	1.3020	15.8634	0.0821	14.7581	22.9503	0.6430	20.7729	31.4191	0.6612	27.0195	38.5711	0.7005	29.6776	42.9420	0.6911	24.1369	44.9453	0.5370
Previous Voicing: voiceless	-43.7583	95.5669	-0.4579	61.4173	152.9677	0.4015	114.0225	220.0843	0.5181	213.4278	306.9633	0.6953	331.1343	382.7509	0.8651	309.8912	425.1789	0.7288	387.1717	444.2704	0.8715
Previous Place: dental	26.5201	52.7976	0.5023	-39.3955	85.4423	-0.4611	-17.9745	123.1270	-0.1460	-16.6822	171.1767	-0.0975	-39.1526	212.6775	-0.1841	-11.4640	236.2445	-0.0485	32.7658	246.6757	0.1328
Previous Place: glottal	7.7965	65.1585	0.1197	10.0844	108.3181	0.0931	6.8409	157.7298	0.0434	-72.6385	218.5644	-0.3323	-202.8211	272.1972	-0.7451	-246.1199	301.0543	-0.8175	-318.6805	312.3767	-1.0202
Previous Place: palatal	-106.5590	83.5902	-1.2748	-29.5164	135.8582	-0.2173	-14.7455	196.0620	-0.0752	52.5082	272.0482	0.1930	206.1552	338.0628	0.6098	322.6785	374.8166	0.8609	455.6470	390.3485	1.1673
Previous Manner: approximate	-117.2443	86.1605	-1.3608	-66.6028	141.0332	-0.4722	-33.3462	204.2377	-0.1633	42.0834	282.4431	0.1490	194.6176	350.4453	0.5553	296.6473	388.2861	0.7640	432.5730	403.8790	1.0710
Previous Manner: fricative	-89.0643	53.0047	-1.6803	-80.0234	87.9336	-0.9100	-100.4377	128.9055	-0.7792	-71.7098	175.1087	-0.4095	23.9236	214.6633	0.1114	146.7970	237.3518	0.6185	166.2173	245.9133	0.6759
Next Voicing: voiceless	37.2770	17.5621	2.1226	25.8766	29.0079	0.8921	38.2274	42.6533	0.8962	12.9590	57.7349	0.2245	-19.2732	70.1447	-0.2748	-57.0591	77.7854	-0.7335	-67.3625	80.7406	-0.8343
Next Place: dental	79.5153	38.8980	2.0442	75.0632	63.9863	1.1731	97.2466	93.7928	1.0368	29.1291	127.1139	0.2292	-74.6506	155.6229	-0.4797	-183.3408	172.0487	-1.0656	-272.3735	178.3600	-1.5271
Next Place: diphthong	-34.5198	38.8407	-0.8888	-85.1381	65.8668	-1.2926	-85.9329	96.8303	-0.8875	-26.5293	132.2323	-0.2006	33.1971	162.9757	0.2037	149.2620	179.9397	0.8295	225.9209	185.8888	1.2154
Next Place: glottal	22.4290	30.4129	0.7375	22.7699	50.6654	0.4494	44.2418	74.3329	0.5952	35.9134	101.0496	0.3554	17.0191	124.6764	0.1365	-29.4806	137.3830	-0.2146	-34.2247	141.9297	-0.2411
Next Place: labial	-25.0641	32.8851	-0.7622	-35.7694	55.8272	-0.6407	-30.6690	82.0309	-0.3739	-25.3457	112.3393	-0.2256	23.2723	138.9322	0.1675	146.0301	153.2622	0.9528	208.2943	158.2218	1.3165
Next Place: labio-dental	27.4147	37.4128	0.7328	27.2913	61.9222	0.4407	63.9851	90.5993	0.7062	63.8204	123.4853	0.5168	54.4321	152.6685	0.3565	81.3901	168.2740	0.4837	94.8992	174.0439	0.5453
Next Place: lax	-7.8482	35.1493	-0.2233	-33.5586	59.8092	-0.5611	-45.6851	87.8674	-0.5199	-59.3177	120.4707	-0.4924	-70.1960	149.0298	-0.4710	30.2717	164.4938	0.1840	11.4622	169.9110	0.0675
Next Place: palatal	38.8433	36.6779	1.0590	70.6932	61.9286	1.1415	110.9055	90.7433	1.2222	115.5143	124.5794	0.9272	113.1288	154.0095	0.7346	127.5381	170.2204	0.7493	31.4837	176.1543	0.1787
Next Place: palato-alveolar	-19.2033	38.7569	-0.4955	-37.9581	65.3185	-0.5811	-22.9827	96.1112	-0.2391	-27.0745	130.6591	-0.2072	-31.7035	161.5178	-0.1963	-0.2215	177.4526	-0.0012	42.7632	182.6077	0.2342
Next Place: tense	22.7473	38.2331	0.5950	24.2536	64.7238	0.3747	62.0763	95.0903	0.6528	89.4102	130.0193	0.6877	144.8094	160.7249	0.9010	225.4619	177.2965	1.2717	164.7930	183.0881	0.9001
Next Manner: flap	34.1216	27.9444	1.2211	6.0230	47.1885	0.1276	-24.9530	69.3962	-0.3596	-88.6649	94.7827	-0.9355	-174.0988	117.2048	-1.4854	-171.1900	129.2146	-1.3249	-189.2845	133.3637	-1.4193
Next Manner: fricative	-83.2666	49.2321	-1.6913	-109.7363	82.5605	-1.3292	-184.5337	121.2229	-1.5223	-203.2373	164.8312	-1.2330	-186.0226	202.6815	-0.9178	-55.6300	223.6482	-0.2487	-43.2807	231.1296	-0.1873
Next Manner: nasal	12.3723	32.3202	0.3828	-45.7766	55.1188	-0.8305	-131.5756	81.0594	-1.6232	-224.0690	111.1480	-2.0160	-313.6297	137.8166	-2.2757	-348.6734	151.8588	-2.2960	-393.4464	156.6066	-2.5123
Next Manner: stop	-45.4499	22.1362	-2.0532	-99.4038	37.4807	-2.6521	-168.7322	55.1532	-3.0593	-208.5196	75.5833	-2.7588	-261.4399	93.7921	-2.7874	-207.2145	103.3571	-2.0048	-193.9857	106.6452	-1.8190
Duration (log) x Frequency (log)	0.0426	0.0998	0.4273	-0.0813	0.1567	-0.5186	-0.2690	0.2293	-1.1730	-0.2807	0.3055	-0.9189	-0.1985	0.3634	-0.5463	-0.1719	0.4067	-0.4227	-0.0458	0.4264	-0.1074

ʊ F1

	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	33.3086	370.4685	0.0899	-95.9760	472.8666	-0.2030	-211.1426	656.7783	-0.3215	-142.9834	786.8549	-0.1817	19.1313	821.5831	0.0233	138.6239	827.7682	0.1675	77.7900	817.1155	0.0952
Tense: past	-5.0057	90.3393	-0.0554	23.2337	113.8409	0.2041	53.8476	157.4748	0.3419	33.9387	188.3985	0.1801	-8.8699	196.7492	-0.0451	-32.1516	198.3685	-0.1621	-32.5022	197.0430	-0.1649
NDL Cue Strength	41.5217	167.4066	0.2480	18.2727	210.6529	0.0867	-41.6101	291.2459	-0.1429	-4.6680	348.0959	-0.0134	83.6609	363.4146	0.2302	130.9266	365.5146	0.3582	136.6864	363.0971	0.3764
Duration (log)	-1.0010	4.5835	-0.2184	-0.0450	5.7517	-0.0078	2.9936	8.0796	0.3705	3.0502	9.7562	0.3126	0.9711	10.2003	0.0952	-0.1386	10.3684	-0.0134	0.6547	10.3255	0.0634
Frequency (log)	-7.2092	64.8756	-0.1111	19.2753	83.1810	0.2317	36.0707	114.6643	0.3146	26.7163	136.6895	0.1955	5.2438	142.5979	0.0368	-13.3697	143.0584	-0.0935	4.4070	140.8670	0.0313
Previous Voicing: voiceless	-11.9132	100.7682	-0.1182	10.8045	126.1312	0.0857	72.2540	176.4808	0.4094	60.3527	213.0175	0.2833	1.6920	222.8767	0.0076	-31.2977	226.2876	-0.1383	-55.4711	225.8903	-0.2456
Previous Place: dental	20.5100	119.7367	0.1713	17.3241	152.4188	0.1137	-60.2826	209.6501	-0.2875	-73.7390	250.4800	-0.2944	-36.3304	261.5946	-0.1389	-17.5171	264.0557	-0.0663	-2.3241	261.6044	-0.0089
Next Voicing: voiceless	-2.4729	15.4846	-0.1597	-16.6555	20.0380	-0.8312	-20.3846	27.5146	-0.7409	-18.2094	32.7903	-0.5553	-19.7670	34.2037	-0.5779	-17.5440	34.3347	-0.5110	-17.6027	33.7762	-0.5212
Duration (log) x Frequency (log)	0.2956	0.9570	0.3089	0.0912	1.2016	0.0759	-0.5615	1.6872	-0.3328	-0.6052	2.0355	-0.2973	-0.1975	2.1276	-0.0928	0.0137	2.1612	0.0064	-0.1690	2.1521	-0.0785

ʊ F2

	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	168.8374	350.4106	0.4818	536.8706	605.3910	0.8868	292.4776	809.5044	0.3613	467.7774	963.5887	0.4855	560.7604	1021.8686	0.5488	708.3600	1068.2513	0.6631	986.8001	1123.2638	0.8785
Tense: past	0.1800	87.7823	0.0021	-44.4909	148.4864	-0.2996	29.0870	197.9661	0.1469	19.5090	237.0644	0.0823	106.1735	253.3196	0.4191	131.5413	274.6966	0.4789	67.8534	280.9760	0.2415
NDL Cue Strength	-2.6960	162.6115	-0.0166	82.9314	274.7024	0.3019	-57.4567	366.5708	-0.1567	-48.0285	439.6297	-0.1092	-231.7317	470.6679	-0.4923	-306.1541	512.7945	-0.5970	-230.0592	523.3970	-0.4396
Duration (log)	-2.3961	4.4913	-0.5335	-7.5464	7.6351	-0.9884	-2.7848	10.1616	-0.2740	-3.5728	12.0736	-0.2959	-2.7024	12.7937	-0.2112	-1.6044	13.5834	-0.1181	-5.1487	14.1244	-0.3645
Frequency (log)	-44.0521	60.4627	-0.7286	-108.8684	105.1018	-1.0358	-73.2111	140.8220	-0.5199	-114.4215	167.9996	-0.6811	-155.6423	178.6106	-0.8714	-197.9454	186.8424	-1.0594	-240.1201	196.3390	-1.2230
Previous Voicing: voiceless	7.1808	99.5087	0.0722	-50.8285	166.8283	-0.3047	27.8028	221.6959	0.1254	47.0151	264.8307	0.1775	180.3201	282.8968	0.6374	260.6175	310.4745	0.8394	217.9375	315.9987	0.6897
Previous Place: dental	8.6769	113.3274	0.0766	35.9619	194.3890	0.1850	-53.0557	259.5345	-0.2044	-106.4971	310.4501	-0.3430	-217.4742	331.6241	-0.6558	-310.3097	354.3883	-0.8756	-227.3825	365.8654	-0.6215
Next Voicing: voiceless	17.9972	14.0254	1.2832	27.5378	24.8383	1.1087	40.2323	33.2472	1.2101	54.2041	39.4231	1.3749	58.0166	41.6777	1.3920	58.7978	42.6438	1.3788	61.7475	45.5040	1.3570
Duration (log) x Frequency (log)	0.6695	0.9387	0.7132	1.7985	1.5945	1.1280	0.8469	2.1218	0.3991	1.0574	2.5216	0.4193	0.8727	2.6721	0.3266	0.6532	2.8355	0.2303	1.3714	2.9484	0.4651

o F1

	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	10.5688	76.0156	0.1390	-21.9695	94.0877	-0.2335	-23.5320	103.1975	-0.2280	-38.1513	106.5630	-0.3580	14.1878	107.1919	0.1324	19.5775	109.0889	0.1795	32.8711	111.8192	0.2940
Tense: past	-9.9548	12.8076	-0.7773	-6.9101	15.8660	-0.4355	-6.4706	17.4419	-0.3710	-5.0618	18.0808	-0.2800	-1.1349	18.2213	-0.0623	8.1905	18.7226	0.4375	18.8525	18.9994	0.9923
NDL Cue Strength	26.7464	66.0753	0.4048	-1.1899	81.8656	-0.0145	-23.4748	89.9183	-0.2611	-22.5927	92.9697	-0.2430	-6.0996	93.5828	-0.0652	49.2823	95.8786	0.5140	79.9114	97.5957	0.8188
Duration (log)	0.1198	0.1636	0.7320	0.2243	0.2016	1.1127	0.2261	0.2208	1.0241	0.2432	0.2267	1.0726	0.2096	0.2239	0.9365	0.1198	0.2294	0.5224	0.0531	0.2326	0.2285
Frequency (log)	-4.4683	8.3341	-0.5361	2.0861	10.3385	0.2018	4.6004	11.3753	0.4044	5.0836	11.7400	0.4330	0.5428	11.7885	0.0460	0.0089	12.0811	0.0007	0.1034	12.2715	0.0084
Previous Voicing: voiceless	-8.2563	55.4896	-0.1488	2.1132	68.6508	0.0308	4.3875	75.2441	0.0583	25.9814	77.5466	0.3350	-13.1963	77.8232	-0.1696	-7.6416	78.7854	-0.0970	-7.2656	81.2088	-0.0895
Previous Place: dental	-25.3499	77.2558	-0.3281	-52.5652	95.6884	-0.5493	-47.0870	104.9539	-0.4486	-75.1993	108.2946	-0.6944	-74.2309	108.9800	-0.6811	-58.3143	111.1452	-0.5247	-14.1907	113.6868	-0.1248
Previous Place: diphthong	-0.1149	43.5257	-0.0026	11.6638	53.8018	0.2168	31.8294	58.9065	0.5403	43.6085	60.5959	0.7197	19.7846	60.7315	0.3258	8.8665	61.2683	0.1447	-0.6610	63.5126	-0.0104
Previous Place: glottal	-14.7090	65.1289	-0.2258	-5.1978	80.5427	-0.0645	28.2281	88.2031	0.3200	23.0782	90.6960	0.2545	14.8125	90.9666	0.1628	37.4083	91.8090	0.4075	69.1441	95.0765	0.7272

Previous Place: labial	7.6894	35.7381	0.2152	5.0834	44.4211	0.1144	-16.1881	48.9834	-0.3305	-16.0135	50.6365	-0.3162	-17.7434	50.9834	-0.3480	-42.1536	52.8531	-0.7976	-48.2292	53.0338	-0.9094
Previous Place: lax	-2.8980	42.7154	-0.0678	6.6268	52.8063	0.1255	16.6940	57.8139	0.2888	35.3735	59.4511	0.5950	14.8704	59.5721	0.2496	-8.5286	60.0820	-0.1419	-21.7024	62.2702	-0.3485
Previous Place: palatal	1.3612	34.2664	0.0397	-8.1157	42.4413	-0.1912	-4.8877	46.5563	-0.1050	-9.8763	48.0029	-0.2057	4.9398	48.2000	0.1025	-13.3573	48.9770	-0.2727	-24.8911	50.1941	-0.4959
Previous Place: palato-alveolar	4.5455	50.2743	0.0904	19.0700	62.4084	0.3056	24.2842	68.7164	0.3534	7.4282	70.8359	0.1049	3.9216	70.9587	0.0553	2.3228	73.1082	0.0318	61.3477	73.7834	0.8315
Previous Place: tense	-0.8776	48.4971	-0.0181	2.5619	59.9561	0.0427	11.8108	65.6479	0.1799	41.9247	67.5303	0.6208	27.4264	67.7086	0.4051	9.3824	68.3132	0.1373	2.9889	70.7913	0.0422
Previous Manner: approximate	-10.9127	49.7999	-0.2191	0.4280	61.5921	0.0069	3.2008	67.4920	0.0474	22.8400	69.6296	0.3280	-4.0367	69.9680	-0.0577	2.1705	70.8801	0.0306	4.2386	73.0787	0.0580
Previous Manner: flap	-3.8750	55.7751	-0.0695	22.0568	68.9754	0.3198	45.6489	75.5715	0.6041	81.2435	77.9185	1.0427	70.8804	78.2391	0.9059	77.7494	79.1613	0.9822	103.0723	81.7399	1.2610
Previous Manner: fricative	25.4969	72.7764	0.3503	44.7229	90.0418	0.4967	34.8340	98.6602	0.3531	52.4984	101.5019	0.5172	82.1433	101.8145	0.8068	74.7833	103.0609	0.7256	43.2804	106.3365	0.4070
Previous Manner: lax	-4.4671	23.6032	-0.1893	1.4368	29.1850	0.0492	5.4944	31.9587	0.1719	1.6239	32.8620	0.0494	1.2895	32.9358	0.0392	15.5334	33.2061	0.4678	32.5289	34.4116	0.9453
Previous Manner: nasal	17.0428	37.7535	0.4514	30.3962	46.6602	0.6514	39.2821	51.0793	0.7690	59.5174	52.5396	1.1328	44.2957	52.6415	0.8415	29.2754	53.1011	0.5513	15.0564	55.0503	0.2735
Next Voicing: voiceless	-1.2181	8.8141	-0.1382	2.8688	10.9064	0.2630	3.4434	11.9538	0.2881	5.0636	12.2994	0.4117	7.2418	12.3133	0.5881	12.9708	12.4779	1.0395	14.2478	12.8344	1.1101
Next Place: dental	8.8811	13.6964	0.6484	13.0187	16.9398	0.7685	10.9126	18.5508	0.5883	15.5881	19.0796	0.8170	1.7908	19.1034	0.0937	3.0236	19.2770	0.1569	-7.3532	19.9102	-0.3693
Next Place: diphthong	17.9400	29.6943	0.6042	22.4609	36.7229	0.6116	26.6248	40.1905	0.6625	33.5427	41.2921	0.8123	38.2427	41.3872	0.9240	41.8785	41.7398	1.0033	39.8861	43.2049	0.9232
Next Place: glottal	12.1849	10.5903	1.1506	15.7487	13.0885	1.2032	17.3887	14.3258	1.2138	23.6913	14.7328	1.6081	17.4982	14.7378	1.1873	20.2836	14.8473	1.3661	21.0506	15.3617	1.3703
Next Place: labial	-2.9452	7.8670	-0.3744	1.6083	9.7316	0.1653	9.6143	10.6586	0.9020	17.9764	10.9667	1.6392	21.9713	10.9826	2.0005	25.8277	11.0837	2.3303	29.5805	11.4379	2.5862
Next Place: labio-dental	2.7026	13.8136	0.1956	7.0059	17.0845	0.4101	9.7946	18.7052	0.5236	16.8891	19.2279	0.8784	-5.7071	19.2567	-0.2964	-19.7766	19.4313	-1.0178	-34.0776	20.0793	-1.6972
Next Place: lax	11.6957	29.3923	0.3979	13.5657	36.3499	0.3732	10.5267	39.7818	0.2646	12.0311	40.8727	0.2944	11.6379	40.9724	0.2840	7.6405	41.3280	0.1849	-2.3740	42.7759	-0.0555
Next Place: palatal	1.7225	9.9308	0.1735	8.4897	12.2810	0.6913	14.7707	13.4567	1.0976	24.7841	13.8530	1.7891	29.8543	13.8621	2.1537	32.8878	14.0129	2.3470	34.5304	14.4487	2.3899
Next Place: palato-alveolar	36.0103	20.2118	1.7816	49.9546	24.9746	2.0002	44.6047	27.3192	1.6327	36.7449	28.0657	1.3092	8.9624	28.0276	0.3198	-16.3502	28.1334	-0.5812	-16.7076	29.1719	-0.5727
Next Place: tense	10.8911	31.2460	0.3486	13.8143	38.6282	0.3576	7.8288	42.2620	0.1852	4.7896	43.4125	0.1103	1.6631	43.4546	0.0383	7.8501	43.7693	0.1794	20.6370	45.3195	0.4554
Next Manner: approximate	11.6053	29.9942	0.3869	7.8401	37.0882	0.2114	-2.4568	40.5890	-0.0605	-9.2191	41.7108	-0.2210	-14.9139	41.8101	-0.3567	-20.2310	42.1773	-0.4797	-30.0855	43.6602	-0.6891
Next Manner: flap	23.0650	33.5500	0.6875	34.7036	41.5074	0.8361	33.8797	45.4598	0.7453	28.7815	46.7632	0.6155	19.2548	46.9078	0.4105	11.6235	47.4245	0.2451	-3.3836	48.9525	-0.0691
Next Manner: fricative	1.1216	28.7628	0.0390	-6.1084	35.5706	-0.1717	-9.3387	38.9318	-0.2399	-12.0884	40.0089	-0.3021	-0.4170	40.1158	-0.0104	-4.3364	40.4874	-0.1071	-4.5819	41.8933	-0.1094
Next Manner: nasal	25.4481	30.8533	0.8248	24.8125	38.1496	0.6504	18.8203	41.7497	0.4508	14.6431	42.9122	0.3412	12.1532	43.0234	0.2825	4.2030	43.4186	0.0968	-13.2409	44.9307	-0.2947
Next Manner: stop	14.2719	30.0306	0.4752	12.3768	37.1328	0.3333	11.7823	40.6388	0.2899	7.1557	41.7663	0.1713	-0.4854	41.8718	-0.0116	-7.6231	42.2457	-0.1804	-18.4501	43.7284	-0.4219
Duration (log) x Frequency (log)	0.0335	0.0221	1.5160	0.0171	0.0273	0.6255	0.0086	0.0300	0.2868	-0.0017	0.0308	-0.0559	-0.0041	0.0305	-0.1329	0.0054	0.0312	0.1738	0.0132	0.0317	0.4162

o F2

	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	100.0666	78.6472	1.2723	244.3529	125.5209	1.9467	309.2424	169.9001	1.8201	344.3197	210.3932	1.6366	434.5461	242.4093	1.7926	489.0929	264.4648	1.8494	516.7654	278.7420	1.8539
Tense: past	1.0600	13.2879	0.0798	-7.3642	21.2006	-0.3474	-8.6222	28.5647	-0.3018	4.3633	35.3484	0.1234	10.4718	40.7007	0.2573	22.2108	44.3930	0.5003	36.6121	46.7781	0.7827
NDL Cue Strength	-94.3514	68.4871	-1.3777	-164.5264	109.2186	-1.5064	-282.9473	147.1912	-1.9223	-339.1643	182.1241	-1.8623	-337.4354	209.7477	-1.6088	-220.2900	228.8855	-0.9624	-93.0395	241.2025	-0.3857
Duration (log)	0.0197	0.1783	0.1104	-0.5536	0.2847	-1.9445	-0.8486	0.3809	-2.2276	-1.0337	0.4653	-2.2218	-0.8421	0.5252	-1.6034	-0.6386	0.5634	-1.1333	-0.6143	0.5884	-1.0441
Frequency (log)	-10.6051	8.6155	-1.2309	-28.7282	13.7432	-2.0904	-28.5195	18.5780	-1.5351	-23.9521	23.0656	-1.0384	-20.9907	26.5706	-0.7900	-24.4956	28.9988	-0.8447	-27.8944	30.5741	-0.9124
Previous Voicing: voiceless	-42.7860	57.2721	-0.7471	-56.5406	91.3936	-0.6186	-11.6219	124.1073	-0.0936	-33.1692	153.8254	-0.2156	-105.3207	177.2902	-0.5941	-98.5740	193.4135	-0.5097	-53.4801	203.8391	-0.2624
Previous Place: dental	-4.1035	79.5452	-0.0516	48.3562	127.1403	0.3803	64.9341	172.6972	0.3760	28.0842	213.9158	0.1313	-2.2749	246.5639	-0.0092	-3.9818	269.0346	-0.0148	23.3613	283.4365	0.0824
Previous Place: diphthong	-6.5858	44.7566	-0.1471	-0.9076	71.4828	-0.0127	-17.9059	97.6767	-0.1833	-87.3002	121.1698	-0.7205	-173.8647	139.6127	-1.2453	-195.1960	152.1817	-1.2827	-198.2958	160.3129	-1.2369
Previous Place: glottal	-31.0734	66.9262	-0.4643	-42.7827	106.8860	-0.4003	-68.6305	145.9492	-0.4702	-125.7102	181.0546	-0.6943	-174.5350	208.6952	-0.8363	-144.2265	227.6471	-0.6336	-97.7523	239.9085	-0.4075
Previous Place: labial	-11.9198	36.9359	-0.3227	-56.5940	58.9359	-0.9603	-74.7747	79.3719	-0.9421	-47.7024	98.3580	-0.4850	-40.6858	113.1623	-0.3595	-43.2523	123.5371	-0.3501	-15.5702	130.2091	-0.1196
Previous Place: lax	4.3581	43.8858	0.0993	32.0408	70.1271	0.4569	91.0797	95.7686	0.9510	76.6095	118.7724	0.6450	10.5536	136.8578	0.0771	11.5861	149.2199	0.0776	22.3005	157.2152	0.1418
Previous Place: palatal	60.1737	35.3663	1.7014	132.8768	56.4874	2.3523	172.6009	76.4747	2.2570	188.1407	94.7300	1.9861	204.4093	109.1670	1.8724	226.7153	119.1472	1.9028	236.4182	125.5791	1.8826
Previous Place: palato-alveolar	130.9286	51.9964	2.5180	240.0479	82.9428	2.8941	335.4784	112.1023	2.9926	417.9743	138.8828	3.0095	435.2033	159.5744	2.7273	337.9510	173.8669	1.9437	216.4357	182.9736	1.1829
Previous Place: tense	26.0968	49.7964	0.5241	83.8847	79.5980	1.0539	144.3999	108.7736	1.3275	116.0731	134.8977	0.8605	50.5845	155.4433	0.3254	45.0792	169.4852	0.2660	18.8979	178.5731	0.1058
Previous Manner: approximate	-29.2398	51.3614	-0.5693	-61.2761	82.0194	-0.7471	-69.7563	111.4614	-0.6258	-109.1259	138.1270	-0.7900	-178.2739	159.2279	-1.1196	-186.3451	173.6925	-1.0728	-170.0878	183.0402	-0.9292
Previous Manner: flap	-6.6408	57.4557	-0.1156	18.2371	91.7600	0.1987	38.3521	124.9017	0.3071	16.7903	154.8356	0.1084	-26.3704	178.4813	-0.1477	18.2459	194.6799	0.0937	119.5312	205.1620	0.5826
Previous Manner: fricative	-1.4043	74.9276	-0.0187	-53.5111	119.6098	-0.4474	-98.3418	162.8915	-0.6037	-64.3586	201.9651	-0.3187	-19.8769	232.7132	-0.0854	-48.0192	253.8312	-0.1892	-119.8244	267.4672	-0.4480
Previous Manner: lax	4.9293	24.1760	0.2039	0.2381	38.7052	0.0062	-31.0134	52.9894	-0.5853	-36.6439	65.7562	-0.5573	-16.2471	75.7624	-0.2144	-26.2338	82.5723	-0.3177	-62.1109	86.9804	-0.7141
Previous Manner: nasal	9.2747	38.8583	0.2387	36.5115	62.0378	0.5885	58.3125	84.6820	0.6886	34.7709	105.0267	0.3311	-18.6201	121.0074	-0.1539	-15.6735	131.9043	-0.1188	4.4982	138.9488	0.0324
Next Voicing: voiceless	-18.3004	9.1153	-2.0076	-15.6730	14.5380	-1.0781	5.0667	19.7080	0.2571	28.5000	24.4060	1.1677	42.8642	28.0869	1.5261	38.4801	30.6140	1.2569	39.6554	32.2441	1.2299
Next Place: dental	-32.1603	14.1177	-2.2780	-29.0368	22.5532	-1.2875	-6.0560	30.6642	-0.1975	13.2322	37.9880	0.3483	27.4970	43.7438	0.6286	14.0161	47.6837	0.2939	10.5915	50.2310	0.2109
Next Place: diphthong	-25.7876	30.6785	-0.8406	-36.0643	48.9019	-0.7375	-62.9173	66.3065	-0.9489	-39.6901	82.1369	-0.4832	-57.5414	94.6615	-0.6079	-92.7709	103.3096	-0.8980	-122.5827	108.9089	-1.1256
Next Place: glottal	7.5074	10.9201	0.6875	18.1042	17.4468	1.0377	28.4033	23.7977	1.1935	40.4905	29.4891	1.3731	58.1131	33.9347	1.7125	72.3377	36.9444	1.9580	93.2897	38.8855	2.3991
Next Place: labial	1.4631	8.1079	0.1805	0.9337	12.9523	0.0721	8.5891	17.6168	0.4876	30.3350	21.8325	1.3894	59.8936	25.1448	2.3819	109.2493	27.4083	3.9860	166.3590	28.8685	5.7626
Next Place: labio-dental	-27.0314	14.2584	-1.8958	-30.1484	22.7537	-1.3250	-16.9059	30.8984	-0.5471	-6.2360	38.2771	-0.1629	8.4731	44.0868	0.1922	29.5831	48.0759	0.6153	80.3927	50.6543	1.5871
Next Place: lax	-11.8781	30.3658	-0.3912	-12.6782	48.4052	-0.2619	-32.6740	65.6244	-0.4979	-9.0813	81.2856	-0.1117	-24.2103	93.6824	-0.2584	-64.0027	102.2468	-0.6260	-98.5869	107.7915	-0.9146
Next Place: palatal	4.0814	10.2651	0.3976	-15.2672	16.3832	-0.9319	-39.5166	22.2171	-1.7787	-68.3025	27.5212	-2.4818	-86.8905	31.6795	-2.7428	-96.1963	34.5263	-2.7862	-115.4324	36.3700	-3.1738
Next Place: palato-alveolar	-28.6496	20.9240	-1.3692	-27.0398	33.3583	-0.8106	-24.8758	45.2807	-0.5494	-35.7089	56.0992	-0.6365	-60.3480	64.5916	-0.9343	-115.0227	70.3742	-1.6344	-173.8104	74.1121	-2.3452
Next Place: tense	-0.5855	32.3117	-0.0181	25.0490	51.5326	0.4861	23.1487	69.8836	0.3312	46.8388	86.5306	0.5413	37.2388	99.6608	0.3737	14.0974	108.6816	0.1297	-13.8048	114.5188	-0.1205
Next Manner: approximate	-5.9439	31.0089	-0.1917	5.9708	49.4193	0.1208	-5.0094	66.9864	-0.0748	15.2413	82.9721	0.1837	-6.1175	95.6142	-0.0640	-56.8402	104.3359	-0.5448	-94.5296	109.9865	-0.8595

Next Manner: flap	-15.8737	34.6588	-0.4580	-9.2429	55.2703	-0.1672	-23.9079	74.9032	-0.3192	-9.5262	92.7799	-0.1027	-50.6611	106.9207	-0.4738	-115.2337	116.6885	-0.9875	-166.4012	123.0091	-1.3528
Next Manner: fricative	16.4262	29.7428	0.5523	4.2375	47.3908	0.0894	-46.0142	64.1911	-0.7168	-68.5840	79.5058	-0.8626	-127.3191	91.6301	-1.3895	-180.6905	100.0119	-1.8067	-245.3056	105.4453	-2.3264
Next Manner: nasal	-12.7964	31.9096	-0.4010	-19.8234	50.8529	-0.3898	-50.3446	68.8907	-0.7308	-39.4905	85.3134	-0.4629	-70.8784	98.3108	-0.7210	-135.4109	107.2808	-1.2622	-200.7035	113.0898	-1.7747
Next Manner: stop	-2.0177	31.0544	-0.0650	9.8487	49.4849	0.1990	-13.5433	67.0645	-0.2019	-20.5148	83.0710	-0.2470	-63.6362	95.7292	-0.6648	-127.4339	104.4625	-1.2199	-172.1602	110.1243	-1.5633
Duration (log) x Frequency (log)	0.0734	0.0230	3.1941	0.1957	0.0367	5.3364	0.2702	0.0499	5.4103	0.3228	0.0619	5.2161	0.3226	0.0707	4.5617	0.3195	0.0765	4.1761	0.3205	0.0802	3.9992

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	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	-54.9963	87.5336	-0.6283	-87.2341	130.0562	-0.6707	-91.6720	162.2176	-0.5651	-101.8011	183.1563	-0.5558	-141.6695	182.9123	-0.7745	-110.2256	189.2361	-0.5825	-165.1104	193.3523	-0.8539
Tense: past	41.8449	44.2995	0.9446	22.9503	65.2859	0.3515	5.4848	81.3998	0.0674	38.3624	89.3641	0.4293	73.5939	88.7267	0.8294	71.0341	92.0448	0.7717	46.4721	96.2761	0.4827
NDL Cue Strength	-34.7648	235.7528	-0.1475	-193.9667	359.8113	-0.5391	-318.3984	470.4401	-0.6768	-439.1904	528.3805	-0.8312	-424.6132	514.7861	-0.8248	-434.2028	542.9763	-0.7997	-429.9763	566.6553	-0.7588
Duration (log)	0.3960	0.6184	0.6404	0.8057	0.9320	0.8644	0.9122	1.1648	0.7831	1.1646	1.3242	0.8795	1.4347	1.3600	1.0549	1.0547	1.4029	0.7517	1.0340	1.4626	0.7070
Frequency (log)	9.1412	24.6213	0.3713	25.9738	36.6339	0.7090	35.0539	46.0843	0.7606	46.6325	51.6885	0.9022	59.6908	50.3634	1.1852	50.8276	52.8447	0.9618	62.3433	53.9347	1.1559
Previous Voicing: voiceless	17.2921	67.4400	0.2564	57.4174	101.3748	0.5664	90.9210	127.3957	0.7137	60.1518	143.7875	0.4183	29.9687	149.0208	0.2011	41.0046	152.2412	0.2693	108.8120	160.3617	0.6785
Previous Place: glottal	69.1131	87.0802	0.7937	10.5857	127.5588	0.0830	-57.0969	158.0442	-0.3613	-58.1319	174.3582	-0.3334	-2.2414	169.5469	-0.0132	-11.3320	177.0100	-0.0640	-19.2864	182.9068	-0.1054
Previous Place: labial	-9.5648	55.2461	-0.1731	12.0272	83.6269	0.1438	45.6041	105.0508	0.4341	16.2190	119.4585	0.1358	1.3583	124.0608	0.0109	6.2551	126.8403	0.0493	78.5173	133.3399	0.5889
Previous Place: labio-dental	3.7631	73.6871	0.0511	-66.2075	108.0397	-0.6128	-114.7913	134.4848	-0.8536	-109.7982	148.1348	-0.7412	-57.8543	143.1623	-0.4041	-48.2641	149.8069	-0.3222	-36.7755	154.4130	-0.2382
Previous Place: palatal	114.3643	180.4125	0.6339	316.4650	265.4800	1.1920	391.2824	332.8405	1.1756	487.2041	368.7935	1.3211	422.2804	349.7274	1.2075	444.0241	369.3211	1.2023	445.2474	375.7962	1.1848
Previous Manner: fricative	-10.5007	66.3468	-0.1583	9.5548	96.1397	0.0994	24.2086	118.3341	0.2046	43.8195	130.2416	0.3364	21.0454	126.4640	0.1664	11.8703	130.5913	0.0909	-44.0609	133.0940	-0.3311
Next Voicing: voiceless	-51.4344	71.9472	-0.7149	-63.7524	108.4853	-0.5877	-69.9103	133.5945	-0.5233	-23.5735	151.4687	-0.1556	-41.0692	158.1881	-0.2596	-6.3041	161.2181	-0.0391	-0.2026	169.3907	-0.0012
Next Place: dental	-42.5307	74.3651	-0.5719	-46.3534	112.2075	-0.4131	-55.0518	138.4761	-0.3976	0.0461	156.9070	0.0003	-7.2970	163.5187	-0.0446	24.6700	167.0449	0.1477	29.3601	175.8687	0.1669
Next Place: glottal	-0.2102	27.7683	-0.0076	34.1023	40.6561	0.8388	43.6156	49.2012	0.8865	60.8350	54.5961	1.1143	58.9382	55.9027	1.0543	55.3238	55.7080	0.9931	23.5357	56.7048	0.4151
Next Place: labial	55.0260	42.6268	1.2909	41.6615	64.9896	0.6410	10.3355	82.3475	0.1255	-8.5929	94.2406	-0.0912	-21.9057	97.1665	-0.2254	-33.9056	98.2360	-0.3451	-35.9894	101.2654	-0.3554
Next Place: lax	13.7060	21.7444	0.6303	12.2545	32.9230	0.3722	10.3117	40.7397	0.2531	2.6435	45.8167	0.0577	-0.7164	47.3688	-0.0151	9.1505	47.4840	0.1927	28.9702	48.7295	0.5945
Next Place: tense	26.1855	31.3903	0.8342	10.1092	48.1987	0.2097	0.3441	61.3520	0.0056	-1.8279	70.6850	-0.0259	-12.8949	73.5003	-0.1754	-23.9099	75.1913	-0.3180	18.8041	78.7737	0.2387
Next Manner: fricative	39.7633	72.6900	0.5470	48.3446	109.4825	0.4416	59.4538	135.1737	0.4398	3.3458	153.1396	0.0218	6.6134	159.0388	0.0416	-27.0974	162.7360	-0.1665	-21.5778	171.0756	-0.1261
Next Manner: nasal	-27.0688	42.9458	-0.6303	-6.8303	65.4779	-0.1043	36.2009	83.4421	0.4338	61.1352	95.8888	0.6376	76.6271	98.6657	0.7766	103.7539	100.6055	1.0313	109.2703	104.3185	1.0475
Next Manner: stop	37.3007	52.4380	0.7113	44.4626	80.0090	0.5557	53.4707	101.6828	0.5259	3.1463	117.0707	0.0269	-9.0775	121.0113	-0.0750	-32.4301	123.3456	-0.2629	-36.6605	128.0065	-0.2864
Duration (log) x Frequency (log)	-0.0114	0.1565	-0.0727	-0.1143	0.2344	-0.4877	-0.1672	0.2895	-0.5775	-0.2567	0.3249	-0.7899	-0.3152	0.3301	-0.9550	-0.2207	0.3416	-0.6461	-0.2088	0.3550	-0.5882

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Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	-45.2395	106.7686	-0.4237	-90.9441	149.7237	-0.6074	43.9548	184.4617	0.2383	65.8767	205.5078	0.3206	105.5216	223.7142	0.4717	117.8052	224.2897	0.5252	136.6741	212.2589	0.6439
Tense: past	20.8074	55.4177	0.3755	11.0737	79.5661	0.1392	27.3585	104.4488	0.2619	48.4137	116.0544	0.4172	71.6644	126.0070	0.5687	89.6333	125.5473	0.7139	20.7202	117.5012	0.1763
NDL Cue Strength	-381.6192	281.3917	-1.3562	-506.5678	396.9945	-1.2760	227.0048	539.3467	0.4209	704.2033	605.2536	1.1635	1217.6098	667.0453	1.8254	1293.7366	674.1131	1.9192	1979.4453	636.5730	3.1095
Duration (log)	0.2040	0.8131	0.2509	0.6554	1.1373	0.5763	-0.0962	1.3691	-0.0703	-0.1985	1.5100	-0.1315	-0.1999	1.6370	-0.1221	-0.2662	1.6604	-0.1603	0.1080	1.5655	0.0690
Frequency (log)	11.5641	28.8035	0.4015	17.4854	40.3129	0.4337	-43.7562	51.5829	-0.8483	-61.4046	57.8319	-1.0618	-77.1669	63.2519	-1.2200	-82.6320	63.4655	-1.3020	-111.8733	60.1724	-1.8592
Previous Voicing: voiceless	-8.2156	93.3390	-0.0880	49.4587	130.5746	0.3788	86.2233	157.7607	0.5465	90.4357	173.3953	0.5216	97.4351	187.6726	0.5192	75.3406	191.4733	0.3935	186.8389	179.2784	1.0422
Previous Place: glottal	3.2235	104.6487	0.0308	-22.7687	147.4584	-0.1544	98.0920	188.2860	0.5210	186.6156	210.9038	0.8848	277.9835	229.3479	1.2121	343.0423	227.3013	1.5092	443.7222	214.5555	2.0681
Previous Place: labial	50.7881	75.4130	0.6735	104.9316	107.6955	0.9743	101.8533	123.4440	0.8251	118.0071	135.5892	0.8703	103.6651	147.4825	0.7029	119.3723	147.5975	0.8088	221.9847	139.1762	1.5950
Previous Place: labio-dental	-44.6804	84.5942	-0.5282	-94.2197	119.7951	-0.7865	28.4706	155.7520	0.1828	124.5992	176.4544	0.7061	205.9102	193.1091	1.0663	255.3061	189.5667	1.3468	316.8451	179.7472	1.7627
Previous Place: palatal	327.8517	198.2325	1.6539	554.3720	278.3929	1.9913	381.7428	366.9970	1.0402	168.0456	417.5482	0.4025	-116.0955	458.4804	-0.2532	-208.1000	450.7846	-0.4616	-268.9042	429.0779	-0.6267
Previous Manner: fricative	39.6479	77.2797	0.5130	28.7139	105.9350	0.2711	-79.0166	143.6394	-0.5501	-155.9426	162.1101	-0.9620	-241.4779	175.7004	-1.3744	-262.8364	176.1832	-1.4918	-376.6005	165.9275	-2.2697
Next Voicing: voiceless	-26.3039	117.5532	-0.2238	-100.4096	166.4729	-0.6032	-126.7536	190.1225	-0.6667	-120.9114	202.1037	-0.5983	-103.8489	213.1534	-0.4872	-56.8688	219.2153	-0.2594	49.5795	201.3994	0.2462
Next Place: dental	-27.8391	120.8586	-0.2303	-85.7554	170.9357	-0.5017	-108.5023	195.1716	-0.5559	-93.9264	207.8070	-0.4520	-65.5349	219.5701	-0.2985	-4.9360	225.7019	-0.0219	71.3470	207.6186	0.3436
Next Place: glottal	-6.3846	36.2049	-0.1763	22.4188	52.0890	0.4304	41.8392	60.4533	0.6921	56.6050	66.7025	0.8486	73.7808	72.4618	1.0182	98.2132	70.7968	1.3873	41.4530	66.5446	0.6229
Next Place: labial	-65.0314	56.0137	-1.1610	-83.2638	80.0344	-1.0404	-114.5103	88.3554	-1.2960	-116.5658	97.9263	-1.1903	-132.7503	107.5929	-1.2338	-52.3542	106.1105	-0.4934	106.6537	100.9009	1.0570
Next Place: lax	29.9925	30.9445	0.9692	50.6745	44.6205	1.1357	59.6182	49.1751	1.2124	56.1565	53.7748	1.0443	25.1438	58.5390	0.4295	41.5439	58.1778	0.7141	37.5992	54.7679	0.6865
Next Place: tense	14.7172	41.4243	0.3553	23.4958	58.3815	0.4025	23.7227	64.8994	0.3655	20.4692	72.2748	0.2832	9.2789	79.3121	0.1170	31.9763	78.9490	0.4050	55.2462	75.3335	0.7334
Next Manner: fricative	58.5531	116.6687	0.5019	146.6004	164.7151	0.8900	179.1483	189.3443	0.9462	157.5696	201.9478	0.7802	93.5559	213.2910	0.4386	37.6372	219.1613	0.1717	-30.1409	201.6943	-0.1494
Next Manner: nasal	146.2664	54.8282	2.6677	192.2199	77.7875	2.4711	210.9686	87.1992	2.4194	198.8510	97.1739	2.0463	188.9278	106.8211	1.7686	128.3812	105.2254	1.2201	-3.7780	100.3297	-0.0377
Next Manner: stop	64.3304	64.7420	0.9936	99.6345	91.2905	1.0914	140.7046	104.1711	1.3507	143.8919	117.1511	1.2283	137.8379	128.9322	1.0691	83.6066	126.6629	0.6601	-61.5810	121.3256	-0.5076
Duration (log) x Frequency (log)	0.0973	0.2024	0.4806	0.0656	0.2828	0.2319	0.2622	0.3451	0.7598	0.2864	0.3823	0.7490	0.2592	0.4144	0.6253	0.2870	0.4190	0.6851	0.1711	0.3954	0.4328

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	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	-53.3101	191.7697	-0.2780	15.7714	201.4514	0.0783	142.9377	258.1285	0.5537	299.5494	289.6769	1.0341	391.7695	305.2719	1.2833	368.7058	295.2039	1.2490	377.7656	279.4739	1.3517
Tense: past	10.5424	33.6460	0.3133	22.6650	36.6064	0.6192	32.2110	43.3471	0.7431	41.9700	48.4994	0.8654	52.4231	52.0620	1.0069	47.7237	53.2012	0.8970	28.4599	52.8406	0.5386

NDL Cue Strength	11.9345	113.9690	0.1047	-39.3574	121.0188	-0.3252	25.5389	147.2456	0.1734	25.7940	164.8875	0.1564	36.3323	176.7845	0.2055	-42.5288	177.2866	-0.2399	24.9952	174.7249	0.1431
Duration (log)	0.7000	0.4252	1.6461	0.1576	0.5377	0.2931	-0.2215	0.7423	-0.2983	-0.4981	0.8187	-0.6084	-0.5811	0.8149	-0.7131	-0.4571	0.7602	-0.6013	-0.3176	0.6106	-0.5200
Frequency (log)	4.7693	59.6828	0.0799	8.2632	62.5157	0.1322	-24.4033	77.9604	-0.3130	-62.1893	87.4687	-0.7110	-87.4948	93.1447	-0.9393	-67.7119	91.6576	-0.7387	-80.6251	88.8110	-0.9078
Previous Voicing: voiceless	10.5493	16.0468	0.6574	3.9672	18.8535	0.2104	-15.3046	21.4948	-0.7120	-30.7368	23.8454	-1.2890	-41.7447	25.6950	-1.6246	-51.5331	27.2404	-1.8918	-49.2413	27.4395	-1.7945
Previous Place: diphthong	-73.2875	180.3025	-0.4065	-153.9082	186.6714	-0.8245	-108.9990	228.5162	-0.4770	-7.6669	257.1655	-0.0298	71.4535	275.8661	0.2590	25.5510	273.9497	0.0933	53.5573	269.5288	0.1987
Previous Place: labial	-122.0371	99.8426	-1.2223	-160.1819	97.5894	-1.6414	-133.0171	123.3802	-1.0781	29.0780	140.2011	0.2074	49.6449	150.1805	0.3306	-13.8234	144.6918	-0.0955	15.2357	141.0793	0.1080
Previous Place: labio-dental	-63.3385	45.2814	-1.3988	-32.1667	46.9622	-0.6849	11.4166	58.5875	0.1949	56.1919	65.9274	0.8523	90.7044	70.1932	1.2922	55.0109	69.1861	0.7951	20.4009	67.3673	0.3028
Previous Place: palatal	-53.8949	176.7282	-0.3050	-112.6074	182.0846	-0.6184	-61.8584	223.6852	-0.2765	47.8177	251.9348	0.1898	127.8192	270.1933	0.4731	76.6398	267.4831	0.2865	102.3727	262.7927	0.3896
Previous Place: palato-alveolar	-36.7952	73.8947	-0.4979	7.7237	75.2260	0.1027	28.4711	92.5946	0.3075	21.4470	104.8214	0.2046	22.8924	112.3995	0.2037	29.4481	110.7851	0.2658	20.9197	108.8794	0.1921
Previous Place: tense	-43.7193	181.8717	-0.2404	-86.8297	188.7129	-0.4601	-45.9178	230.8118	-0.1989	49.0334	259.6378	0.1889	126.8040	278.5265	0.4553	84.7784	276.8795	0.3062	116.8347	272.4565	0.4288
Previous Manner: fricative	11.6678	100.3684	0.1162	-54.5903	101.4017	-0.5384	-28.8199	124.9964	-0.2306	-19.6761	141.3901	-0.1392	-17.0870	151.7042	-0.1126	-46.9754	149.4725	-0.3143	-25.1638	147.1520	-0.1710
Previous Manner: nasal	-33.0269	257.6205	-0.1282	-124.0680	269.1679	-0.4609	-23.1788	328.3597	-0.0706	120.2266	369.0072	0.3258	218.5041	395.6759	0.5522	122.7342	394.2596	0.3113	188.5706	387.8668	0.4862
Previous Manner: stop	22.9501	23.9539	0.9581	20.3018	27.8490	0.7290	28.2214	31.3973	0.8988	32.3379	34.7816	0.9297	26.6453	37.5269	0.7100	28.9670	39.9402	0.7253	32.4333	40.3988	0.8028
Next Voicing: voiceless	-2.5000	11.0335	-0.2266	-3.8320	12.9481	-0.2960	-1.1376	14.6772	-0.0775	2.9339	16.2653	0.1804	2.2870	17.5106	0.1306	3.7479	18.5999	0.2015	6.4034	18.7406	0.3417
Next Place: dental	56.6108	56.7318	0.9979	126.5745	69.0224	1.8338	144.2011	80.1650	1.7988	133.6637	88.6568	1.5077	112.2070	93.7340	1.1971	91.1757	98.6379	0.9243	69.2393	97.4110	0.7108
Next Place: diphthong	-4.2468	30.6402	-0.1386	-0.9759	35.6088	-0.0274	2.2075	40.5819	0.0544	2.7131	44.9718	0.0603	20.4689	48.3255	0.4236	38.6038	51.0711	0.7559	67.4091	51.2408	1.3155
Next Place: glottal	-3.8845	11.2147	-0.3464	-4.4327	13.2084	-0.3356	2.7899	14.9814	0.1862	13.1100	16.6150	0.7890	19.2339	17.8917	1.0750	29.6222	19.0049	1.5587	42.6567	19.1621	2.2261
Next Place: labial	-5.4740	13.2969	-0.4117	-7.6664	15.5831	-0.4920	0.8419	17.6751	0.0476	8.3903	19.5937	0.4282	14.2738	21.0954	0.6766	16.8228	22.4042	0.7509	18.4378	22.5935	0.8161
Next Place: labio-dental	7.0085	40.1564	0.1745	8.3891	46.6489	0.1798	10.2506	52.5483	0.1951	12.2400	58.2755	0.2100	16.8321	62.8425	0.2678	21.6314	66.8489	0.3236	27.9827	67.5917	0.4140
Next Place: lax	16.2561	24.6578	0.6593	15.3155	28.6002	0.5355	13.4469	32.9193	0.4085	12.9598	36.4683	0.3554	25.2473	39.1215	0.6454	43.9226	41.1089	1.0684	69.9892	41.0116	1.7066
Next Place: palatal	-7.2361	22.1410	-0.3268	-9.6627	26.2743	-0.3678	-22.2620	29.8769	-0.7451	-20.7845	33.0840	-0.6282	-29.9714	35.4448	-0.8456	-60.7262	37.5504	-1.6172	-57.3427	37.4985	-1.5292
Next Manner: flap	21.3318	23.4697	0.9089	23.1336	27.1823	0.8511	26.6745	31.1268	0.8570	26.9350	34.4815	0.7811	32.6281	37.0150	0.8815	45.0964	38.9928	1.1565	60.7601	38.9985	1.5580
Next Manner: fricative	13.3829	36.7250	0.3644	12.8237	43.0472	0.2979	8.9916	49.0321	0.1834	-6.6627	54.3170	-0.1227	10.8511	58.3857	0.1859	22.6965	61.8038	0.3672	36.4482	62.0293	0.5876
Next Manner: nasal	30.4386	29.3831	1.0359	10.6936	34.1547	0.3131	-20.1922	38.9609	-0.5183	-25.2639	43.1397	-0.5856	-23.1996	46.4280	-0.4997	-15.3001	49.1098	-0.3115	8.7568	49.3369	0.1775
Next Manner: stop	24.1482	24.6601	0.9792	27.8602	28.6134	0.9737	25.8468	32.7240	0.7898	17.9986	36.2418	0.4966	21.5489	38.9314	0.5535	25.5983	41.0680	0.6233	34.3530	41.1251	0.8353
Duration (log) x Frequency (log)	0.0041	0.0659	0.0615	0.1402	0.0836	1.6759	0.2134	0.1149	1.8574	0.2471	0.1268	1.9494	0.2382	0.1264	1.8848	0.2000	0.1184	1.6901	0.1645	0.0958	1.7158

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Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	35.7912	262.0140	0.1366	79.9289	346.6402	0.2306	273.0748	416.2197	0.6561	247.7578	508.8926	0.4869	493.8875	496.9916	0.9938	455.0889	531.8901	0.8556	95.2651	551.4618	0.1728
Tense: past	-52.4639	44.6464	-1.1751	-54.1877	60.4728	-0.8961	-70.6075	71.6861	-0.9850	-84.6453	82.2575	-1.0290	-107.7800	84.8285	-1.2706	-75.3618	91.2987	-0.8254	-57.1975	95.4078	-0.5995
NDL Cue Strength	115.0608	149.2122	0.7711	47.4130	199.7604	0.2373	73.7973	238.4885	0.3094	20.3347	282.8646	0.0719	133.5595	285.0128	0.4686	44.6897	307.9224	0.1451	-181.8287	320.8870	-0.5666
Duration (log)	0.4711	0.7583	0.6213	0.0945	1.0233	0.0923	-0.0864	1.2084	-0.0715	-0.3932	1.4395	-0.2732	-0.4696	1.3859	-0.3389	-0.6593	1.3922	-0.4736	-0.9270	1.5178	-0.6108
Frequency (log)	-22.0838	79.0443	-0.2794	-7.5716	104.9869	-0.0721	-62.1396	125.8490	-0.4938	-41.6589	152.0383	-0.2740	-102.2878	150.6005	-0.6792	-80.9525	162.3347	-0.4987	63.7499	168.4053	0.3786
Previous Voicing: voiceless	0.1403	21.9943	0.0064	-24.9623	30.3719	-0.8219	-47.5340	35.4627	-1.3404	-62.2283	39.3940	-1.5796	-74.9043	42.0295	-1.7822	-74.8467	44.8591	-1.6685	-58.9081	48.7549	-1.2082
Previous Place: diphthong	-42.4851	232.4023	-0.1828	-104.4470	308.5301	-0.3385	55.7721	370.4126	0.1506	28.5167	445.6499	0.0640	199.2434	444.5519	0.4482	207.3522	482.9018	0.4294	-131.9981	498.4062	-0.2648
Previous Place: labial	135.0381	125.2422	1.0782	142.9986	162.1076	0.8821	258.0417	197.3855	1.3073	558.1720	250.2028	2.2309	714.4549	241.6738	2.9563	858.9320	265.5580	3.2344	945.6310	269.0437	3.5148
Previous Place: labio-dental	-60.7742	58.1955	-1.0443	-91.1029	77.6113	-1.1738	-103.5570	93.8517	-1.1034	-70.0431	110.3343	-0.6348	-19.2844	110.6551	-0.1743	8.7246	120.0218	0.0727	-14.0239	122.4753	-0.1145
Previous Place: palatal	10.2896	227.4001	0.0452	-13.7181	301.2028	-0.0455	171.7541	362.0131	0.4744	133.0433	437.6010	0.3040	278.1301	435.2221	0.6391	273.7186	473.1554	0.5785	-79.3605	487.4037	-0.1628
Previous Place: palato-alveolar	22.9779	93.8571	0.2448	121.5872	123.8186	0.9820	111.4542	149.7024	0.7445	155.4460	180.6318	0.8606	95.4774	179.7297	0.5312	94.3603	196.2257	0.4809	191.3993	200.1329	0.9564
Previous Place: tense	-49.3518	234.5624	-0.2104	-119.7187	311.6506	-0.3841	52.5342	373.9943	0.1405	25.1012	449.2711	0.0559	147.2152	448.7013	0.3281	97.7914	487.2386	0.2007	-252.0648	503.3487	-0.5008
Previous Manner: fricative	6.6553	126.4528	0.0526	-3.3638	166.6704	-0.0202	87.0343	201.7762	0.4313	102.7318	244.6930	0.4198	145.5127	242.3704	0.6004	137.7680	265.0496	0.5198	7.4025	270.0513	0.0274
Previous Manner: nasal	-4.4323	334.3474	-0.0133	-132.2308	445.0088	-0.2971	76.8180	532.9928	0.1441	13.4187	638.5910	0.0210	258.0582	639.0499	0.4038	234.5573	692.7479	0.3386	-297.8498	717.9744	-0.4148
Previous Manner: stop	0.0502	32.7259	0.0015	-8.6983	45.1988	-0.1924	3.1545	52.7079	0.0598	41.7827	58.2755	0.7170	51.0865	62.1023	0.8226	55.4133	66.2199	0.8368	61.3166	71.6422	0.8559
Next Voicing: voiceless	-25.8807	15.2660	-1.6953	-21.6626	21.0975	-1.0268	-19.9713	24.6176	-0.8113	-17.7489	27.2210	-0.6520	-3.7241	28.9782	-0.1285	7.9350	30.8567	0.2572	11.9065	33.4284	0.3562
Next Place: dental	-39.8780	84.6772	-0.4709	-29.9607	117.4754	-0.2550	-69.5106	136.9384	-0.5076	-97.0147	151.1564	-0.6418	-70.0449	158.5295	-0.4418	-48.7987	166.0250	-0.2939	-26.5068	181.0187	-0.1464
Next Place: diphthong	-5.1504	42.2682	-0.1219	-63.1716	58.2559	-1.0844	-84.8533	68.0143	-1.2476	-91.6810	75.5535	-1.2135	-83.1123	80.0375	-1.0384	-128.3297	85.2016	-1.5062	-201.0166	92.0666	-2.1834
Next Place: glottal	-12.8685	15.5908	-0.8254	-15.6694	21.5524	-0.7270	-12.7321	25.1532	-0.5062	-2.4342	27.8382	-0.0874	19.2487	29.6494	0.6492	41.5979	31.5877	1.3169	55.1746	34.1999	1.6133
Next Place: labial	0.0177	18.3787	0.0010	-22.8379	25.4050	-0.8990	-13.6442	29.6567	-0.4601	16.7725	32.8187	0.5111	37.1487	34.9434	1.0631	63.2048	37.2216	1.6981	93.9109	40.2857	2.3311
Next Place: labio-dental	12.7067	55.0474	0.2308	35.8605	75.8958	0.4725	15.6754	88.4590	0.1772	19.4868	98.2514	0.1983	56.8039	104.4302	0.5439	111.8964	111.3773	1.0047	135.2974	120.4558	1.1232
Next Place: lax	16.8771	34.1160	0.4947	-21.5930	46.9731	-0.4597	-16.3740	54.8859	-0.2983	-33.1995	61.2273	-0.5422	-47.8753	64.6445	-0.7406	-74.7852	68.7393	-1.0880	-148.7674	74.1772	-2.0056
Next Place: palatal	-29.4687	31.2827	-0.9420	-35.7721	43.1998	-0.8281	-27.5581	50.3564	-0.5473	-31.7521	55.6768	-0.5703	-38.5011	58.9872	-0.6527	-20.0548	62.5065	-0.3208	-7.7859	67.9302	-0.1146
Next Manner: flap	32.4868	32.4230	1.0020	-9.2274	44.6486	-0.2067	-16.9974	52.1296	-0.3261	-39.0059	58.0709	-0.6717	-52.8175	61.3508	-0.8609	-88.4912	65.2542	-1.3561	-161.2413	70.4322	-2.2893
Next Manner: fricative	10.9861	50.9884	0.2155	-41.0580	70.3868	-0.5833	-55.1183	82.1409	-0.6710	-102.5817	91.0580	-1.1266	-167.9999	96.6597	-1.7381	-250.1729	102.8452	-2.4325	-366.0845	111.3055	-3.2890
Next Manner: nasal	57.9200	40.3025	1.4371	26.7286	55.6302	0.4805	20.2203	64.9658	0.3112	-8.1994	72.0014	-0.1139	-41.1260	76.4773	-0.5378	-107.9335	81.4430	-1.3253	-211.7977	88.0349	-2.4058
Next Manner: stop	49.0511	34.0589	1.4402	6.8662	46.9512	0.1462	-3.1114	54.8117	-0.0568	-30.3607	60.9240	-0.4983	-65.0135	64.4721	-1.0084	-122.3123	68.5817	-1.7835	-208.9852	74.0425	-2.8225
Duration (log) x Frequency (log)	0.1321	0.1173	1.1264	0.2597	0.1584	1.6397	0.3313	0.1870	1.7713	0.3816	0.2223	1.7165	0.3709	0.2146	1.7284	0.3677	0.2158	1.7042	0.3709	0.2354	1.5754

Table A.15: Coefficients for the F1 and F2 global (all vowels pooled) LMER models of formant deviance from vowel offset.

	F1			F2		
Predictor	Estimate	std.Error	t.value	Estimate	std.Error	t.value
(Intercept)	66.3801	25.7837	2.5745	-323.3378	53.9555	-5.9927
Tense: past	8.9709	2.3693	3.7863	21.9640	5.6273	3.9031
Percent: 20	43.2560	9.5612	4.5241	-34.0596	22.9678	-1.4829
Percent: 30	7.5149	9.5612	0.7860	15.8201	22.9678	0.6888
Percent: 40	-19.7632	9.5612	-2.0670	32.5551	22.9678	1.4174
Percent: 50	-33.6481	9.5612	-3.5192	24.1125	22.9678	1.0498
Percent: 60	-31.8003	9.5612	-3.3260	6.5882	22.9678	0.2868
Percent: 70	-19.2364	9.5612	-2.0119	-9.3547	22.9678	-0.4073
NDL Cue Strength	3.1865	5.4124	0.5887	42.9038	12.8821	3.3305
Vowel: a	4.6388	2.3306	1.9904	-23.5051	5.5363	-4.2456
Vowel: æ	0.8579	3.6543	0.2348	75.9621	8.5085	8.9278
Vowel: ɔ	-10.4355	3.1416	-3.3217	-10.4197	7.3663	-1.4145
Vowel: ɛ	-10.5689	1.9504	-5.4189	40.9406	4.6122	8.8766
Vowel: ɪ	-16.2781	1.9030	-8.5541	67.5045	4.4982	15.0069
Vowel: i	-36.2872	2.0572	-17.6391	74.4523	4.8727	15.2795
Vowel: o	4.0685	1.6536	2.4604	21.9665	3.9298	5.5897
Vowel: ʊ	-21.6768	3.5339	-6.1340	16.2345	8.3539	1.9433
Vowel: u	-24.5765	2.4346	-10.0947	91.4753	5.7577	15.8875
Duration (log)	-10.8249	5.0196	-2.1565	61.3587	10.0282	6.1186
Frequency (log)	-89.6837	11.1034	-8.0771	-16.2488	23.3614	-0.6955
Previous Voicing: voiceless	7.1656	2.4110	2.9720	-63.7964	5.7003	-11.1918
Previous Place: dental	-2.2642	8.9349	-0.2534	9.0964	20.9684	0.4338
Previous Place: diphthong	9.4173	10.9339	0.8613	-45.3689	25.6995	-1.7654
Previous Place: glottal	0.2229	4.2227	0.0528	-6.0658	9.6496	-0.6286
Previous Place: labial	0.4681	2.4252	0.1930	-21.3936	5.6509	-3.7858
Previous Place: labio-dental	-1.3620	4.1816	-0.3257	-25.1245	9.7442	-2.5784
Previous Place: lax	-14.9449	10.9752	-1.3617	23.8618	25.7794	0.9256
Previous Place: palatal	14.1047	2.8051	5.0282	25.3416	6.5985	3.8405
Previous Place: palato-alveolar	-26.1420	4.7487	-5.5050	11.6917	10.9906	1.0638
Previous Place: tense	-4.2643	9.0928	-0.4690	18.6937	21.1135	0.8854
Previous Manner: approximate	8.6944	7.7342	1.1241	19.9713	17.7579	1.1246
Previous Manner: diphthong	-31.9397	10.9266	-2.9231	51.1131	26.0177	1.9646
Previous Manner: flap	46.3441	13.5000	3.4329	112.0965	31.5445	3.5536
Previous Manner: fricative	12.4986	6.9529	1.7976	62.5417	15.8534	3.9450
Previous Manner: lax	21.9349	8.5791	2.5568	8.9289	20.5230	0.4351
Previous Manner: nasal	15.8642	7.6300	2.0792	65.3351	17.5159	3.7301
Previous Manner: stop	-5.4552	7.5791	-0.7198	69.1918	17.3753	3.9822
Next Voicing: voiceless	-4.6593	1.4323	-3.2530	-4.7926	3.4089	-1.4059
Next Place: dental	-27.2848	2.9286	-9.3167	-10.0329	6.9638	-1.4407
Next Place: diphthong	5.8042	8.6878	0.6681	56.4078	20.7686	2.7160
Next Place: glottal	-6.8019	1.5732	-4.3236	7.8620	3.7352	2.1048
Next Place: labial	18.9502	1.6204	11.6948	133.9861	3.8432	34.8634
Next Place: labio-dental	-28.1782	3.1639	-8.9062	70.8835	7.5194	9.4268
Next Place: lax	103.2242	17.7883	5.8029	224.3376	42.5506	5.2723
Next Place: palatal	30.7080	1.9571	15.6908	35.8240	4.5182	7.9288
Next Place: palato-alveolar	41.7064	5.8408	7.1405	15.2668	13.8944	1.0988
Next Place: tense	15.4496	9.0826	1.7010	74.1030	21.6758	3.4187
Next Manner: approximate	-3.2728	8.5785	-0.3815	98.4722	20.5167	4.7996
Next Manner: flap	6.4928	8.5840	0.7564	20.1476	20.5195	0.9819
Next Manner: fricative	35.6179	8.3128	4.2847	13.3819	19.8735	0.6734
Next Manner: lax	-103.4286	15.6543	-6.6070	-196.4742	37.4548	-5.2456
Next Manner: nasal	13.3191	8.6655	1.5370	39.6846	20.7117	1.9160
Next Manner: stop	15.7541	8.4403	1.8665	-1.8307	20.1736	-0.0907
Tense: past x Percent: 20	-11.2110	2.7873	-4.0222	-72.0284	6.6956	-10.7576
Tense: past x Percent: 30	-11.8572	2.7873	-4.2540	-67.8654	6.6956	-10.1358
Tense: past x Percent: 40	-8.6475	2.7873	-3.1025	-56.6778	6.6956	-8.4649
Tense: past x Percent: 50	-3.5021	2.7873	-1.2565	-42.0690	6.6956	-6.2831
Tense: past x Percent: 60	-0.1844	2.7873	-0.0662	-28.8128	6.6956	-4.3032
Tense: past x Percent: 70	1.6025	2.7873	0.5749	-15.6407	6.6956	-2.3360
Percent: 20 x NDL Cue Strength	-7.3538	5.8511	-1.2568	14.0322	14.0555	0.9983
Percent: 30 x NDL Cue Strength	-11.7397	5.8511	-2.0064	11.2217	14.0555	0.7984
Percent: 40 x NDL Cue Strength	-9.4204	5.8511	-1.6100	7.5815	14.0555	0.5394
Percent: 50 x NDL Cue Strength	-5.1803	5.8511	-0.8853	6.7728	14.0555	0.4819
Percent: 60 x NDL Cue Strength	-1.5174	5.8511	-0.2593	7.8729	14.0555	0.5601
Percent: 70 x NDL Cue Strength	0.6944	5.8511	0.1187	6.1474	14.0555	0.4374
Duration (log) x Frequency (log)	20.1893	2.3383	8.6341	-1.0055	5.1297	-0.1960
Percent: 20 x Duration (log)	2.0239	2.1749	0.9306	61.8992	5.2246	11.8478
Percent: 30 x Duration (log)	9.0893	2.1749	4.1792	42.1071	5.2246	8.0595
Percent: 40 x Duration (log)	13.8384	2.1749	6.3627	29.4238	5.2246	5.6318
Percent: 50 x Duration (log)	15.1681	2.1749	6.9741	21.7016	5.2246	4.1538
Percent: 60 x Duration (log)	12.7588	2.1749	5.8663	16.6359	5.2246	3.1842
Percent: 70 x Duration (log)	7.4390	2.1749	3.4204	11.5016	5.2246	2.2015

Table A.16: Coefficients for the F1 and F2 by vowel LMER models of formant deviance from vowel offset.

i F1

	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	67.2315	51.7188	1.2999	76.7006	50.7684	1.5108	57.5494	47.7814	1.2044	49.1380	44.7851	1.0972	61.9497	42.4909	1.4580	47.2769	37.7469	1.2525	29.5392	28.1389	1.0498
Tense: past	-6.2655	20.2649	-0.3092	1.2859	19.6538	0.0654	3.1680	18.3102	0.1730	4.0025	17.1117	0.2339	5.3323	16.2174	0.3288	7.0302	14.4060	0.4880	4.1398	10.7951	0.3835
NDL Cue Strength	68.6840	82.4041	0.8335	66.0725	80.3128	0.8227	65.6352	75.0761	0.8742	57.3179	70.1377	0.8172	63.4475	66.5390	0.9535	54.1111	59.0957	0.9157	25.2358	44.3131	0.5695
Duration (log)	0.0223	0.2264	0.0984	-0.1135	0.2198	-0.5166	-0.0809	0.2080	-0.3889	0.0220	0.1998	0.1102	0.0299	0.1902	0.1572	0.0793	0.1700	0.4663	0.0682	0.1231	0.5543
Frequency (log)	-15.0994	8.4479	-1.7873	-18.4607	8.2350	-2.2417	-16.3934	7.7095	-2.1264	-13.1460	7.2376	-1.8163	-12.3906	6.8487	-1.8092	-8.1925	6.0850	-1.3463	-2.4829	4.5304	-0.5480
Previous Voicing: voiceless	39.0859	28.2722	1.3825	24.0280	27.6306	0.8696	33.9161	25.8425	1.3124	35.0905	24.1429	1.4534	29.7017	22.9789	1.2926	16.8540	20.4276	0.8251	0.6309	15.3774	0.0410
Previous Place: diphthong	-39.6615	31.1340	-1.2739	-7.8190	30.6902	-0.2548	13.1616	29.0917	0.4524	30.3159	27.5655	1.0998	24.9175	26.2322	0.9499	6.7034	23.3706	0.2868	2.2097	17.3046	0.1277
Previous Place: labial	-3.0619	17.0062	-0.1800	5.4480	16.3664	0.3329	-5.4259	15.1498	-0.3581	-10.8177	14.1811	-0.7628	-7.3259	13.4675	-0.5440	-8.1633	11.9852	-0.6811	-6.5359	9.0207	-0.7245
Previous Place: labio-dental	-40.9096	35.3815	-1.1562	-40.7611	34.2148	-1.1913	-36.5668	31.7894	-1.1503	-27.1783	29.7005	-0.9151	-16.8567	28.1787	-0.5982	-0.7707	25.0521	-0.0308	14.6477	18.8459	0.7772
Previous Place: lax	-45.5341	19.7921	-2.3006	-31.1184	19.2869	-1.6134	-20.5711	18.0449	-1.1400	-10.1738	16.9063	-0.6018	-8.1655	16.0952	-0.5073	-3.9904	14.3136	-0.2788	-0.3580	10.7137	-0.0334
Previous Place: palatal	38.9531	34.0422	1.1443	32.0534	33.3708	0.9605	26.2474	31.3016	0.8385	14.6766	29.2549	0.5017	9.4194	27.8410	0.3383	-13.5579	24.7578	-0.5476	-33.1055	18.6068	-1.7792
Previous Place: palato-alveolar	-4.6563	46.4021	-0.1003	-5.2069	46.0754	-0.1130	-8.8411	43.5421	-0.2030	-12.3879	40.4853	-0.3060	-9.4870	38.3179	-0.2476	0.3894	33.9499	0.0115	9.8853	25.4066	0.3891
Previous Place: tense	-8.8324	25.1991	-0.3505	4.3529	24.6001	0.1769	-3.0431	23.0087	-0.1323	-10.0524	21.5423	-0.4666	-9.5651	20.4957	-0.4667	-5.0122	18.2465	-0.2747	6.9339	13.7615	0.5039
Previous Manner: fricative	-45.1843	42.8133	-1.0554	-14.9049	41.9118	-0.3556	-18.8709	39.2403	-0.4809	-18.6759	36.6469	-0.5096	-16.7455	34.8240	-0.4809	-8.8147	30.9395	-0.2849	-2.5514	23.2602	-0.1097
Previous Manner: nasal	-17.8372	19.9489	-0.8941	-13.0630	19.2266	-0.6794	0.1928	17.8428	0.0108	10.1326	16.7025	0.6067	9.5406	15.8496	0.6019	11.5633	14.0952	0.8204	7.1123	10.5938	0.6714
Previous Manner: stop	-66.5907	29.9484	-2.2235	-45.8798	29.3107	-1.5653	-36.5224	27.4558	-1.3302	-26.1118	25.6709	-1.0172	-19.4741	24.4256	-0.7973	-0.9390	21.7226	-0.0432	13.2914	16.3672	0.8121
Next Voicing: voiceless	3.7737	9.2664	0.4072	-0.3318	9.1328	-0.0363	-2.5498	8.5904	-0.2968	-5.4560	8.0301	-0.6794	-6.3319	7.6048	-0.8326	-2.8538	6.7539	-0.4225	3.1869	5.0666	0.6290
Next Place: dental	-8.4364	14.3406	-0.5883	-13.1584	14.1769	-0.9282	-15.2352	13.3599	-1.1404	-17.6984	12.4630	-1.4201	-18.3192	11.7999	-1.5525	-10.8895	10.4689	-1.0402	-1.9845	7.8415	-0.2531
Next Place: diphthong	137.2048	41.9822	3.2682	121.8273	41.4645	2.9381	114.5612	39.1036	2.9297	89.5077	36.5028	2.4521	55.6198	34.6584	1.6048	31.9728	30.7856	1.0386	-0.4838	23.0541	-0.0210
Next Place: glottal	8.7333	11.0877	0.7877	7.2652	10.9666	0.6625	5.7791	10.3386	0.5590	3.2807	9.6507	0.3399	2.8638	9.1434	0.3132	8.3909	8.1155	1.0339	11.2543	6.0813	1.8506
Next Place: labial	-13.4569	9.9136	-1.3574	-11.7487	9.8117	-1.1974	-11.6778	9.2633	-1.2606	-5.6307	8.6573	-0.6504	-2.3234	8.1868	-0.2838	-2.2903	7.2613	-0.3154	-2.8985	5.4082	-0.5359
Next Place: labio-dental	-3.1122	20.8520	-0.1493	-9.9460	20.6159	-0.4824	-9.6101	19.5857	-0.4907	-6.0370	18.5166	-0.3260	-12.9192	17.5541	-0.7360	-8.5085	15.6201	-0.5447	0.2079	11.5353	0.0180
Next Place: lax	145.3987	51.3954	2.8290	143.6989	50.8952	2.8234	138.6653	48.0879	2.8836	114.9885	44.8952	2.5613	68.4196	42.6002	1.6061	29.7237	37.8096	0.7861	-3.5562	28.2702	-0.1258
Next Place: palatal	-0.3066	11.3897	-0.0269	8.7434	11.1663	0.7830	10.6095	10.4775	1.0126	15.5169	9.8082	1.5820	13.1503	9.2815	1.4168	6.3109	8.2373	0.7661	1.1862	6.1500	0.1929
Next Place: palato-alveolar	18.8611	28.4621	0.6627	15.0439	28.2766	0.5320	7.8455	26.7520	0.2933	-7.7580	25.0249	-0.3100	-23.8018	23.7335	-1.0029	-19.7638	21.0889	-0.9372	-19.1347	15.8067	-1.2105
Next Place: tense	116.1487	42.0438	2.7626	102.2658	41.5707	2.4600	98.5800	39.2200	2.5135	77.7105	36.6092	2.1227	52.6595	34.7482	1.5155	36.9165	30.8618	1.1962	15.1191	23.1333	0.6536
Next Manner: approximate	50.5858	40.6443	1.2446	38.4546	40.1741	0.9572	33.2742	37.8928	0.8781	9.1538	35.3808	0.2587	-16.0206	33.5677	-0.4773	-24.4749	29.8078	-0.8211	-23.0104	22.3279	-1.0306
Next Manner: flap	40.0406	40.4278	0.9904	35.4690	39.9647	0.8875	38.6081	37.7137	1.0237	22.4424	35.2360	0.6369	-1.9803	33.4434	-0.0592	-12.6861	29.6989	-0.4272	-17.6664	22.2388	-0.7944
Next Manner: fricative	45.1698	38.9056	1.1610	40.7260	38.4525	1.0591	38.6791	36.2606	1.0667	23.5466	33.8363	0.6959	2.9627	32.1014	0.0923	-11.7115	28.5086	-0.4108	-18.9557	21.3921	-0.8861
Next Manner: lax	-83.6326	33.1186	-2.5252	-91.4094	32.9064	-2.7779	-91.0089	31.1634	-2.9204	-86.2935	29.0828	-2.9672	-64.0923	27.5423	-2.3271	-35.5333	24.4191	-1.4551	-7.0592	18.2051	-0.3878
Next Manner: nasal	51.0658	41.0215	1.2449	46.8030	40.5442	1.1544	41.8323	38.2471	1.0937	21.8039	35.7052	0.6107	-2.9541	33.8886	-0.0872	-11.8202	30.0949	-0.3928	-10.2785	22.5441	-0.4559
Next Manner: stop	46.6044	39.7150	1.1735	41.3712	39.2293	1.0546	42.0792	37.0036	1.1372	22.8115	34.5692	0.6599	-2.5579	32.8194	-0.0779	-13.9410	29.1526	-0.4782	-20.3193	21.8392	-0.9304
Duration (log) x Frequency (log)	0.0019	0.0381	0.0505	0.0303	0.0371	0.8147	0.0287	0.0351	0.8189	0.0212	0.0335	0.6342	0.0236	0.0318	0.7431	0.0175	0.0284	0.6166	0.0167	0.0207	0.8050

i F2

	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	49.7251	185.7302	0.2677	100.4307	178.8287	0.5616	126.6252	174.5949	0.7253	222.2522	171.8643	1.2932	233.7899	164.9451	1.4174	155.1524	148.4066	1.0455	170.8993	118.8108	1.4384
Tense: past	-80.9010	74.2075	-1.0902	-106.7432	70.6987	-1.5098	-128.0701	68.3178	-1.8746	-159.0269	66.9232	-2.3763	-153.0595	64.1129	-2.3873	-112.9118	57.7202	-1.9562	-59.6334	46.3194	-1.2874
NDL Cue Strength	-383.9393	301.2894	-1.2743	-555.3075	288.4798	-1.9249	-624.8867	279.7244	-2.2339	-692.6175	274.0328	-2.5275	-649.8375	262.3393	-2.4771	-485.9790	235.5949	-2.0628	-186.3095	188.6162	-0.9878
Duration (log)	-0.1246	0.7449	-0.1673	-0.3191	0.7124	-0.4480	-0.2779	0.7088	-0.3921	-0.3217	0.7142	-0.4504	-0.2549	0.6940	-0.3673	-0.0856	0.6350	-0.1348	-0.2023	0.5150	-0.3928
Frequency (log)	-24.9611	30.4146	-0.8207	-26.6148	29.0034	-0.9176	-25.7739	28.1375	-0.9160	-18.8695	27.7080	-0.6810	-10.6002	26.6593	-0.3976	-7.9480	24.1377	-0.3293	-17.9488	19.4209	-0.9242
Previous Voicing: voiceless	-63.3338	102.9250	-0.6153	-102.0024	99.0192	-1.0301	-116.5203	96.5709	-1.2066	-96.7353	94.7820	-1.0206	-72.4691	90.7034	-0.7990	-41.8750	81.2322	-0.5155	9.8103	64.8890	0.1512
Previous Place: diphthong	-245.7165	107.7441	-2.2806	-115.2488	104.1071	-1.1070	-24.2676	103.3427	-0.2348	-6.1617	103.0376	-0.0598	-20.7334	99.3700	-0.2086	-28.6015	89.8007	-0.3185	-40.8187	72.0939	-0.5662
Previous Place: labial	107.1907	62.6069	1.7121	13.1070	59.3651	0.2208	-16.9833	57.2113	-0.2969	-31.4617	55.9927	-0.5619	-30.2867	53.5924	-0.5651	-35.6930	48.2319	-0.7400	-14.9309	38.7644	-0.3852
Previous Place: labio-dental	-99.3647	130.3413	-0.7623	-178.0048	123.9501	-1.4361	-216.8053	119.5203	-1.8140	-229.5892	116.9231	-1.9636	-174.7575	111.9442	-1.5611	-84.5646	100.6633	-0.8401	-0.4243	80.7159	-0.0053
Previous Place: lax	-102.3551	71.7907	-1.4257	46.0829	68.8670	0.6692	114.1450	67.0584	1.7022	129.9861	65.8345	1.9744	116.5745	63.0220	1.8497	110.5176	56.5481	1.9544	65.9579	45.2818	1.4566
Previous Place: palatal	215.4436	123.1206	1.7499	134.2143	118.7861	1.1299	140.9279	116.3052	1.2117	145.8541	114.3853	1.2751	136.8131	109.4837	1.2496	139.3486	97.9734	1.4223	144.1168	78.1548	1.8440
Previous Place: palato-alveolar	48.5306	167.5752	0.2896	72.6160	163.4592	0.4442	75.8388	159.9067	0.4743	94.3510	156.8621	0.6015	93.3761	150.1754	0.6218	81.1397	134.3487	0.6039	63.7083	106.8085	0.5965
Previous Place: tense	-163.1186	91.3578	-1.7855	-58.2089	87.5850	-0.6646	-10.9821	85.7449	-0.1281	-10.4416	84.4959	-0.1236	-52.3587	80.9754	-0.6466	-63.8908	72.6430	-0.8795	-63.1231	58.0859	-1.0867
Previous Manner: fricative	57.2652	155.7485	0.3677	225.9671	150.0161	1.5063	290.6069	146.1540	1.9884	284.8775	143.3934	1.9867	228.4384	137.2972	1.6638	158.8211	123.0975	1.2902	30.0299	98.3513	0.3053
Previous Manner: nasal	-167.9185	73.4891	-2.2849	-103.3949	69.6708	-1.4840	-46.1678	67.1527	-0.6875	-30.5862	65.7051	-0.4655	-21.4292	62.8857	-0.3408	-0.1784	56.6205	-0.0032	-5.4200	45.5155	-0.1191
Previous Manner: stop	-172.8293	108.9548	-1.5862	-1.9243	104.7592	-0.0184	54.0484	102.3450	0.5281	64.5348	100.6149	0.6414	56.0974	96.3635	0.5821	37.6091	86.3507	0.4355	-30.6725	68.9685	-0.4447
Next Voicing: voiceless	32.0093	33.4845	0.9559	-16.7965	32.3774	-0.5188	-50.2631	31.6706	-1.5871	-67.5082	31.1583	-2.1666	-56.4338	29.8790	-1.8887	-34.2399	26.8226	-1.2765	-14.0927	21.4132	-0.6581
Next Place: dental	97.9057	51.8596	1.8879	82.3964	50.3248	1.6373	51.5661	49.1969	1.0482	40.5771	48.3219	0.8397	44.2365	46.2956	0.9555	47.7491	41.4952	1.1507	32.9215	33.0730	0.9954
Next Place: diphthong	376.8502	151.2324	2.4919	284.8121	146.8850	1.9390	210.3969	143.9658	1.4614	78.0190	141.5278	0.5513	9.9930	135.4506	0.0738	5.7765	121.1252	0.0477	-28.2372	96.4500	-0.2928
Next Place: glottal	37.8356	39.9121	0.9480	-13.7644	38.7528	-0.3552	-68.8881	37.9906	-1.8133	-113.9147	37.3840	-3.0471	-113.9401	35.8348	-3.1796	-94.3354	32.1282	-2.9362	-58.7910	25.6107	-2.2956

Next Place: labial	48.5360	35.5839	1.3640	97.8556	34.5267	2.8342	140.1695	33.7364	4.1548	150.3183	33.1749	4.5311	142.1637	31.8446	4.4643	116.8782	28.6330	4.0819	75.7604	22.8570	3.3145
Next Place: labio-dental	72.9095	72.4795	1.0059	39.5506	70.2230	0.5632	-21.6209	69.4093	-0.3115	-54.7445	68.9819	-0.7936	-58.1776	66.4433	-0.8756	-33.5227	59.9932	-0.5588	-34.2444	48.1176	-0.7117
Next Place: lax	667.4166	184.8106	3.6114	617.8534	179.8491	3.4354	570.9476	176.3722	3.2372	434.9418	173.3820	2.5086	303.1262	166.0366	1.8257	141.5192	148.5848	0.9524	-1.4912	118.3189	-0.0126
Next Place: palatal	94.3635	41.2642	2.2868	77.7259	39.6652	1.9595	66.8576	38.5406	1.7347	30.9468	37.8427	0.8178	-8.3836	36.3223	-0.2308	-26.7075	32.7263	-0.8161	-38.4316	26.2200	-1.4657
Next Place: palato-alveolar	258.0967	102.1735	2.5261	174.1675	99.6196	1.7483	100.9472	98.0581	1.0295	-8.1691	96.6376	-0.0845	-73.7207	92.5931	-0.7962	-73.6270	82.8694	-0.8885	-70.9264	65.9812	-1.0749
Next Place: tense	403.1223	151.5845	2.6594	329.3204	147.3147	2.2355	288.7480	144.4649	1.9987	173.2123	142.0376	1.2195	103.8791	135.9513	0.7641	81.7693	121.5732	0.6726	25.1417	96.7945	0.2597
Next Manner: approximate	585.5659	146.6328	3.9934	452.0785	142.3945	3.1748	363.8219	139.4817	2.6084	216.9334	137.0957	1.5823	138.5217	131.2584	1.0553	131.4036	117.4712	1.1186	68.4333	93.5881	0.7312
Next Manner: flap	320.0967	145.7318	2.1965	197.9924	141.4894	1.3993	148.9807	138.6619	1.0744	36.1045	136.3430	0.2648	-16.1711	130.5547	-0.1239	10.3729	116.8559	0.0888	-13.4507	93.1246	-0.1444
Next Manner: fricative	358.7871	140.5391	2.5529	304.0571	136.4364	2.2286	287.1416	133.6948	2.1477	172.2922	131.4316	1.3109	90.4878	125.8172	0.7192	64.0956	112.5574	0.5694	3.9410	89.6483	0.0440
Next Manner: lax	-265.8399	118.6318	-2.2409	-341.4229	115.7305	-2.9502	-364.9032	113.4993	-3.2150	-370.7277	111.5811	-3.3225	-311.8756	106.9601	-2.9158	-148.0065	95.8543	-1.5441	-35.4836	76.3319	-0.4649
Next Manner: nasal	373.1479	147.9537	2.5221	243.6489	143.7274	1.6952	133.2729	140.8466	0.9462	-12.1302	138.4354	-0.0876	-70.4742	132.5059	-0.5319	-51.4289	118.5219	-0.4339	-58.4248	94.3896	-0.6190
Next Manner: stop	360.9791	143.2013	2.5208	261.0548	138.9834	1.8783	193.7342	136.2053	1.4224	74.1546	133.9249	0.5537	4.4319	128.2105	0.0346	12.0953	114.7160	0.1054	-16.9340	91.4051	-0.1853
Duration (log) x Frequency (log)	0.1109	0.1268	0.8747	0.1807	0.1215	1.4870	0.2106	0.1209	1.7420	0.2486	0.1215	2.0453	0.2573	0.1180	2.1807	0.2277	0.1078	2.1126	0.2069	0.0872	2.3729

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	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	12.7164	62.7500	0.2027	-2.5633	59.0881	-0.0434	-20.9963	54.2128	-0.3873	-40.9974	49.0871	-0.8352	-42.0905	44.9615	-0.9361	-42.7592	40.6062	-1.0530	-32.0488	34.1878	-0.9374
Tense: past	26.6366	14.1484	1.8827	29.8519	13.3986	2.2280	25.1018	12.3838	2.0270	20.1436	11.1379	1.8086	15.2424	10.2063	1.4934	13.3672	9.2639	1.4429	5.6772	7.9414	0.7149
NDL Cue Strength	-17.5672	26.6861	-0.6583	-22.5897	25.3060	-0.8927	-26.0651	23.4134	-1.1133	-31.1411	21.0564	-1.4789	-35.2843	19.2887	-1.8293	-32.3865	17.5187	-1.8487	-14.3627	15.0135	-0.9567
Duration (log)	0.2040	0.3324	0.6136	0.3155	0.3078	1.0252	0.5115	0.2701	1.8935	0.6219	0.2573	2.4169	0.4635	0.2320	1.9976	0.4302	0.2097	2.0520	0.4096	0.1574	2.6017
Frequency (log)	2.7847	5.9907	0.4648	5.8851	5.5916	1.0525	7.7570	5.0871	1.5248	7.4339	4.6380	1.6028	3.9586	4.2510	0.9312	2.8925	3.8274	0.7557	2.0000	3.1965	0.6257
Previous Voicing: voiceless	20.0890	11.0205	1.8229	27.2436	10.4686	2.6024	27.8210	9.6807	2.8739	25.6357	8.7730	2.9221	21.3258	8.0366	2.6536	17.2977	7.3176	2.3639	11.2370	6.2861	1.7876
Previous Place: glottal	10.2190	31.8859	0.3205	6.2313	29.9691	0.2079	-10.6941	27.5863	-0.3877	-20.7662	24.8109	-0.8370	-19.5239	22.7727	-0.8573	-15.9156	20.5422	-0.7748	-10.8142	17.5534	-0.6161
Previous Place: labial	65.8682	32.8108	2.0075	59.6538	30.6551	1.9460	50.9160	28.0329	1.8163	34.0239	25.2526	1.3473	24.8227	23.2118	1.0694	7.7545	20.8138	0.3726	-7.0742	17.5210	-0.4038
Previous Place: labio-dental	-58.4527	49.5959	-1.1786	-70.3862	47.1342	-1.4933	-58.7291	43.7262	-1.3431	-49.1786	39.3097	-1.2511	-42.3845	35.9945	-1.1775	-35.1689	32.8419	-1.0709	-22.2896	28.4405	-0.7837
Previous Place: lax	11.4378	64.3834	0.1777	7.7731	60.9924	0.1274	5.7403	56.4134	0.1018	5.0274	50.7164	0.0991	20.4614	46.4707	0.4403	24.2989	42.1726	0.5762	20.7836	36.1720	0.5746
Previous Place: palatal	16.6662	20.6480	0.8072	7.4899	19.5239	0.3836	2.1456	17.9935	0.1192	-1.3480	16.2641	-0.0829	-0.6497	14.9091	-0.0436	-0.7963	13.5253	-0.0589	-5.9850	11.5297	-0.5191
Previous Place: palato-alveolar	-32.5024	37.4820	-0.8671	-30.5528	35.5953	-0.8583	-27.1524	32.9903	-0.8230	-15.2450	29.5990	-0.5151	-6.5243	27.0854	-0.2409	-3.0663	24.5976	-0.1247	-6.1141	21.1047	-0.2897
Previous Place: tense	6.1680	64.6301	0.0954	1.2893	61.1479	0.0211	-10.4257	56.4844	-0.1846	-9.3948	50.8005	-0.1849	11.7918	46.5399	0.2534	20.5419	42.1868	0.4869	18.3195	36.0995	0.5075
Previous Manner: approximate	-14.1602	63.1312	-0.2243	-11.7419	59.7894	-0.1964	-10.5302	55.2746	-0.1905	-0.1597	49.6889	-0.0032	15.3481	45.5083	0.3373	21.5146	41.2704	0.5213	23.1571	35.2968	0.6561
Previous Manner: flap	-56.7881	80.4439	-0.7059	-59.7237	76.2509	-0.7833	-54.3930	70.5543	-0.7709	-28.9098	63.4977	-0.4553	-4.5937	58.1817	-0.0790	5.2699	52.9013	0.0996	6.9111	45.5078	0.1519
Previous Manner: fricative	-11.4596	56.7425	-0.2020	-20.5209	53.6751	-0.3823	-21.0576	49.5928	-0.4246	-8.0022	44.5352	-0.1797	14.5429	40.7995	0.3564	18.6773	36.9654	0.5053	12.4170	31.6287	0.3926
Previous Manner: nasal	2.0889	65.2602	0.0320	-20.3221	61.6804	-0.3295	-42.3353	56.9407	-0.7435	-17.7102	51.2313	-0.3457	8.1136	46.9439	0.1728	13.0758	42.5598	0.3072	12.8193	36.4621	0.3516
Previous Manner: stop	-13.2429	59.8329	-0.2213	-11.9348	56.6038	-0.2108	-9.2267	52.2966	-0.1764	5.6065	47.0034	0.1193	25.8122	43.0630	0.5994	27.8017	39.0467	0.7120	24.0757	33.4184	0.7204
Next Voicing: voiceless	-12.7404	7.4990	-1.6989	-10.0643	7.1191	-1.4137	-2.0456	6.5832	-0.3107	7.9474	5.9442	1.3370	6.9871	5.4384	1.2848	6.3666	4.9517	1.2857	2.3198	4.2425	0.5468
Next Place: dental	-6.6648	21.7429	-0.3065	-4.1787	20.6378	-0.2025	1.5237	19.1006	0.0798	-0.0783	17.2072	-0.0046	-7.0663	15.7320	-0.4492	-6.4420	14.3455	-0.4491	-11.1461	12.3661	-0.9013
Next Place: diphthong	60.0575	21.4267	2.8029	49.4830	20.3462	2.4321	45.9720	18.8459	2.4394	48.7735	16.9850	2.8716	45.3615	15.5489	2.9173	39.2811	14.1848	2.7692	21.7619	12.2537	1.7759
Next Place: glottal	11.4504	8.0867	1.4160	8.8372	7.6731	1.1517	10.1300	7.0931	1.4282	12.1188	6.3999	1.8936	6.4151	5.8511	1.0964	3.3103	5.3265	0.6215	-1.4520	4.5619	-0.3183
Next Place: labial	0.7393	11.9969	0.0616	2.0330	11.3821	0.1786	4.6803	10.5354	0.4442	6.2364	9.4867	0.6574	7.1765	8.6715	0.8276	7.4514	7.8952	0.9438	2.5998	6.7923	0.3828
Next Place: labio-dental	29.9470	20.4447	1.4648	27.7846	19.3772	1.4339	22.9730	17.9230	1.2818	18.1191	16.1327	1.1231	3.5940	14.7650	0.2434	-1.3007	13.4404	-0.0968	-6.2371	11.5693	-0.5391
Next Place: lax	45.8707	12.1953	3.7614	40.0213	11.5796	3.4562	35.1913	10.7077	3.2865	31.9562	9.6719	3.3040	19.3259	8.8476	2.1843	11.9931	8.0673	1.4866	1.6624	6.9301	0.2399
Next Place: palatal	18.4002	17.0609	1.0785	16.6264	16.0982	1.0328	19.4079	14.8212	1.3095	20.3968	13.3605	1.5266	19.2166	12.2447	1.5694	14.9996	11.0902	1.3525	5.0353	9.4473	0.5330
Next Place: palato-alveolar	-6.0019	34.7991	-0.1725	-4.9343	33.0566	-0.1493	-1.5950	30.6396	-0.0521	-6.6945	27.5425	-0.2431	-4.2500	25.1932	-0.1687	-3.0962	22.9834	-0.1347	-0.8582	19.8582	-0.0432
Next Place: tense	116.4430	49.7914	2.3386	117.5185	47.3268	2.4831	121.3546	43.9016	2.7642	127.3257	39.4276	3.2294	116.8258	36.0818	3.2378	89.7473	32.9166	2.7265	36.0671	28.4574	1.2674
Next Manner: approximate	9.1043	17.9313	0.5077	7.4571	17.0158	0.4382	4.0008	15.7499	0.2540	7.0724	14.1823	0.4987	1.1740	12.9677	0.0905	-1.0260	11.8221	-0.0868	-2.6795	10.1853	-0.2631
Next Manner: flap	10.2369	7.8693	1.3009	4.6186	7.4709	0.6182	3.8014	6.9103	0.5501	6.0715	6.2333	0.9740	1.2834	5.7036	0.2250	0.4325	5.1930	0.0833	-1.4309	4.4533	-0.3213
Next Manner: fricative	-17.0146	14.9455	-1.1384	-12.9292	14.1883	-0.9113	-4.7062	13.1395	-0.3582	-0.0761	11.8178	-0.0064	7.4229	10.8017	0.6872	10.4924	9.8540	1.0648	10.3137	8.5094	1.2120
Next Manner: nasal	14.0988	14.1869	0.9938	10.5691	13.4419	0.7863	9.7559	12.4235	0.7853	13.0136	11.1833	1.1637	9.5240	10.2217	0.9317	8.5404	9.2841	0.9199	6.6234	7.9418	0.8340
Duration (log) x Frequency (log)	0.0295	0.0518	0.5690	-0.0010	0.0481	-0.0214	-0.0341	0.0425	-0.8013	-0.0474	0.0402	-1.1787	-0.0143	0.0363	-0.3930	-0.0056	0.0329	-0.1692	-0.0109	0.0253	-0.4287

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	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	14.0417	173.3539	0.0810	60.7836	164.8450	0.3687	81.6507	151.8043	0.5379	101.9420	134.2837	0.7592	64.8000	113.1728	0.5726	57.8920	88.9150	0.6511	42.7461	60.0350	0.7120
Tense: past	-49.1860	39.2922	-1.2518	-40.1749	37.5156	-1.0709	-40.0554	34.7717	-1.1520	-31.0498	30.8868	-1.0053	-16.2221	26.0892	-0.6218	-8.0240	20.4900	-0.3916	4.6907	13.7155	0.3420
NDL Cue Strength	45.1995	74.2523	0.6087	56.2775	70.9206	0.7935	57.1684	65.7930	0.8689	67.5121	58.4666	1.1547	38.9583	49.3609	0.7893	34.9233	38.7351	0.9016	24.3548	25.9044	0.9402
Duration (log)	2.3405	0.8600	2.7217	2.1338	0.8002	2.6668	2.0703	0.7228	2.8641	1.5151	0.6360	2.3822	1.1664	0.5279	2.2093	1.0919	0.4167	2.6204	0.4526	0.3116	1.4524
Frequency (log)	13.3148	16.4270	0.8105	15.2094	15.5639	0.9772	16.1666	14.2501	1.1345	10.8228	12.5753	0.8606	12.3941	10.6149	1.1676	11.9231	8.3545	1.4271	4.0567	5.6888	0.7131
Previous Voicing: voiceless	-13.5326	31.1061	-0.4350	-2.6654	29.7273	-0.0897	2.0112	27.6283	0.0728	9.4912	24.5407	0.3868	16.9692	20.6964	0.8199	19.9383	16.1703	1.2330	13.5733	10.7705	1.2602

Previous Place: glottal	166.7517	88.8657	1.8764	136.1090	84.6210	1.6085	99.5715	77.8701	1.2787	66.9076	68.8438	0.9719	35.9282	58.2228	0.6171	10.3166	45.7717	0.2254	-10.6302	30.5538	-0.3479
Previous Place: labial	252.9889	90.0936	2.8081	198.6200	85.5818	2.3208	164.2691	78.2594	2.0990	114.7165	68.9397	1.6640	118.5546	58.2890	2.0339	104.9675	46.0085	2.2815	101.6170	30.9173	3.2867
Previous Place: labio-dental	49.4773	139.0330	0.3559	44.7737	132.8842	0.3369	21.2079	123.7064	0.1714	-5.5253	110.2354	-0.0501	-21.5390	93.1091	-0.2313	-35.1553	73.0191	-0.4815	-16.3807	48.8178	-0.3355
Previous Place: lax	23.4105	180.1426	0.1300	-15.1624	171.8321	-0.0882	-37.5683	159.1448	-0.2361	-42.5189	141.2335	-0.3011	-27.9272	119.1562	-0.2344	-48.9183	93.4883	-0.5233	-23.7675	62.4642	-0.3805
Previous Place: palatal	169.9094	57.4141	2.9594	152.9309	54.7764	2.7919	117.8887	50.6923	2.3256	95.5599	44.9694	2.1250	77.2614	37.9669	2.0350	44.1229	29.8046	1.4804	31.1518	20.0034	1.5573
Previous Place: palato-alveolar	-64.1963	105.3589	-0.6093	-76.5142	100.5274	-0.7611	-93.9609	93.2020	-1.0081	-88.2712	82.7139	-1.0672	-75.7632	69.6623	-1.0876	-59.7559	54.5650	-1.0951	-20.4377	36.3942	-0.5616
Previous Place: tense	-2.4044	180.6243	-0.0133	-56.7848	172.1678	-0.3298	-102.7639	159.2551	-0.6453	-134.2351	141.2266	-0.9505	-116.8306	119.1373	-0.9806	-136.7749	93.5042	-1.4628	-82.3978	62.5362	-1.3176
Previous Manner: approximate	-39.7612	177.1108	-0.2245	-86.9459	168.7730	-0.5152	-113.6037	156.1078	-0.7277	-131.8239	138.3849	-0.9526	-129.8438	116.6197	-1.1134	-122.7271	91.4546	-1.3419	-71.9431	61.1281	-1.1769
Previous Manner: flap	-162.7585	225.0937	-0.7231	-258.8928	214.7877	-1.2053	-277.6821	199.2324	-1.3938	-271.1151	177.0747	-1.5311	-255.5730	149.4889	-1.7096	-213.4064	117.3041	-1.8193	-124.1784	78.4723	-1.5824
Previous Manner: fricative	-78.2980	158.5166	-0.4939	-129.7817	151.0472	-0.8592	-154.9972	139.6382	-1.1100	-159.3967	123.7969	-1.2876	-136.2504	104.4224	-1.3048	-133.2546	81.9925	-1.6252	-73.7668	54.8373	-1.3452
Previous Manner: nasal	-91.6497	182.5342	-0.5021	-142.9121	173.9135	-0.8217	-167.7349	160.7927	-1.0432	-163.3111	142.5813	-1.1454	-138.5337	120.3196	-1.1514	-145.7788	94.4636	-1.5432	-70.6716	63.2156	-1.1179
Previous Manner: stop	-80.7415	167.1261	-0.4831	-135.8519	159.2494	-0.8531	-152.0852	147.2881	-1.0326	-162.9831	130.6533	-1.2474	-151.9372	110.2197	-1.3785	-139.5222	86.5524	-1.6120	-86.6077	57.9593	-1.4943
Next Voicing: voiceless	-43.1017	20.9941	-2.0530	-48.9951	20.0487	-2.4438	-48.8127	18.6248	-2.6208	-34.5435	16.5615	-2.0858	-24.9488	13.9681	-1.7861	-17.4035	10.9408	-1.5907	-6.2380	7.3263	-0.8515
Next Place: dental	-54.3707	60.9237	-0.8924	-13.9332	58.1836	-0.2395	11.6041	54.1071	0.2145	22.2648	48.1736	0.4622	22.3439	40.6512	0.5496	22.1241	31.8546	0.6945	20.4989	21.3395	0.9606
Next Place: diphthong	59.6410	60.1296	0.9919	42.9111	57.4440	0.7470	48.3165	53.4383	0.9042	57.4424	47.5837	1.2072	66.6135	40.1734	1.6581	60.0098	31.4839	1.9060	36.1771	21.0714	1.7169
Next Place: glottal	-59.3641	22.6527	-2.6206	-61.7809	21.6245	-2.8570	-52.6282	20.0788	-2.6211	-33.0085	17.8495	-1.8493	-20.4261	15.0487	-1.3573	-14.4299	11.7854	-1.2244	-7.1798	7.8939	-0.9095
Next Place: labial	118.6449	34.2662	3.4624	134.4329	32.6456	4.1179	139.1107	30.2426	4.5998	119.9024	26.8002	4.4739	97.4938	22.5309	4.3271	69.3751	17.5849	3.9452	41.6605	11.7139	3.5565
Next Place: labio-dental	47.7027	57.1604	0.8345	77.7863	54.5610	1.4257	84.8056	50.6550	1.6742	88.9946	45.0586	1.9751	85.4719	38.0403	2.2469	68.1989	29.8403	2.2855	43.0107	19.9886	2.1518
Next Place: lax	-26.1286	34.0351	-0.7677	-35.1713	32.5090	-1.0819	-34.5687	30.2366	-1.1433	-28.4803	26.9217	-1.0579	-19.5677	22.7220	-0.8612	-15.6958	17.8100	-0.8813	-10.6749	11.9604	-0.8925
Next Place: palatal	113.6596	47.3616	2.3998	110.2998	45.1255	2.4443	91.6350	41.6660	2.1993	76.8013	36.9264	2.0798	77.6899	31.1759	2.4920	48.4645	24.5107	1.9773	42.2909	16.4731	2.5673
Next Place: palato-alveolar	-81.5292	97.5352	-0.8359	-69.1244	93.1586	-0.7420	-53.8674	86.6695	-0.6215	-52.7292	77.2106	-0.6829	-47.5350	65.1654	-0.7295	-36.8393	51.0927	-0.7210	-18.2671	34.2111	-0.5340
Next Place: tense	-25.7186	139.1734	-0.1848	-5.4241	132.9831	-0.0408	27.1931	123.7817	0.2197	74.1422	110.3222	0.6721	117.5067	93.1611	1.2613	121.9170	73.0928	1.6680	80.2253	48.9483	1.6390
Next Manner: approximate	211.7525	50.4796	4.1948	200.3314	48.1680	4.1590	196.9055	44.7399	4.4011	183.4621	39.7872	4.6111	143.8973	33.5422	4.2900	84.2518	26.2676	3.2074	34.1384	17.5897	1.9408
Next Manner: flap	-2.5209	21.9986	-0.1146	-6.5595	21.0118	-0.3122	-4.9697	19.5219	-0.2546	5.2156	17.3619	0.3004	10.7869	14.6474	0.7364	9.2426	11.4769	0.8053	7.4078	7.6857	0.9638
Next Manner: fricative	41.3540	41.8540	0.9881	3.5336	39.9693	0.0884	-8.2261	37.1822	-0.2212	-11.2019	33.1202	-0.3382	-5.0543	27.9500	-0.1808	-5.0879	21.9085	-0.2322	-4.1047	14.6825	-0.2796
Next Manner: nasal	27.6660	40.1813	0.6885	15.6211	38.2854	0.4080	22.6695	35.4245	0.6399	41.5574	31.3785	1.3244	41.7887	26.3929	1.5833	36.3525	20.6362	1.7616	19.8868	13.7760	1.4436
Duration (log) x Frequency (log)	-0.0575	0.1360	-0.4231	-0.0803	0.1273	-0.6309	-0.1185	0.1157	-1.0240	-0.0668	0.1020	-0.6550	-0.0425	0.0851	-0.5003	-0.0581	0.0670	-0.8677	0.0071	0.0490	0.1448

ε F1

	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	202.7220	52.1005	3.8910	136.8474	48.7883	2.8049	107.0937	47.2003	2.2689	91.7892	44.3356	2.0703	68.0630	39.6659	1.7159	39.2923	34.2996	1.1456	-17.7019	22.5675	-0.7844
Tense: past	-56.2118	14.0110	-4.0120	-42.2427	12.8082	-3.2981	-23.8975	11.9621	-1.9978	-10.8009	11.0122	-0.9808	-4.4152	9.8146	-0.4499	-2.8511	8.3606	-0.3410	-0.2110	6.0791	-0.0347
NDL Cue Strength	53.4132	30.4586	1.7536	35.7260	27.7132	1.2891	15.8328	25.8161	0.6133	2.8785	23.6910	0.1215	-3.4876	21.0671	-0.1655	-2.3538	17.9774	-0.1309	-1.7087	13.3463	-0.1280
Duration (log)	-0.1278	0.3455	-0.3700	0.6027	0.3045	1.9794	0.7390	0.2978	2.4815	0.6696	0.2890	2.3173	0.5527	0.2598	2.1278	0.5802	0.2238	2.5927	0.7293	0.1661	4.3897
Frequency (log)	-28.0076	9.4633	-2.9596	-17.4668	8.7718	-1.9912	-11.9017	8.3886	-1.4188	-10.7765	7.7985	-1.3819	-8.5460	6.9542	-1.2289	-6.5148	5.9849	-1.0885	1.3670	4.0450	0.3380
Previous Voicing: voiceless	-70.2231	24.1162	-2.9119	-47.7541	21.8134	-2.1892	-20.6514	20.2390	-1.0204	-6.4473	18.5279	-0.3480	11.8565	16.4769	0.7196	15.3315	14.0031	1.0949	10.3332	10.5502	0.9794
Previous Place: glottal	73.7704	44.2039	1.6689	29.9368	40.7189	0.7352	-4.0812	38.2246	-0.1068	-8.2375	35.2044	-0.2340	-17.1427	31.3535	-0.5468	-16.9637	26.7360	-0.6345	-1.3098	19.1200	-0.0685
Previous Place: labial	-24.6756	21.4012	-1.1530	-29.9889	19.8778	-1.5087	-41.9195	18.6831	-2.2437	-46.0726	17.2597	-2.6694	-39.8578	15.3994	-2.5883	-27.7771	13.1680	-2.1094	-11.2048	9.1795	-1.2206
Previous Place: labio-dental	61.6705	41.5294	1.4850	41.4786	38.4397	1.0791	28.0547	36.3979	0.7708	27.1857	33.6855	0.8070	20.8286	30.0369	0.6934	13.8744	25.7174	0.5395	16.9957	17.8100	0.9543
Previous Place: lax	-32.0188	40.8224	-0.7843	-42.4729	36.6399	-1.1592	-55.1654	34.1447	-1.6156	-72.7444	31.6716	-2.2968	-74.8502	28.2187	-2.6525	-60.9101	24.0784	-2.5297	-50.6912	18.2740	-2.7739
Previous Place: palatal	-0.4530	30.4717	-0.0149	21.3100	27.5178	0.7744	23.5327	25.5670	0.9204	12.7662	23.5506	0.5421	3.9606	20.9861	0.1887	-2.2412	17.8621	-0.1255	-8.8137	13.3986	-0.6578
Previous Place: tense	-8.8150	62.6225	-0.1408	-4.8896	56.4053	-0.0867	-8.3646	51.7189	-0.1617	-18.8576	47.1950	-0.3996	-21.6677	42.0646	-0.5151	-18.7640	35.6893	-0.5258	-30.9040	27.1503	-1.1383
Previous Manner: fricative	6.0640	35.4337	0.1711	-1.8042	32.2262	-0.0560	-17.3284	29.9862	-0.5779	-27.7167	27.5948	-1.0044	-35.6943	24.5882	-1.4517	-29.4341	20.9385	-1.4057	-24.2351	15.5925	-1.5543
Previous Manner: nasal	35.1188	21.1845	1.6578	41.9161	19.5889	2.1398	41.2617	18.4055	2.2418	30.3618	16.9987	1.7861	23.3607	15.1602	1.5409	17.1210	12.9548	1.3216	-0.2232	9.1319	-0.0244
Previous Manner: stop	12.6730	25.5036	0.4969	-8.2511	23.0816	-0.3575	-20.6537	21.3553	-0.9671	-24.1538	19.5958	-1.2326	-21.2636	17.4644	-1.2175	-10.6031	14.8303	-0.7150	-10.9411	11.1572	-0.9806
Next Voicing: voiceless	-39.7133	15.2563	-2.6031	-30.4440	13.7542	-2.2134	-19.1692	12.7941	-1.4983	-2.8894	11.8191	-0.2445	0.4119	10.5326	0.0391	-1.0890	8.9763	-0.1213	6.1067	6.8188	0.8956
Next Place: dental	-104.7997	42.0556	-2.4919	-59.4239	37.9035	-1.5678	-23.4004	34.9956	-0.6687	-11.9271	31.9755	-0.3730	-12.7749	28.3958	-0.4499	-11.7641	24.1833	-0.4865	5.8425	18.2942	0.3194
Next Place: diphthong	52.8734	35.0921	1.5067	29.1071	31.6625	0.9193	-3.3786	29.1984	-0.1157	-11.6585	26.6684	-0.4372	-15.3691	23.7082	-0.6483	-13.0789	20.1494	-0.6491	1.2491	15.0926	0.0828
Next Place: glottal	-18.6300	15.3527	-1.2135	-25.2938	13.8254	-1.8295	-28.3440	12.8822	-2.2002	-20.9013	11.9159	-1.7541	-20.6356	10.6176	-1.9435	-19.2587	9.0496	-2.1281	-6.7478	6.8802	-0.9808
Next Place: labial	79.6264	25.9048	3.0738	40.4287	23.3553	1.7310	10.3446	21.6661	0.4775	11.2364	19.7936	0.5677	7.9786	17.5699	0.4541	4.9646	14.9434	0.3322	7.9263	11.2173	0.7066
Next Place: labio-dental	-188.4378	59.7306	-3.1548	-114.7450	54.3038	-2.1130	-77.1986	50.4867	-1.5291	-49.1799	46.2930	-1.0624	-33.1292	41.1784	-0.8045	-21.1206	35.0625	-0.6024	9.8449	26.3142	0.3741
Next Place: lax	74.8924	26.2598	2.8520	56.2056	23.9047	2.3512	37.1299	22.1123	1.6792	28.4091	20.2385	1.4037	15.5410	18.0141	0.8627	14.6633	15.3331	0.9563	17.7397	11.3981	1.5564
Next Place: palatal	-22.0538	32.7152	-0.6741	3.0410	29.4073	0.1034	23.8464	27.2203	0.8761	41.0917	24.9880	1.6445	46.3498	22.2313	2.0849	38.9563	18.9129	2.0598	23.3485	14.4148	1.6198
Next Manner: flap	43.7035	21.0900	2.0722	22.6913	19.2612	1.1781	0.2093	17.9772	0.0116	1.6832	16.4525	0.1023	7.9755	14.6181	0.5456	14.2497	12.4632	1.1433	21.2192	9.0640	2.3410
Next Manner: fricative	118.2699	41.1287	2.8756	66.1214	37.0815	1.7831	54.9546	34.1676	1.6084	43.0533	31.1539	1.3820	36.5829	27.6635	1.3224	29.2108	23.5565	1.2400	12.9948	17.7660	0.7314
Next Manner: nasal	12.3121	25.0862	0.4908	19.8798	23.1649	0.8582	12.4318	21.7114	0.5726	13.6355	19.8922	0.6855	13.9775	17.6822	0.7905	16.1481	15.1035	1.0692	18.4268	10.6881	1.7240
Next Manner: stop	69.3574	23.5092	2.9502	50.5878	21.3317	2.3715	33.4751	19.9408	1.6787	27.1366	18.3496	1.4789	27.0563	16.3210	1.6578	27.0379	13.9209	1.9423	20.8563	10.2676	2.0313
Duration (log) x Frequency (log)	0.0376	0.0564	0.6666	-0.0763	0.0498	-1.5331	-0.0799	0.0479	-1.6685	-0.0459	0.0455	-1.0092	-0.0140	0.0407	-0.3437	-0.0139	0.0348	-0.3989	-0.0469	0.0259	-1.8068

ε F2

	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	389.9283	102.2726	3.8126	262.8248	94.3889	2.7845	174.7433	85.6914	2.0392	137.0918	75.5531	1.8145	115.2171	64.6566	1.7820	94.8533	51.0895	1.8566	41.3221	34.8690	1.1851
Tense: past	-106.3981	31.5404	-3.3734	-77.4256	29.3729	-2.6360	-49.1632	26.7342	-1.8390	-30.7109	23.5183	-1.3058	-15.9099	20.1557	-0.7894	-6.8824	15.1990	-0.4528	-3.5865	10.2824	-0.3488
NDL Cue Strength	29.1190	71.6164	0.4066	-21.9925	66.7137	-0.3297	-77.9642	60.6191	-1.2861	-95.8661	53.1413	-1.8040	-90.7448	45.3461	-2.0012	-71.5942	33.4768	-2.1386	-36.5772	22.4118	-1.6320
Duration (log)	-0.2672	0.7186	-0.3718	0.2124	0.6629	0.3204	0.3049	0.6031	0.5056	0.2012	0.5302	0.3795	0.0554	0.4548	0.1218	-0.1401	0.3430	-0.4084	0.1492	0.2309	0.6461
Frequency (log)	-31.0222	19.0328	-1.6299	-14.6833	17.6036	-0.8341	-4.7858	15.9639	-0.2998	-5.1746	14.0461	-0.3684	-4.4081	12.0155	-0.3669	-5.5998	9.3753	-0.5973	-1.9125	6.3784	-0.2998
Previous Voicing: voiceless	-187.1357	56.5391	-3.3098	-174.5247	52.8122	-3.3046	-149.6116	48.1410	-3.1078	-127.6899	42.3592	-3.0145	-100.7425	36.3488	-2.7715	-82.9743	27.0161	-3.0713	-57.9575	18.2051	-3.1836
Previous Place: glottal	282.3764	94.6366	2.9838	229.2423	88.1322	2.6011	158.6985	80.3025	1.9763	101.1417	70.8968	1.4266	39.3736	60.7617	0.6480	0.9973	47.0035	0.0212	-19.5315	31.9338	-0.6116
Previous Place: labial	6.1175	45.2883	0.1351	-5.0188	42.0929	-0.1192	-14.2079	38.2471	-0.3715	-14.4164	33.6531	-0.4284	-15.5904	28.7769	-0.5418	-7.8431	22.1637	-0.3539	-1.4979	15.0528	-0.0995
Previous Place: labio-dental	-35.5769	85.1119	-0.4180	-41.8601	79.2794	-0.5280	-55.2226	72.2839	-0.7640	-65.5437	63.8556	-1.0264	-54.0303	54.7329	-0.9872	-25.5121	42.5679	-0.5993	-17.8457	28.9486	-0.6165
Previous Place: lax	-86.7571	96.4274	-0.8997	-39.7705	89.8725	-0.4425	-8.7116	81.6788	-0.1067	16.3670	71.5894	0.2286	15.4770	61.2654	0.2526	7.7479	45.0576	0.1720	-3.4265	30.2802	-0.1132
Previous Place: palatal	122.9756	71.7277	1.7145	123.3698	66.8111	1.8465	119.1318	60.7679	1.9604	105.7966	53.3617	1.9826	79.1965	45.7065	1.7327	58.6160	33.9530	1.7264	23.9186	22.8760	1.0456
Previous Place: tense	111.5994	155.2016	0.7191	96.7452	144.3041	0.6704	100.4752	130.8259	0.7680	99.2801	114.3247	0.8684	68.7060	97.4239	0.7052	42.5922	71.1515	0.5986	23.3242	47.7211	0.4888
Previous Manner: fricative	150.3038	83.1822	1.8069	176.1246	77.5699	2.2705	183.9101	70.6326	2.6038	171.4022	62.1035	2.7599	142.7250	53.2386	2.6809	116.3009	39.6648	2.9321	78.5967	26.7448	2.9388
Previous Manner: nasal	-11.1976	45.7796	-0.2446	17.5425	42.6130	0.4117	42.1427	38.7586	1.0873	52.4623	34.1058	1.5382	54.0509	29.1905	1.8517	44.9802	22.2896	2.0180	27.1201	15.1127	1.7945
Previous Manner: stop	69.1572	60.7195	1.1390	61.0754	56.5557	1.0799	50.6062	51.4447	0.9837	49.2219	45.1666	1.0898	45.0716	38.6944	1.1648	29.7996	28.6916	1.0386	23.9139	19.3406	1.2365
Next Voicing: voiceless	-35.9258	36.3504	-0.9883	-14.3342	33.9063	-0.4228	-5.1402	30.8319	-0.1667	-10.4063	27.0418	-0.3848	-9.4575	23.1180	-0.4091	-9.6281	17.0089	-0.5661	-9.1438	11.4051	-0.8017
Next Place: dental	107.1613	99.8525	1.0732	121.8057	93.0724	1.3087	113.9392	84.5056	1.3483	48.3137	73.9767	0.6531	38.6762	63.2861	0.6111	26.5662	46.3867	0.5727	7.5200	31.1482	0.2414
Next Place: diphthong	-65.3325	82.1561	-0.7952	-56.5605	76.5670	-0.7387	-57.3296	69.5616	-0.8242	-38.5975	60.9776	-0.6330	-36.5813	52.2084	-0.7007	-53.8167	38.5954	-1.3944	-53.0073	26.0190	-2.0372
Next Place: glottal	-38.6022	36.5310	-1.0567	-20.2864	34.0718	-0.5954	-8.5957	30.9824	-0.2774	-8.2271	27.1756	-0.3027	-6.4380	23.2364	-0.2771	-8.9289	17.1114	-0.5218	-6.9365	11.4812	-0.6042
Next Place: labial	278.5246	59.8613	4.6528	235.7329	55.9041	4.2167	200.1127	50.9066	3.9310	168.1251	44.7323	3.7585	139.4227	38.3843	3.6323	115.9887	28.4355	4.0790	72.7736	19.1590	3.7984
Next Place: labio-dental	296.7127	139.5641	2.1260	328.5801	130.2318	2.5230	348.3694	118.5089	2.9396	281.5168	104.0784	2.7049	244.3564	88.8992	2.7487	128.5769	66.0408	1.9469	63.2545	44.3504	1.4262
Next Place: lax	-39.7276	62.2563	-0.6381	-41.3505	57.9323	-0.7138	-34.7001	52.6282	-0.6593	-28.6755	46.1316	-0.6216	-34.6092	39.3602	-0.8793	-26.9334	29.1153	-0.9251	-11.8190	19.5382	-0.6049
Next Place: palatal	-95.4201	78.4258	-1.2167	-21.1846	73.2222	-0.2893	48.4816	66.6575	0.7273	77.9366	58.5066	1.3321	85.1307	50.1378	1.6979	79.9308	36.8131	2.1713	47.3588	24.7442	1.9139
Next Manner: flap	-94.7348	46.7279	-2.0274	-86.9793	43.5892	-1.9954	-76.8673	39.6987	-1.9363	-68.8446	34.9448	-1.9701	-66.4214	29.9446	-2.2181	-52.1561	22.6075	-2.3070	-29.6316	15.2780	-1.9395
Next Manner: fricative	-147.6747	96.9570	-1.5231	-155.9775	90.3803	-1.7258	-150.7851	82.0354	-1.8380	-104.6918	71.7857	-1.4584	-87.9690	61.3264	-1.4344	-59.1676	44.9754	-1.3156	-20.7852	30.1684	-0.6890
Next Manner: nasal	-109.8720	53.1087	-2.0688	-83.2512	49.5254	-1.6810	-74.2838	45.1236	-1.6462	-51.3878	39.7879	-1.2915	-43.6785	34.0661	-1.2822	-43.3571	26.1475	-1.6582	-30.6021	17.7297	-1.7260
Next Manner: stop	-65.5502	52.9308	-1.2384	-82.5510	49.3648	-1.6723	-86.0817	44.9331	-1.9158	-70.1578	39.5097	-1.7757	-65.7377	33.8607	-1.9414	-45.1047	25.3808	-1.7771	-23.2988	17.1296	-1.3601
Duration (log) x Frequency (log)	0.1584	0.1212	1.3073	0.0480	0.1121	0.4283	0.0111	0.1018	0.1088	0.0185	0.0893	0.2070	0.0318	0.0764	0.4154	0.0598	0.0569	1.0504	0.0132	0.0383	0.3438

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Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	1204.0709	637.8023	1.8878	1250.8906	588.0924	2.1270	868.3672	643.2331	1.3500	529.4020	530.6322	0.9977	562.7754	486.4928	1.1568	643.0504	507.7320	1.2665	332.4470	302.1262	1.1004
Tense: past	-631.4394	297.4891	-2.1226	-584.7577	274.4667	-2.1305	-411.2664	305.1249	-1.3479	-239.2387	250.2921	-0.9558	-269.5689	231.1847	-1.1660	-329.0034	242.4668	-1.3569	-163.5158	144.8291	-1.1290
NDL Cue Strength	470.9529	483.8955	0.9733	630.6301	446.9277	1.4110	459.7141	517.3947	0.8885	256.9050	414.8536	0.6193	316.6777	392.1476	0.8075	459.6724	428.1219	1.0737	199.7498	253.1804	0.7890
Duration (log)	-2.0494	1.2530	-1.6355	-1.7707	1.1628	-1.5228	-0.8093	1.1640	-0.6952	-0.5446	1.0530	-0.5172	-0.2642	0.8237	-0.3208	0.2878	0.6653	0.4326	0.1032	0.5334	0.1934
Frequency (log)	-159.2310	111.9164	-1.4228	-189.4876	103.2408	-1.8354	-129.7583	111.3334	-1.1655	-77.3485	92.7812	-0.8337	-82.6885	83.8936	-0.9856	-92.6121	86.5314	-1.0703	-51.4415	52.2378	-0.9848
Previous Voicing: voiceless	-95.0861	144.6460	-0.6574	-159.5496	133.6494	-1.1938	-95.9495	152.0055	-0.6312	-23.9067	124.1717	-0.1925	-49.8263	119.8973	-0.4156	-100.7691	128.8065	-0.7823	-44.1515	81.4131	-0.5423
Previous Place: glottal	-385.1335	218.2667	-1.7645	-333.9496	201.0498	-1.6610	-248.7243	216.3687	-1.1495	-167.1775	180.2811	-0.9273	-205.8480	161.6195	-1.2737	-237.0577	162.8791	-1.4554	-127.3829	95.4488	-1.3346
Previous Place: labio-dental	216.8070	266.7055	0.8129	328.5954	246.2520	1.3344	206.2435	279.2868	0.7385	87.0561	228.0681	0.3817	131.6406	218.4389	0.6026	203.0774	233.6210	0.8693	110.1058	145.2491	0.7580
Next Voicing: voiceless	-53.0974	80.4366	-0.6601	-130.2141	73.5908	-1.7694	-129.3914	75.3855	-1.7164	-131.7291	64.4530	-2.0438	-130.1599	64.4047	-2.0210	-108.1956	63.5707	-1.7020	-79.8715	42.3693	-1.8851
Next Place: glottal	-123.4361	77.3309	-1.5962	-149.0438	71.1085	-2.0960	-111.4287	71.2045	-1.5649	-89.3184	62.9035	-1.4199	-75.7187	57.2327	-1.3230	-52.9485	51.4715	-1.0287	-78.5945	37.4159	-2.1006
Next Place: labio-dental	225.7737	68.9354	3.2751	282.9725	63.4480	4.4599	244.9196	64.8378	3.7774	234.9013	57.9764	4.0517	259.9033	58.1635	4.4685	239.1482	54.7069	4.3714	207.0362	39.4139	5.2529
Next Manner: stop	60.8207	56.5150	1.0762	117.7019	52.0474	2.2614	105.0035	53.6924	1.9557	76.8412	47.6748	1.6118	73.8094	47.4161	1.5566	71.5178	44.4392	1.6093	56.8944	31.8509	1.7863
Duration (log) x Frequency (log)	0.6064	0.3895	1.5569	0.5321	0.3614	1.4722	0.2841	0.3646	0.7791	0.2066	0.3293	0.6274	0.1606	0.2579	0.6228	-0.0001	0.2085	-0.0005	0.0878	0.1711	0.5136

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Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	3550.8451	1258.6856	2.8211	3310.2459	1221.9974	2.7089	3382.8604	1028.4798	3.2892	3075.3638	960.9545	3.2003	2574.3156	828.5654	3.1070	1516.2417	637.1003	2.3799	729.1488	444.4222	1.6407
Tense: past	-1951.2768	609.6098	-3.2009	-1753.1294	589.2672	-2.9751	-1809.9151	494.7695	-3.6581	-1687.0457	460.6898	-3.6620	-1399.1896	396.0805	-3.5326	-743.2298	306.4069	-2.4256	-309.3740	214.3172	-1.4435
NDL Cue Strength	2662.4304	1061.2064	2.5089	2345.9873	1035.6258	2.2653	2332.7948	876.0238	2.6629	2079.2683	823.3510	2.5254	1730.9520	709.5614	2.4395	1077.7686	542.4230	1.9870	520.5136	372.0907	1.3989
Duration (log)	1.6899	2.4700	0.6842	0.8773	2.2492	0.3901	1.3838	1.8493	0.7483	1.6188	1.7661	0.9166	1.0698	1.6212	0.6599	0.7884	1.2058	0.6539	0.1652	0.8346	0.1980
Frequency (log)	-454.2901	218.0947	-2.0830	-460.1440	211.3114	-2.1776	-482.2009	177.8472	-2.7113	-435.5375	166.6121	-2.6141	-371.5563	144.1088	-2.5783	-236.7608	110.4508	-2.1436	-119.6163	76.8610	-1.5563
Previous Voicing: voiceless	-749.8252	345.1068	-2.1727	-694.6210	334.3047	-2.0778	-745.0005	282.9612	-2.6329	-683.6230	269.9919	-2.5320	-577.3940	236.7134	-2.4392	-385.7028	177.2579	-2.1759	-195.2625	119.6460	-1.6320
Previous Place: glottal	-1303.6485	402.8620	-3.2360	-1152.5006	387.0842	-2.9774	-1180.7111	321.1650	-3.6763	-1107.4372	290.5871	-3.8110	-907.6812	244.7890	-3.7080	-431.3452	196.8587	-2.1911	-158.1277	142.9554	-1.1061
Previous Place: labio-dental	1214.6722	614.0243	1.9782	1147.6062	595.3530	1.9276	1216.4499	503.1715	2.4176	1102.6433	476.7029	2.3131	924.4668	415.1755	2.2267	584.3769	313.9603	1.8613	271.0395	213.6369	1.2687
Next Voicing: voiceless	169.0411	184.6296	0.9156	175.7186	181.7474	0.9668	150.3118	150.9911	0.9955	95.6570	135.7707	0.7045	42.7201	112.6167	0.3793	31.8174	93.0580	0.3419	42.2942	65.3737	0.6470

Next Place: glottal	-60.2424	165.4270	-0.3642	-61.6712	155.1325	-0.3975	-51.2479	126.1829	-0.4061	-73.6803	110.2947	-0.6680	-82.9755	90.5570	-0.9163	-43.3371	76.5101	-0.5664	-3.0968	56.4074	-0.0549
Next Place: labio-dental	282.6578	179.2175	1.5772	292.7798	174.8959	1.6740	290.6385	142.8967	2.0339	319.5053	124.9126	2.5578	335.5643	102.0206	3.2892	297.2647	87.4085	3.4009	266.2087	63.3190	4.2043
Next Manner: stop	-5.5459	144.4127	-0.0384	-3.1852	139.6493	-0.0228	3.5488	113.8364	0.0312	20.1439	99.5771	0.2023	50.8686	82.0830	0.6197	22.0787	69.2265	0.3189	-10.6493	50.5951	-0.2105
Duration (log) x Frequency (log)	-0.4490	0.7885	-0.5694	-0.0049	0.7049	-0.0070	0.0320	0.5787	0.0554	0.0192	0.5440	0.0352	0.1213	0.4848	0.2502	0.0701	0.3723	0.1882	0.0786	0.2595	0.3030

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Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	224.3917	118.8258	1.8884	260.9394	112.8397	2.3125	261.2389	109.1375	2.3937	257.1080	101.0710	2.5438	189.5236	88.6978	2.1367	143.9523	73.4070	1.9610	99.7030	53.2486	1.8724
Tense: past	-45.6481	41.0109	-1.1131	-58.5078	39.0815	-1.4971	-63.2372	37.8941	-1.6688	-64.0963	35.1027	-1.8260	-46.5592	30.6861	-1.5173	-35.4181	25.1147	-1.4103	-23.9125	18.0805	-1.3226
NDL Cue Strength	6.6921	96.0157	0.0697	35.0723	91.6104	0.3828	61.9934	88.7084	0.6988	64.9259	81.9859	0.7919	39.2096	71.7935	0.5461	24.9320	58.8341	0.4238	-0.0891	42.4068	-0.0021
Duration (log)	-0.2903	0.4643	-0.6253	-0.3693	0.4457	-0.8285	-0.3594	0.4480	-0.8022	-0.1405	0.4278	-0.3284	0.1957	0.3925	0.4987	0.1935	0.3400	0.5693	0.2212	0.2402	0.9208
Frequency (log)	-24.5940	18.0817	-1.3602	-26.5475	17.2423	-1.5397	-30.0762	16.7407	-1.7966	-31.0333	15.5300	-1.9983	-19.2393	13.6327	-1.4113	-18.1681	11.1911	-1.6234	-11.6437	8.0458	-1.4472
Previous Voicing: voiceless	54.2416	42.4384	1.2781	45.0349	40.4226	1.1141	34.2767	39.0363	0.8781	11.7184	36.0094	0.3254	6.5900	31.5173	0.2091	7.2877	25.8319	0.2821	-2.9137	18.6904	-0.1559
Previous Place: dental	208.6706	106.9462	1.9512	191.7845	102.1275	1.8779	188.8680	99.7131	1.8941	162.8422	92.8800	1.7533	120.8468	81.0958	1.4902	107.8927	66.4051	1.6248	92.6652	47.3502	1.9570
Previous Place: diphthong	75.3187	82.4120	0.9139	74.9744	78.0499	0.9606	77.0871	74.8570	1.0298	79.2281	68.7856	1.1518	46.0424	59.9475	0.7680	36.7612	49.2489	0.7464	27.1895	36.0439	0.7543
Previous Place: glottal	106.6805	73.0390	1.4606	82.4994	70.1725	1.1757	61.8466	69.0007	0.8963	43.6958	64.6218	0.6762	31.4829	56.5043	0.5572	44.2492	46.2355	0.9570	32.5571	32.6497	0.9972
Previous Place: labial	44.0575	38.2261	1.1525	56.1208	36.3588	1.5435	58.6504	35.4809	1.6530	61.6774	33.0759	1.8647	50.5578	28.8781	1.7507	33.8823	23.6910	1.4302	21.0399	16.9568	1.2408
Previous Place: labio-dental	26.4412	82.1367	0.3219	21.2560	78.2807	0.2715	25.7502	76.5655	0.3363	31.0063	71.5538	0.4333	-4.2999	62.3688	-0.0689	-6.0633	51.3314	-0.1181	-4.1803	36.6390	-0.1141
Previous Place: lax	0.9838	101.4507	0.0097	16.1329	95.9312	0.1682	29.8851	92.1243	0.3244	38.2116	84.8567	0.4503	12.8776	74.2934	0.1733	-2.1237	61.3350	-0.0346	-2.9337	44.9643	-0.0652
Previous Place: palatal	57.1178	40.0555	1.4260	48.0574	38.2785	1.2555	43.3071	37.1890	1.1645	50.1057	34.4762	1.4533	34.7901	30.2350	1.1507	32.7117	24.8050	1.3188	27.2047	17.8012	1.5282
Previous Manner: diphthong	-90.2047	114.6585	-0.7867	-82.9316	108.2205	-0.7663	-45.3283	103.4201	-0.4383	-39.9904	94.8885	-0.4214	-16.5737	82.7552	-0.2003	15.0644	67.8874	0.2219	12.1468	49.8957	0.2434
Previous Manner: flap	202.3338	102.5168	1.9737	193.4150	97.1314	1.9913	192.6577	93.3021	2.0649	190.9133	85.8862	2.2229	156.0761	75.0912	2.0785	133.3697	61.7032	2.1615	112.4050	45.0555	2.4948
Previous Manner: fricative	-86.2028	64.6216	-1.3340	-66.9030	62.0003	-1.0791	-45.0735	60.4566	-0.7456	-12.8860	56.1560	-0.2295	1.1850	49.1544	0.0241	-13.0293	40.3074	-0.3232	-6.6751	28.7958	-0.2318
Previous Manner: lax	32.2382	105.9660	0.3042	8.6431	99.8960	0.0865	-1.5591	95.8651	-0.0163	-12.5720	88.4150	-0.1422	-26.6994	77.7131	-0.3436	-0.2755	64.7833	-0.0043	-0.5119	47.7482	-0.0107
Previous Manner: nasal	53.4002	51.2850	1.0412	44.6821	48.8576	0.9145	52.9475	47.2782	1.1199	64.2775	43.7126	1.4705	47.3814	38.2954	1.2373	48.1036	31.4830	1.5279	38.6306	22.7449	1.6984
Previous Manner: stop	-7.6021	40.4747	-0.1878	-4.1071	38.4948	-0.1067	7.3290	37.1635	0.1972	13.7821	34.3114	0.4017	19.6926	30.0043	0.6563	11.7286	24.5536	0.4777	8.3364	17.7702	0.4691
Next Voicing: voiceless	5.1851	35.6708	0.1454	-4.2305	33.9215	-0.1247	1.3607	32.7626	0.0415	4.1187	30.2522	0.1361	3.1550	26.5016	0.1191	0.2906	21.7700	0.0133	-10.1395	15.7795	-0.6426
Next Place: dental	-6.1075	61.7258	-0.0989	-15.3893	58.6510	-0.2624	-9.9400	56.6721	-0.1754	5.8442	52.3700	0.1116	2.0323	45.9961	0.0442	-4.6930	37.8955	-0.1238	-21.2825	27.5074	-0.7737
Next Place: diphthong	-26.4914	97.6025	-0.2714	-70.6119	92.2559	-0.7654	-97.1581	88.4769	-1.0981	-110.8384	81.3934	-1.3618	-108.9788	71.1736	-1.5312	-79.6391	58.7532	-1.3555	-71.3332	43.1070	-1.6548
Next Place: glottal	24.7327	33.5434	0.7373	11.9860	31.7742	0.3772	4.4533	30.5774	0.1456	-1.6329	28.1941	-0.0579	-12.9195	24.7121	-0.5228	-8.8408	20.3691	-0.4340	-19.7395	14.8636	-1.3280
Next Place: labial	-25.2941	30.5268	-0.8286	-13.5126	29.0453	-0.4652	-6.6920	28.0007	-0.2390	2.7095	25.7971	0.1050	-5.9103	22.5485	-0.2621	-7.7020	18.4814	-0.4167	-7.8678	13.4126	-0.5866
Next Place: labio-dental	21.2624	65.7474	0.3234	-9.7594	62.3506	-0.1565	-33.3885	60.0401	-0.5561	-30.9827	55.3566	-0.5597	-40.0167	48.3676	-0.8273	-35.4012	39.7021	-0.8917	-33.1470	28.9077	-1.1466
Next Place: lax	-53.2611	93.6427	-0.5688	-88.9911	88.4137	-1.0065	-91.6783	84.7893	-1.0812	-99.5302	78.0515	-1.2752	-97.4233	68.3091	-1.4262	-64.8981	56.5347	-1.1479	-57.2083	41.5106	-1.3782
Next Place: palatal	-23.9638	36.5045	-0.6565	-4.1648	34.7773	-0.1198	6.3513	33.6634	0.1887	14.9633	31.1302	0.4807	7.0166	27.3202	0.2568	-6.1867	22.4436	-0.2757	-4.8993	16.2339	-0.3018
Next Place: palato-alveolar	-5.6268	59.3400	-0.0948	-12.9139	56.4570	-0.2287	-23.6588	54.4564	-0.4345	-33.1809	50.1813	-0.6612	-49.3778	43.9711	-1.1230	-49.1566	36.0353	-1.3641	-43.6698	26.1808	-1.6680
Next Place: tense	-101.4318	104.5250	-0.9704	-126.9522	98.7505	-1.2856	-110.6277	94.5859	-1.1696	-107.3825	86.9295	-1.2353	-97.4039	75.9471	-1.2825	-61.7101	62.7891	-0.9828	-54.4631	46.1952	-1.1790
Next Manner: approximate	-33.1411	98.8911	-0.3351	-67.1545	93.3007	-0.7198	-75.3571	89.3497	-0.8434	-95.3477	82.1731	-1.1603	-88.6276	71.8357	-1.2338	-45.2524	59.4724	-0.7609	-40.8781	43.7549	-0.9343
Next Manner: flap	-21.9754	98.7182	-0.2226	-69.6792	93.2388	-0.7473	-86.9363	89.4606	-0.9718	-94.6602	82.3801	-1.1491	-90.3156	72.0909	-1.2528	-44.3622	59.6343	-0.7439	-36.0379	43.7432	-0.8239
Next Manner: fricative	-66.4707	83.7853	-0.7933	-69.4823	78.6479	-0.8835	-67.9258	74.9187	-0.9067	-74.8472	68.7532	-1.0886	-65.1378	59.9811	-1.0860	-34.9064	49.8441	-0.7003	-15.0549	37.0068	-0.4068
Next Manner: nasal	-71.1030	96.6806	-0.7354	-98.4733	91.2964	-1.0786	-89.3635	87.5799	-1.0204	-91.8154	80.6422	-1.1386	-81.1296	70.5286	-1.1503	-46.0009	58.3652	-0.7882	-37.8917	42.8370	-0.8846
Next Manner: stop	-53.5998	88.3823	-0.6065	-79.6944	83.2696	-0.9571	-81.4946	79.6534	-1.0231	-81.1558	73.2414	-1.1081	-74.5297	64.0439	-1.1637	-29.8604	53.0974	-0.5624	-13.8799	39.1344	-0.3547
Duration (log) x Frequency (log)	0.1247	0.0828	1.5057	0.1308	0.0791	1.6539	0.1341	0.0787	1.7033	0.0990	0.0748	1.3241	0.0404	0.0681	0.5933	0.0412	0.0587	0.7007	0.0297	0.0419	0.7084

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Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	-63.4796	206.6244	-0.3072	-102.9116	190.4461	-0.5404	-123.7343	169.6900	-0.7292	-122.9673	145.9375	-0.8426	-160.2857	126.6881	-1.2652	-110.0760	107.2877	-1.0260	-81.2976	78.8938	-1.0305
Tense: past	-52.6325	72.1391	-0.7296	-37.5372	66.5833	-0.5638	-22.7757	59.4346	-0.3832	-16.7144	50.9875	-0.3278	1.8428	44.0846	0.0418	-2.0529	36.8986	-0.0556	-2.0737	26.5989	-0.0780
NDL Cue Strength	-32.7805	169.5474	-0.1933	-59.7660	156.3161	-0.3823	-69.7447	139.3486	-0.5005	-39.3279	119.4864	-0.3291	-34.1604	103.3091	-0.3307	-11.0507	86.2409	-0.1281	-5.5205	62.1651	-0.0888
Duration (log)	2.8834	0.8148	3.5387	2.8646	0.7421	3.8602	2.8018	0.6479	4.3243	2.6136	0.5610	4.6586	2.3813	0.5012	4.7508	1.5753	0.4467	3.5266	0.9746	0.3646	2.6730
Frequency (log)	9.7104	31.9205	0.3042	16.4473	29.4102	0.5592	21.4858	26.1925	0.8203	20.3152	22.4759	0.9039	21.7553	19.4662	1.1176	15.2100	16.3297	0.9314	9.5575	11.8943	0.8035
Previous Voicing: voiceless	-65.5186	74.7183	-0.8769	-47.0907	68.8633	-0.6838	-35.0569	61.3761	-0.5712	-13.9401	52.6439	-0.2648	-3.3857	45.5191	-0.0744	6.3025	38.0519	0.1656	0.8301	27.4332	0.0303
Previous Place: dental	-189.3465	186.7313	-1.0140	-162.2703	172.3052	-0.9418	-118.0365	153.8064	-0.7674	-82.8906	131.8515	-0.6287	-90.8523	113.9515	-0.7973	-66.2115	95.6431	-0.6923	-49.7418	69.1610	-0.7192
Previous Place: diphthong	-55.1207	142.3856	-0.3871	-57.4396	131.3048	-0.4375	-63.9454	117.1787	-0.5457	-57.2261	100.7169	-0.5682	-43.0574	87.1296	-0.4942	-41.3793	73.3496	-0.5641	-25.8371	52.9884	-0.4876
Previous Place: glottal	35.9141	129.4767	0.2774	24.9389	119.1890	0.2092	0.1247	106.0709	0.0012	1.5232	90.7590	0.0168	-28.4595	78.3703	-0.3631	-47.1364	65.2348	-0.7226	-56.9597	47.2565	-1.2053
Previous Place: labial	223.7848	66.1196	3.3845	153.1943	61.0266	2.5103	106.9351	54.4729	1.9631	69.7343	46.7701	1.4910	34.6914	40.5070	0.8564	20.4013	34.2148	0.5963	7.0894	24.7840	0.2860
Previous Place: labio-dental	85.3368	142.4701	0.5990	93.6303	131.4378	0.7124	77.9558	117.3043	0.6646	70.6600	100.5674	0.7026	20.5316	86.9346	0.2362	-10.8665	73.2296	-0.1484	-55.2936	53.2859	-1.0377
Previous Place: lax	-57.4193	174.9941	-0.3281	-61.0210	161.5965	-0.3776	-13.1695	144.3372	-0.0912	22.2787	124.2720	0.1793	45.5641	107.8218	0.4226	55.1649	91.4986	0.6029	52.2372	66.8376	0.7816
Previous Place: palatal	104.0477	70.8778	1.4680	79.8127	65.2642	1.2229	46.9331	58.0900	0.8079	19.5246	49.7870	0.3922	5.9593	43.0607	0.1384	7.6882	35.9441	0.2139	-2.8655	26.0749	-0.1099

Previous Manner: diphthong	35.2541	197.5902	0.1784	22.3607	182.4250	0.1226	41.8559	162.9878	0.2568	75.3104	140.2296	0.5371	64.5330	121.3839	0.5316	66.4304	102.3991	0.6487	62.8690	73.8861	0.8509
Previous Manner: flap	103.1808	177.8322	0.5802	144.0116	164.2116	0.8770	172.8062	146.7004	1.1780	197.3736	126.2470	1.5634	199.2652	109.3908	1.8216	195.4653	92.3284	2.1171	192.2577	66.7491	2.8803
Previous Manner: fricative	43.7617	114.8844	0.3809	29.9247	105.7195	0.2831	31.8692	94.0436	0.3389	11.3037	80.4766	0.1405	20.3166	69.5000	0.2923	14.3343	57.7142	0.2484	21.1147	41.6449	0.5070
Previous Manner: lax	60.8042	180.6089	0.3367	83.5381	166.7498	0.5010	35.9317	148.8398	0.2414	-27.1825	128.4999	-0.2115	-96.7017	111.9571	-0.8637	-70.5641	96.1700	-0.7337	-70.6109	71.4330	-0.9885
Previous Manner: nasal	52.0707	89.9545	0.5789	51.3030	82.8640	0.6191	40.2551	73.8134	0.5454	33.6944	63.3246	0.5321	27.1795	54.7848	0.4961	17.6100	45.9226	0.3835	13.3820	33.3718	0.4010
Previous Manner: stop	77.5723	71.0587	1.0917	66.7823	65.5902	1.0182	61.9578	58.5576	1.0581	45.0309	50.2759	0.8957	35.8522	43.4855	0.8245	11.0093	36.4327	0.3022	10.1826	26.2524	0.3879
Next Voicing: voiceless	44.8043	62.5073	0.7168	29.9439	57.6653	0.5193	15.7539	51.4393	0.3063	2.5649	44.1727	0.0581	11.4298	38.2512	0.2988	-3.0459	32.1345	-0.0948	-17.3480	23.2642	-0.7457
Next Place: dental	44.7094	107.9260	0.4143	27.8873	99.5780	0.2801	0.8354	88.7955	0.0094	-8.7264	76.3464	-0.1143	17.9351	66.2606	0.2707	6.9163	55.9429	0.1236	-21.6396	40.7252	-0.5314
Next Place: diphthong	0.8856	168.0678	0.0053	11.5514	155.1867	0.0744	9.0138	138.6040	0.0650	6.7324	119.3603	0.0564	24.5442	103.5555	0.2370	-10.3571	87.8154	-0.1179	-10.8826	63.9567	-0.1702
Next Place: glottal	15.2061	58.0549	0.2619	6.7754	53.5788	0.1265	-4.4649	47.8116	-0.0934	-4.5050	41.1601	-0.1095	12.8098	35.7282	0.3585	6.8611	30.2592	0.2267	-8.6337	22.0090	-0.3923
Next Place: labial	51.8484	53.5027	0.9691	37.6907	49.3236	0.7642	38.6971	43.9784	0.8799	45.4525	37.7379	1.2044	38.8198	32.6307	1.1897	39.1819	27.3003	1.4352	34.6293	19.6636	1.7611
Next Place: labio-dental	67.7728	114.3243	0.5928	48.8921	105.5507	0.4632	19.7295	94.2674	0.2093	15.5598	81.0270	0.1920	34.6241	70.1516	0.4936	31.4287	59.0838	0.5319	11.9768	42.6845	0.2806
Next Place: lax	48.0263	160.7010	0.2989	46.0093	148.4200	0.3100	34.2306	132.5866	0.2582	26.6601	114.2484	0.2334	43.8395	99.2021	0.4419	21.7094	84.3846	0.2573	17.5618	61.7237	0.2845
Next Place: palatal	-8.6240	64.3289	-0.1341	5.2542	59.3036	0.0886	30.0419	52.8390	0.5686	44.6622	45.3653	0.9845	50.5446	39.3115	1.2857	64.3566	33.0075	1.9498	44.6550	23.9697	1.8630
Next Place: palato-alveolar	-12.6449	104.5354	-0.1210	8.6223	96.4518	0.0894	12.0751	86.0352	0.1404	21.5213	73.8659	0.2914	16.4757	63.9550	0.2576	-3.4225	53.6234	-0.0638	-7.6424	38.7029	-0.1975
Next Place: tense	20.1001	179.3900	0.1120	39.8173	165.5725	0.2405	44.9105	147.8386	0.3038	52.9779	127.3629	0.4160	68.8417	110.5131	0.6229	18.2333	93.8431	0.1943	16.5087	68.5388	0.2409
Next Manner: approximate	134.0039	169.1200	0.7924	135.2738	156.1466	0.8663	112.5125	139.4677	0.8067	99.7803	120.2114	0.8300	114.5261	104.3703	1.0973	75.8137	88.8263	0.8535	63.6995	64.9783	0.9803
Next Manner: flap	44.8376	169.5715	0.2644	56.7209	156.5932	0.3622	41.4903	139.8708	0.2966	21.5089	120.4987	0.1785	22.7192	104.6065	0.2172	5.1744	88.9238	0.0582	10.1294	65.0346	0.1558
Next Manner: fricative	-32.7632	141.0133	-0.2323	-11.8106	130.3173	-0.0906	4.7992	116.5625	0.0412	10.1064	100.7003	0.1004	2.4677	87.5386	0.0282	-5.4078	75.1016	-0.0720	27.8157	55.1974	0.5039
Next Manner: nasal	80.5275	165.7641	0.4858	84.2029	153.0552	0.5501	65.3251	136.6984	0.4779	48.8985	117.7723	0.4152	60.7976	102.2366	0.5947	28.5227	86.9413	0.3281	22.0300	63.6057	0.3464
Next Manner: stop	-3.9514	150.6155	-0.0262	16.0731	139.1234	0.1155	8.2380	124.3277	0.0663	12.2421	107.2371	0.1142	7.0673	93.1557	0.0759	-5.4609	79.4850	-0.0687	10.6652	58.2809	0.1830
Duration (log) x Frequency (log)	-0.2914	0.1430	-2.0381	-0.3168	0.1306	-2.4258	-0.3205	0.1145	-2.7995	-0.3042	0.0994	-3.0614	-0.2763	0.0886	-3.1168	-0.1474	0.0790	-1.8649	-0.0714	0.0636	-1.1232

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Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	-191.0491	174.4969	-1.0949	-133.9560	162.7088	-0.8233	-177.8137	146.1736	-1.2165	-180.9896	138.7129	-1.3048	-172.8248	126.5698	-1.3655	-162.6148	117.8092	-1.3803	-128.5343	94.3743	-1.3620
Tense: past	72.3311	51.5346	1.4035	59.4741	48.9368	1.2153	56.8982	44.5526	1.2771	55.3160	41.9415	1.3189	51.4989	39.3197	1.3097	45.9510	36.9908	1.2422	25.9305	28.1439	0.9214
NDL Cue Strength	397.5759	314.5170	1.2641	229.0518	293.5912	0.7802	235.0724	266.4253	0.8823	217.4604	252.1301	0.8625	205.4664	228.4682	0.8993	223.6375	211.3511	1.0581	216.6809	170.1022	1.2738
Duration (log)	-0.3547	0.5058	-0.7013	-0.3799	0.4621	-0.8222	-0.1101	0.4052	-0.2717	-0.0824	0.3884	-0.2123	0.1131	0.3536	0.3200	0.1868	0.3296	0.5667	0.3746	0.2768	1.3533
Frequency (log)	4.2136	12.2353	0.3444	4.7755	11.2158	0.4258	11.2965	9.8291	1.1493	12.0944	9.4147	1.2846	13.9600	8.6595	1.6121	12.0899	8.1349	1.4862	8.3814	6.5920	1.2714
Previous Voicing: voiceless	217.1965	113.8484	1.9078	116.5222	106.8329	1.0907	97.7955	96.7881	1.0104	92.6909	91.5967	1.0119	89.8134	84.3811	1.0644	82.0736	78.8643	1.0407	50.7631	61.8955	0.8201
Previous Place: dental	-56.8039	65.1697	-0.8716	-56.8601	60.1381	-0.9455	-39.6463	54.1125	-0.7327	-29.3586	51.2784	-0.5725	-24.0240	46.9185	-0.5120	-20.6680	43.5742	-0.4743	-9.0142	34.9646	-0.2578
Previous Place: glottal	-109.6567	81.5685	-1.3444	-69.8046	76.9980	-0.9066	-71.9704	71.0554	-1.0129	-80.9660	67.4602	-1.2002	-71.8439	61.3712	-1.1706	-64.9728	56.5470	-1.1490	-51.0348	45.6896	-1.1170
Previous Place: palatal	99.8412	102.7278	0.9719	40.8378	95.9495	0.4256	40.2795	86.7949	0.4641	41.8655	82.0505	0.5102	41.1890	74.8187	0.5505	49.5908	69.4504	0.7140	50.1179	55.3480	0.9055
Previous Manner: approximate	129.1579	107.1598	1.2053	78.4659	100.0654	0.7841	83.0382	90.8497	0.9140	83.1782	85.9330	0.9679	79.8383	77.9118	1.0247	81.2538	72.0712	1.1274	72.1601	57.9702	1.2448
Previous Manner: fricative	-76.2892	68.9864	-1.1059	-19.1640	63.4497	-0.3020	2.1092	57.1014	0.0369	6.4049	54.4080	0.1177	-1.8538	48.8659	-0.0379	0.1049	44.8629	0.0023	14.1287	37.7598	0.3742
Next Voicing: voiceless	16.9342	22.0879	0.7667	5.2985	20.4640	0.2589	5.4393	18.5149	0.2938	5.0809	17.7094	0.2869	6.2060	15.9717	0.3886	0.8932	14.6612	0.0609	-9.1363	12.5314	-0.7291
Next Place: dental	22.9582	51.3310	0.4473	-17.1809	46.8165	-0.3670	-25.7164	41.5731	-0.6186	-22.1376	39.8215	-0.5559	-13.3170	35.8443	-0.3715	-16.4453	33.1078	-0.4967	-21.5790	27.9394	-0.7723
Next Place: diphthong	131.7778	49.3266	2.6715	142.0034	46.5684	3.0493	154.6983	43.4280	3.5622	154.8483	41.0679	3.7705	138.8546	36.7046	3.7830	106.9884	33.2520	3.2175	55.3092	28.0446	1.9722
Next Place: glottal	4.2155	41.4234	0.1018	-16.8403	37.7716	-0.4458	-20.8473	33.7351	-0.6180	-23.7353	32.2846	-0.7352	-17.3296	28.9169	-0.5993	-12.1993	26.6175	-0.4583	-7.8687	22.4080	-0.3512
Next Place: labial	19.2667	42.4755	0.4536	22.3319	39.9293	0.5593	28.7467	37.1699	0.7734	21.0376	35.2266	0.5972	8.7551	31.4768	0.2781	3.0021	28.5497	0.1052	0.3255	24.0039	0.0136
Next Place: labio-dental	23.6529	50.8184	0.4654	-0.3868	46.2326	-0.0084	-4.4801	41.1718	-0.1088	3.7182	39.3949	0.0944	8.5654	35.3708	0.2422	7.1355	32.6280	0.2187	8.0540	27.3181	0.2948
Next Place: lax	31.4370	45.1908	0.6957	36.7280	42.5574	0.8630	42.3480	39.7594	1.0651	34.6640	37.6321	0.9211	19.9902	33.6294	0.5944	11.5246	30.4856	0.3780	4.6851	25.5859	0.1831
Next Place: palatal	3.5792	46.5880	0.0768	8.0424	43.7956	0.1836	3.6444	40.7319	0.0895	3.9770	38.5561	0.1031	-9.4854	34.5839	-0.2743	-24.2205	31.4668	-0.7697	-14.8202	26.2540	-0.5645
Next Place: palato-alveolar	-42.6407	54.2077	-0.7866	-35.0320	49.4424	-0.7085	-25.2464	44.3507	-0.5692	-18.5080	42.4266	-0.4362	-19.2956	37.8028	-0.5104	-20.8519	34.6407	-0.6019	-15.4294	29.4300	-0.5243
Next Place: tense	31.2488	49.4532	0.6319	39.1560	46.3611	0.8446	39.5902	42.9991	0.9207	37.5449	40.7635	0.9210	29.6505	36.4644	0.8131	11.3459	33.1393	0.3424	-10.1418	27.8663	-0.3639
Next Manner: flap	12.7438	37.3134	0.3415	14.9197	34.5078	0.4324	19.6677	31.5769	0.6229	20.3138	30.1074	0.6747	10.6609	26.9438	0.3957	7.3487	24.6159	0.2985	-1.8914	20.7759	-0.0910
Next Manner: fricative	-14.4707	64.9721	-0.2227	35.5040	59.9815	0.5919	53.3934	54.4555	0.9805	46.7727	51.8168	0.9027	28.1734	46.2999	0.6085	25.9059	42.2969	0.6125	20.0086	35.7138	0.5602
Next Manner: nasal	-1.2393	42.5526	-0.0291	13.9678	39.8515	0.3505	25.8127	37.0978	0.6958	28.6718	35.2500	0.8134	29.9168	31.5129	0.9494	30.7752	28.6334	1.0748	28.4340	24.1180	1.1790
Next Manner: stop	-6.6269	29.3205	-0.2260	12.4006	27.3279	0.4538	24.9273	25.2569	0.9869	26.8355	24.1255	1.1123	18.7847	21.6566	0.8674	17.1710	19.7705	0.8685	8.9525	16.6844	0.5366
Duration (log) x Frequency (log)	0.0657	0.1140	0.5766	0.0819	0.1049	0.7810	0.0292	0.0925	0.3154	0.0359	0.0886	0.4056	-0.0104	0.0810	-0.1286	-0.0276	0.0755	-0.3653	-0.0569	0.0634	-0.8968

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	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	-921.7613	677.8843	-1.3598	-754.6214	659.3034	-1.1446	-787.1774	627.7551	-1.2540	-487.6113	549.6610	-0.8871	-88.8971	457.1933	-0.1944	-183.6798	383.2703	-0.4792	-305.3275	268.5632	-1.1369
Tense: past	97.9027	230.1454	0.4254	51.9825	223.8065	0.2323	64.5630	213.6778	0.3022	-25.2240	185.4715	-0.1360	-99.3085	151.4676	-0.6556	-5.5303	129.7446	-0.0426	61.6162	93.7032	0.6576
NDL Cue Strength	2924.7322	1219.4812	2.3983	2536.7674	1180.5690	2.1488	2366.7250	1120.5756	2.1121	1568.8981	982.1440	1.5974	781.8539	816.3174	0.9578	586.9515	680.7365	0.8622	495.5642	471.8575	1.0502
Duration (log)	1.7021	1.7830	0.9546	1.6222	1.7370	0.9339	1.5207	1.6140	0.9422	1.9293	1.4239	1.3549	2.0609	1.2022	1.7142	1.1340	0.9880	1.1477	0.6401	0.6698	0.9557

Frequency (log)	11.4646	46.0720	0.2488	13.5564	44.8930	0.3020	20.9339	42.4567	0.4931	22.6365	37.1522	0.6093	15.3988	30.9475	0.4976	5.2812	25.9232	0.2037	-6.8136	18.2467	-0.3734
Previous Voicing: voiceless	490.7737	467.3107	1.0502	326.2250	454.5391	0.7177	302.8777	433.8318	0.6981	65.5048	378.4825	0.1731	-72.8428	312.4180	-0.2332	19.2482	264.2563	0.0728	75.3093	187.5948	0.4014
Previous Place: dental	-38.9615	257.3229	-0.1514	1.2544	248.8551	0.0050	33.7827	236.1327	0.1431	29.4464	206.2936	0.1427	-6.1822	170.4629	-0.0363	-64.7576	143.0592	-0.4527	-141.9304	100.1512	-1.4172
Previous Place: glottal	-299.9701	319.1667	-0.9399	-215.7048	308.8264	-0.6985	-161.9783	292.7749	-0.5533	-24.1462	257.4917	-0.0938	50.7112	215.2052	0.2356	93.7605	177.7633	0.5274	101.8671	121.2330	0.8403
Previous Place: palatal	640.4960	405.6752	1.5788	528.2606	392.9927	1.3442	527.8673	373.5349	1.4132	336.6256	326.9220	1.0297	140.6690	271.0866	0.5189	120.3626	227.0444	0.5301	104.1675	158.3875	0.6577
Previous Manner: approximate	590.6162	417.1929	1.4157	479.8719	403.8153	1.1883	473.9914	383.2744	1.2367	287.0349	335.7984	0.8548	84.6029	278.8956	0.3033	82.9252	232.7673	0.3563	88.7665	161.5892	0.5493
Previous Manner: fricative	236.1494	246.2818	0.9589	248.9958	238.4976	1.0440	242.4667	224.6095	1.0795	242.2142	198.0136	1.2232	159.5532	166.5517	0.9580	101.1131	136.6983	0.7397	107.0639	92.5574	1.1567
Next Voicing: voiceless	-34.0656	78.6770	-0.4330	-47.1083	76.2770	-0.6176	-50.0649	70.9377	-0.7058	-37.8301	62.7487	-0.6029	20.3999	53.1000	0.3842	1.2345	43.2245	0.0286	-14.6821	28.8604	-0.5087
Next Place: dental	-230.2385	178.8059	-1.2876	-232.6837	173.8640	-1.3383	-239.0848	164.0385	-1.4575	-180.9762	144.6889	-1.2508	-39.4294	122.1601	-0.3228	-32.6308	100.3251	-0.3253	-31.2628	68.0912	-0.4591
Next Place: diphthong	381.1614	185.6797	2.0528	399.3961	178.5958	2.2363	372.8257	167.8939	2.2206	335.8418	148.0772	2.2680	221.6230	124.0555	1.7865	232.2505	101.3646	2.2912	195.1350	67.9804	2.8705
Next Place: glottal	-45.5513	143.6931	-0.3170	-60.2730	139.4535	-0.4322	-72.1938	132.3664	-0.5454	-62.0134	116.7912	-0.5310	-15.9220	98.6038	-0.1615	-4.5961	80.8749	-0.0568	-24.1983	54.7525	-0.4420
Next Place: labial	372.5277	158.4148	2.3516	377.7117	152.4287	2.4780	373.8588	143.5614	2.6042	358.7662	126.6991	2.8316	255.2638	106.3063	2.4012	258.4224	86.7565	2.9787	259.9955	58.0416	4.4795
Next Place: labio-dental	200.8928	177.6450	1.1309	158.1190	172.5809	0.9162	125.9912	164.1131	0.7677	116.6512	144.5889	0.8068	153.8738	121.8147	1.2632	112.4442	100.3108	1.1210	64.5397	68.4257	0.9432
Next Place: lax	78.7337	170.3708	0.4621	84.9940	163.7733	0.5190	90.9889	154.2313	0.5900	87.6861	135.9978	0.6448	35.0016	113.8768	0.3074	89.4963	93.0643	0.9617	176.5908	62.4192	2.8291
Next Place: palatal	-22.7212	177.2527	-0.1282	-45.6391	170.5778	-0.2676	-101.5153	160.5776	-0.6322	-67.1036	141.3884	-0.4746	7.3900	118.1448	0.0626	-3.6689	96.9508	-0.0378	-1.3405	65.4962	-0.0205
Next Place: palato-alveolar	77.3220	183.5312	0.4213	74.3905	177.9656	0.4180	73.6729	168.9054	0.4362	77.3897	149.5769	0.5174	72.7782	127.0712	0.5727	46.5177	103.3725	0.4500	27.4397	68.9243	0.3981
Next Place: tense	99.8235	184.0444	0.5424	81.6454	177.3037	0.4605	29.1825	167.3131	0.1744	-37.9276	147.5463	-0.2571	-129.8372	123.7427	-1.0493	-19.6121	101.2337	-0.1937	141.3897	68.0800	2.0768
Next Manner: flap	-303.2432	133.5106	-2.2713	-278.1959	128.9493	-2.1574	-226.4073	121.6510	-1.8611	-162.8530	107.4682	-1.5154	-150.6500	90.6110	-1.6626	-6.4877	73.9026	-0.0878	89.0856	49.4975	1.7998
Next Manner: fricative	26.4540	231.6163	0.1142	85.3989	223.7952	0.3816	138.2293	211.0730	0.6549	141.1912	186.2654	0.7580	5.1192	156.8039	0.0326	92.4332	128.2631	0.7207	191.5530	86.3295	2.2189
Next Manner: nasal	-288.5292	157.0880	-1.8367	-241.3169	151.2549	-1.5954	-187.0761	142.7889	-1.3102	-93.4972	126.1226	-0.7413	-27.7753	106.1045	-0.2618	38.4774	86.4453	0.4451	93.8752	57.7125	1.6266
Next Manner: stop	-243.4598	106.9312	-2.2768	-171.1346	103.2712	-1.6571	-87.0584	97.5742	-0.8922	-48.5608	86.2267	-0.5632	-135.1462	72.7255	-1.8583	-2.1607	59.2415	-0.0365	107.1307	39.5927	2.7058
Duration (log) x Frequency (log)	-0.0525	0.4104	-0.1279	-0.1142	0.3996	-0.2858	-0.1584	0.3696	-0.4286	-0.2897	0.3259	-0.8890	-0.4056	0.2747	-1.4767	-0.2321	0.2258	-1.0279	-0.1097	0.1532	-0.7163

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Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	-266.3285	836.2763	-0.3185	31.0154	774.9834	0.0400	172.9752	580.4854	0.2980	-3.7334	516.6167	-0.0072	-194.7513	493.3216	-0.3948	-151.2915	458.2870	-0.3301	-97.9330	407.9232	-0.2401
Tense: past	64.0154	210.5615	0.3040	-9.1761	187.9551	-0.0488	-34.8338	141.9274	-0.2454	15.1960	125.7120	0.1209	60.9066	121.0889	0.5030	47.4905	118.4197	0.4010	15.2691	108.5507	0.1407
NDL Cue Strength	6.9818	391.3767	0.0178	144.9055	347.1709	0.4174	183.5793	261.1697	0.7029	73.0713	230.9318	0.3164	-48.2628	223.2882	-0.2161	-59.3417	220.5514	-0.2691	-8.8390	203.3641	-0.0435
Duration (log)	3.2141	10.8103	0.2973	-2.9159	9.7268	-0.2998	-4.9796	7.2794	-0.6841	-2.4580	6.4620	-0.3804	0.9622	6.2212	0.1547	1.8067	6.0360	0.2993	1.5420	5.5188	0.2794
Frequency (log)	65.0291	143.7456	0.4524	21.0581	133.9923	0.1572	-6.9089	100.4393	-0.0688	14.8606	89.4541	0.1661	40.6938	85.2707	0.4772	30.4132	78.4498	0.3877	22.9705	69.2432	0.3317
Previous Voicing: voiceless	-30.0697	243.9460	-0.1233	-142.4096	214.8028	-0.6630	-156.4440	162.8633	-0.9606	-85.2508	143.9733	-0.5921	-9.4852	139.1093	-0.0682	5.6316	138.7080	0.0406	-15.8425	128.7699	-0.1230
Previous Place: dental	8.7857	270.3783	0.0325	140.2423	247.8724	0.5658	151.5225	187.9977	0.8060	98.9479	167.3849	0.5911	28.1894	159.6154	0.1766	-18.0768	150.1020	-0.1204	-18.4220	133.7673	-0.1377
Next Voicing: voiceless	-20.0235	33.1904	-0.6033	-3.4464	31.8252	-0.1083	0.7744	23.6329	0.0328	4.6848	21.0985	0.2220	8.7357	19.9865	0.4371	11.1097	17.5625	0.6326	8.3969	14.8333	0.5661
Duration (log) x Frequency (log)	-0.6398	2.2509	-0.2842	0.6509	2.0258	0.3213	1.1014	1.5159	0.7266	0.6009	1.3460	0.4464	-0.1058	1.2957	-0.0817	-0.2970	1.2566	-0.2364	-0.2615	1.1486	-0.2276

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	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	1118.2123	1030.3594	1.0853	680.3215	901.1841	0.7549	740.7210	757.8759	0.9774	575.0158	597.6574	0.9621	415.8894	467.7551	0.8891	158.2996	397.9972	0.3977	60.8897	323.1571	0.1884
Tense: past	77.5023	260.0368	0.2980	133.8886	232.4133	0.5761	8.7579	205.3045	0.0427	-12.9766	165.1521	-0.0786	-55.9972	124.7826	-0.4488	-1.4075	108.8475	-0.0129	2.6256	98.7598	0.0266
NDL Cue Strength	-234.1188	484.4461	-0.4833	-325.2296	433.1367	-0.7509	-97.8865	385.5144	-0.2539	-56.1137	311.2646	-0.1803	27.7881	234.1739	0.1187	-66.4434	204.4900	-0.3249	-14.1326	187.5928	-0.0753
Duration (log)	-9.3985	12.7509	-0.7371	-4.5929	11.4982	-0.3994	-7.9113	10.1640	-0.7784	-7.5631	8.1179	-0.9317	-6.6019	6.1999	-1.0648	-2.8676	5.3682	-0.5342	-2.1392	4.6897	-0.4561
Frequency (log)	-259.6836	181.1685	-1.4334	-178.9431	157.1534	-1.1387	-156.7909	129.8651	-1.2073	-110.0028	101.7462	-1.0811	-64.8526	80.0568	-0.8101	-22.9617	67.8834	-0.3383	-3.5829	54.2080	-0.0661
Previous Voicing: voiceless	192.0172	293.5024	0.6542	238.3033	265.3892	0.8979	53.3822	240.4846	0.2220	-21.7272	195.3816	-0.1112	-80.6431	145.5828	-0.5539	-17.5499	127.9081	-0.1372	-39.2771	120.1300	-0.3270
Previous Place: dental	-38.9767	340.8375	-0.1144	-64.5878	299.6320	-0.2156	65.3892	251.6681	0.2598	150.2427	197.8761	0.7593	180.6763	152.7513	1.1828	88.6807	132.1098	0.6713	63.9174	112.8516	0.5664
Next Voicing: voiceless	50.0580	43.0102	1.1639	40.3235	36.4771	1.1054	37.8785	27.8476	1.3602	34.9209	20.8866	1.6719	26.7864	17.1014	1.5663	16.6461	14.2635	1.1670	7.6238	9.7215	0.7842
Duration (log) x Frequency (log)	2.1916	2.6582	0.8245	1.1492	2.3985	0.4791	1.8259	2.1189	0.8617	1.7518	1.6924	1.0350	1.5150	1.2938	1.1710	0.6985	1.1198	0.6238	0.5078	0.9761	0.5202

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	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	78.6284	116.9006	0.6726	70.8261	113.3628	0.6248	44.7997	106.7653	0.4196	25.7529	98.9476	0.2603	45.5637	89.3623	0.5099	104.4776	79.6361	1.3119	95.4263	61.7139	1.5463
Tense: past	-22.3171	19.7349	-1.1308	-30.4439	19.1742	-1.5878	-26.8786	18.0469	-1.4894	-27.2193	16.6956	-1.6303	-32.3594	15.0629	-2.1483	-34.8705	13.5313	-2.5770	-23.9956	10.5682	-2.2705
NDL Cue Strength	-58.9837	101.4548	-0.5814	-42.0869	98.4716	-0.4274	-28.7513	92.7146	-0.3101	-34.2930	85.8298	-0.3995	-67.1275	77.5879	-0.8652	-76.2626	69.5928	-1.0958	-52.7212	54.2359	-0.9721
Duration (log)	0.4765	0.2456	1.9406	0.5238	0.2396	2.1859	0.5769	0.2263	2.5496	0.5357	0.2097	2.5544	0.4690	0.1863	2.5181	0.3483	0.1649	2.1124	0.3641	0.1292	2.8183
Frequency (log)	1.0122	12.7481	0.0794	0.2532	12.3724	0.0205	1.6592	11.6499	0.1424	0.6063	10.7882	0.0562	-6.1401	9.7537	-0.6295	-13.7843	8.7676	-1.5722	-12.0000	6.8650	-1.7480
Previous Voicing: voiceless	-67.2055	85.0807	-0.7899	-59.9859	82.4167	-0.7278	-51.6518	77.6593	-0.6651	-26.8307	72.0589	-0.3723	-40.3095	65.1043	-0.6192	-64.0020	57.8517	-1.1063	-60.1353	44.7862	-1.3427
Previous Place: dental	132.7139	118.9077	1.1161	160.9148	115.3260	1.3953	143.8845	108.5870	1.3251	176.4974	100.6078	1.7543	168.7048	90.8338	1.8573	129.9922	80.8595	1.6076	55.9803	62.5996	0.8943
Previous Place: diphthong	-18.1673	66.7041	-0.2724	-24.6128	64.5657	-0.3812	-32.9566	60.8595	-0.5415	-11.5499	56.5396	-0.2043	5.4265	51.0235	0.1064	14.3281	45.1415	0.3174	11.6870	34.8476	0.3354
Previous Place: glottal	111.0732	99.8111	1.1128	120.6692	96.6027	1.2491	104.6509	91.0431	1.1495	140.8301	84.5567	1.6655	134.9479	76.3862	1.7667	99.1954	67.6427	1.4665	44.9453	52.2135	0.8608

Previous Place: labial	-98.7960	54.7455	-1.8046	-102.0043	53.2292	-1.9163	-94.9053	50.0683	-1.8955	-77.1826	46.2641	-1.6683	-70.6491	41.8329	-1.6888	-71.7135	37.9046	-1.8919	-55.9032	29.8837	-1.8707
Previous Place: lax	-62.7649	65.3966	-0.9598	-54.6069	63.2950	-0.8627	-46.2778	59.6637	-0.7756	-12.4218	55.4248	-0.2241	7.1215	50.0495	0.1423	11.4743	44.2892	0.2591	9.4980	34.1925	0.2778
Previous Place: palatal	13.3989	52.5069	0.2552	18.4659	50.9058	0.3627	21.2990	47.9537	0.4442	29.3474	44.4461	0.6603	55.9316	40.1845	1.3919	76.4817	35.8093	2.1358	69.9364	27.7540	2.5199
Previous Place: palato-alveolar	226.7911	76.5703	2.9619	216.1937	74.4083	2.9055	189.8828	70.0613	2.7102	146.3543	64.8279	2.2576	125.9398	58.5368	2.1515	116.3314	52.6974	2.2075	67.5624	41.3808	1.6327
Previous Place: tense	-57.1899	74.3370	-0.7693	-53.1276	71.9541	-0.7384	-42.1070	67.8205	-0.6209	-22.4916	62.9964	-0.3570	-4.9702	56.8744	-0.0874	0.1989	50.3324	0.0040	2.8259	38.8396	0.0728
Previous Manner: approximate	-54.6710	76.5697	-0.7140	-44.8502	74.1816	-0.6046	-37.3462	69.8894	-0.5344	-23.3671	64.8398	-0.3604	-41.5097	58.5479	-0.7090	-62.0541	51.9877	-1.1936	-56.4856	40.1778	-1.4059
Previous Manner: flap	44.6414	85.6386	0.5213	19.0213	82.9243	0.2294	4.6252	78.1423	0.0592	11.3962	72.5396	0.1571	17.8569	65.5264	0.2725	17.8221	58.1765	0.3063	11.0280	44.9575	0.2453
Previous Manner: fricative	-87.5730	111.4499	-0.7858	-130.5547	107.9308	-1.2096	-121.5286	101.7069	-1.1949	-166.9128	94.4046	-1.7681	-169.4179	85.2916	-1.9863	-130.2804	75.7042	-1.7209	-60.1467	58.5627	-1.0270
Previous Manner: lax	31.2097	36.1927	0.8623	37.6046	35.0410	1.0732	35.1884	33.0259	1.0655	16.0794	30.6763	0.5242	1.3812	27.6698	0.0499	-2.0434	24.4600	-0.0835	0.5649	18.8606	0.0300
Previous Manner: nasal	-19.8191	57.8110	-0.3428	-14.7503	55.9560	-0.2636	-6.9808	52.7471	-0.1323	14.7360	49.0025	0.3007	28.0853	44.2331	0.6349	31.1869	39.1340	0.7969	23.3284	30.2204	0.7719
Next Voicing: voiceless	20.4104	13.4444	1.5181	18.5176	13.0309	1.4211	13.3014	12.2821	1.0830	7.8229	11.3940	0.6866	6.0096	10.2929	0.5839	10.2594	9.1535	1.1208	7.4248	7.1057	1.0449
Next Place: dental	-8.6289	20.9337	-0.4122	-9.1790	20.2806	-0.4526	-15.2651	19.1167	-0.7985	-18.7317	17.7433	-1.0557	-17.9554	16.0203	-1.1208	-18.6474	14.1881	-1.3143	-17.1688	10.9654	-1.5657
Next Place: diphthong	15.7044	45.3414	0.3464	-6.3786	43.8881	-0.1453	-12.2165	41.3712	-0.2953	-3.3607	38.4084	-0.0875	24.6030	34.7607	0.7078	17.8376	30.8120	0.5789	6.0069	23.8083	0.2523
Next Place: glottal	-6.1844	16.2015	-0.3817	-18.0201	15.6997	-1.1478	-24.1529	14.8005	-1.6319	-18.7450	13.7414	-1.3641	-7.8748	12.3804	-0.6361	-1.1764	10.9274	-0.1077	6.1165	8.4259	0.7259
Next Place: labial	15.8707	12.0345	1.3188	11.1155	11.6604	0.9533	9.7203	10.9899	0.8845	6.9337	10.1986	0.6799	5.7935	9.2066	0.6293	1.8763	8.1520	0.2302	1.7348	6.2963	0.2755
Next Place: labio-dental	-40.5872	21.0976	-1.9238	-29.9920	20.4333	-1.4678	-28.9903	19.2610	-1.5051	-22.2616	17.8783	-1.2452	-19.3366	16.1567	-1.1968	-21.3214	14.3132	-1.4896	-19.5749	11.0611	-1.7697
Next Place: lax	-11.8682	44.8828	-0.2644	-18.3694	43.4436	-0.4228	-17.9491	40.9518	-0.4383	-11.4694	38.0183	-0.3017	13.9604	34.4111	0.4057	6.7872	30.5063	0.2225	-4.3058	23.5708	-0.1827
Next Place: palatal	40.6868	15.1569	2.6844	37.2004	14.6880	2.5327	39.0167	13.8457	2.8180	38.9385	12.8487	3.0305	41.1448	11.6012	3.5466	27.9169	10.3011	2.7101	15.2009	7.9930	1.9018
Next Place: palato-alveolar	90.5993	30.8160	2.9400	109.3003	29.8496	3.6617	107.7432	28.1490	3.8276	106.1556	26.1400	4.0610	103.6109	23.5842	4.3932	71.8618	20.7904	3.4565	30.4640	16.0393	1.8993
Next Place: tense	21.7843	47.6648	0.4570	3.1537	46.1527	0.0683	-0.3996	43.5138	-0.0092	3.4891	40.3980	0.0864	28.4936	36.5213	0.7802	12.3858	32.3138	0.3833	-9.4257	24.9503	-0.3778
Next Manner: approximate	13.0709	45.8050	0.2854	17.8220	44.3389	0.4020	19.0310	41.7968	0.4553	25.0510	38.8036	0.6456	43.7770	35.1131	1.2467	31.2733	31.1312	1.0046	9.6018	24.0632	0.3990
Next Manner: flap	16.7495	51.2969	0.3265	28.2239	49.6746	0.5682	32.9223	46.8157	0.7032	36.2629	43.4426	0.8347	54.5846	39.3068	1.3887	34.4933	34.9121	0.9880	5.4750	27.0127	0.2027
Next Manner: fricative	31.9315	43.9167	0.7271	35.0661	42.5077	0.8249	44.0084	40.0692	1.0983	51.4327	37.1981	1.3827	67.7540	33.6765	2.0119	50.6761	29.8837	1.6958	27.1935	23.1119	1.1766
Next Manner: nasal	17.5165	47.1295	0.3717	22.2177	45.6262	0.4869	36.1147	43.0089	0.8397	49.9320	39.9235	1.2507	75.5251	36.1255	2.0906	55.7183	32.0328	1.7394	23.0931	24.7598	0.9327
Next Manner: stop	51.1182	45.8649	1.1145	55.3708	44.3959	1.2472	63.6389	41.8502	1.5206	68.2573	38.8535	1.7568	84.8250	35.1605	2.4125	64.6646	31.1827	2.0737	33.4542	24.1085	1.3877
Duration (log) x Frequency (log)	-0.0161	0.0333	-0.4817	-0.0158	0.0325	-0.4865	-0.0248	0.0306	-0.8089	-0.0265	0.0284	-0.9349	-0.0242	0.0254	-0.9542	-0.0141	0.0225	-0.6255	-0.0214	0.0177	-1.2149

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Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	266.8157	294.4872	0.9060	103.4481	271.8913	0.3805	-7.8731	243.5521	-0.0323	-87.1082	212.7548	-0.4094	-187.7123	180.5819	-1.0395	-141.2134	155.6425	-0.9073	-28.6785	118.5043	-0.2420
Tense: past	49.3272	49.4090	0.9983	59.6678	45.9006	1.2999	52.4146	40.8835	1.2820	35.1312	35.7494	0.9827	21.8814	30.4069	0.7196	24.9579	26.2895	0.9493	19.0732	20.0495	0.9513
NDL Cue Strength	-58.8497	254.7481	-0.2310	-36.7545	236.0117	-0.1557	21.6599	210.8235	0.1027	-26.3169	184.2929	-0.1428	-107.0013	156.6474	-0.6831	-143.6679	135.3931	-1.0611	-76.9719	103.2900	-0.7452
Duration (log)	0.0621	0.6095	0.1020	0.3728	0.5674	0.6570	0.5327	0.5078	1.0491	0.6222	0.4476	1.3900	0.6477	0.3844	1.6847	0.6313	0.3335	1.8930	0.4435	0.2547	1.7411
Frequency (log)	3.8659	32.2564	0.1198	18.8236	29.9081	0.6294	20.2103	26.6289	0.7590	21.3759	23.2860	0.9180	18.6613	19.8011	0.9424	13.2366	17.1228	0.7730	-0.3897	13.0281	-0.0299
Previous Voicing: voiceless	181.8615	215.2534	0.8449	197.7525	198.3680	0.9969	163.3591	178.0334	0.9176	171.9462	155.5455	1.1054	217.0765	132.0139	1.6443	159.4675	113.7086	1.4024	84.6023	86.5119	0.9779
Previous Place: dental	211.2350	299.1333	0.7062	232.9947	276.0612	0.8440	282.9182	247.4738	1.1432	325.4092	216.1505	1.5055	352.8726	183.4090	1.9240	270.5078	158.0148	1.7119	152.0510	120.1970	1.2650
Previous Place: diphthong	-165.9668	169.0751	-0.9816	-159.7609	155.4432	-1.0278	-99.2042	139.9272	-0.7090	-29.4878	122.3007	-0.2411	55.8333	103.8158	0.5378	59.6466	89.2982	0.6679	52.4049	67.8339	0.7725
Previous Place: glottal	35.7245	253.2186	0.1411	54.7527	232.6948	0.2353	114.9633	209.4604	0.5489	147.7382	183.0009	0.8073	181.2036	155.2652	1.1671	130.3129	133.5783	0.9756	90.9405	101.4471	0.8964
Previous Place: labial	-13.3787	137.4357	-0.0973	-14.1549	128.0792	-0.1105	-11.7766	113.6112	-0.1037	-14.3254	99.4279	-0.1441	-22.2702	84.6929	-0.2630	-21.2975	73.4741	-0.2899	-48.6843	55.9431	-0.8702
Previous Place: lax	73.2550	165.8486	0.4417	38.9928	152.4478	0.2558	33.0579	137.2579	0.2408	41.3023	119.9681	0.3443	110.6881	101.8352	1.0869	99.1953	87.6165	1.1322	61.5885	66.5435	0.9255
Previous Place: palatal	105.4534	132.6127	0.7952	29.2690	122.3848	0.2392	-10.1430	109.6499	-0.0925	-30.9446	95.7835	-0.3231	-35.2198	81.2793	-0.4333	-22.8514	70.0683	-0.3261	12.8308	53.3078	0.2407
Previous Place: palato-alveolar	-169.3599	192.3288	-0.8806	-193.7060	178.7896	-1.0834	-102.5956	159.2801	-0.6441	-33.5798	139.5336	-0.2407	5.5820	118.9254	0.0469	28.6178	103.1439	0.2775	-32.0863	78.5829	-0.4083
Previous Place: tense	15.8091	188.4255	0.0839	50.5229	173.2013	0.2917	116.5591	155.9216	0.7475	142.1035	136.2589	1.0429	177.2337	115.6473	1.5325	165.3292	99.4784	1.6620	116.1818	75.5421	1.5380
Previous Manner: approximate	-24.1717	193.3145	-0.1250	12.0928	178.1471	0.0679	56.8714	159.9235	0.3556	91.0538	139.6890	0.6518	132.4783	118.5094	1.1179	96.1780	102.0013	0.9429	43.7798	77.5900	0.5642
Previous Manner: flap	282.1089	216.6748	1.3020	246.2724	199.5293	1.2343	229.5542	179.2458	1.2807	204.9716	156.5743	1.3091	202.4745	132.8284	1.5243	146.0003	114.2804	1.2776	77.0330	86.8874	0.8866
Previous Manner: fricative	-352.3352	282.2262	-1.2484	-327.5283	259.7407	-1.2610	-293.7359	233.5084	-1.2579	-298.3262	204.0693	-1.4619	-335.6271	173.2415	-1.9373	-250.2671	149.2125	-1.6773	-153.3509	113.4351	-1.3519
Previous Manner: lax	-107.3721	91.7259	-1.1706	-83.2395	84.3118	-0.9873	-55.4881	75.8859	-0.7312	-26.5922	66.3139	-0.4010	-20.9562	56.2743	-0.3724	-3.6251	48.3958	-0.0749	-4.8113	36.7211	-0.1310
Previous Manner: nasal	77.2580	146.5291	0.5273	61.6772	134.7216	0.4578	77.8563	121.2949	0.6419	90.7508	106.0316	0.8559	134.0387	90.0217	1.4890	114.3227	77.4542	1.4760	80.2882	58.8573	1.3641
Next Voicing: voiceless	23.5456	33.9902	0.6927	21.1658	31.3447	0.6753	10.9330	28.1401	0.3885	2.0549	24.6151	0.0835	1.2194	20.9281	0.0583	12.5573	18.0635	0.6952	6.7004	13.7571	0.4871
Next Place: dental	-12.4809	52.9799	-0.2356	-26.8024	48.7539	-0.5497	-47.1783	43.8470	-1.0760	-54.2296	38.3297	-1.4148	-50.1195	32.5505	-1.5397	-32.8438	28.0426	-1.1712	-21.4202	21.3253	-1.0045
Next Place: diphthong	-118.8829	115.0488	-1.0333	-68.3502	105.6630	-0.6469	-41.1005	95.1877	-0.4318	-33.6211	83.1723	-0.4042	13.2383	70.6006	0.1875	-5.0699	60.8329	-0.0833	-29.8331	46.3185	-0.6441
Next Place: glottal	98.2893	40.9406	2.4008	78.6314	37.6632	2.0878	55.0957	33.8983	1.6253	36.9288	29.6403	1.2459	12.4259	25.1719	0.4936	-1.7350	21.6668	-0.0801	-0.5238	16.4718	-0.0318
Next Place: labial	245.9681	30.4404	8.0803	236.5578	28.0203	8.4424	201.8174	25.1875	8.0126	157.6994	22.0126	7.1641	115.7223	18.6848	6.1934	70.7198	16.0924	4.3946	39.5367	12.2350	3.2314
Next Place: labio-dental	161.6806	53.4439	3.0252	156.7430	49.1448	3.1894	151.6203	44.2274	3.4282	128.7037	38.6577	3.3293	98.7078	32.8259	3.0070	63.1068	28.2855	2.2311	43.3417	21.5231	2.0137
Next Place: lax	-130.5862	113.8786	-1.1467	-82.1661	104.5840	-0.7856	-54.2847	94.2199	-0.5761	-37.7559	82.3238	-0.4586	16.6710	69.8774	0.2386	12.6601	60.2099	0.2103	-11.2771	45.8454	-0.2460
Next Place: palatal	-114.5846	38.3582	-2.9872	-84.8273	35.3739	-2.3980	-48.3544	31.7507	-1.5229	-15.2290	27.7747	-0.5483	8.4890	23.6142	0.3595	13.7348	20.3695	0.6743	19.4855	15.5022	1.2570
Next Place: palato-alveolar	-183.8168	78.0937	-2.3538	-151.5547	71.7667	-2.1118	-76.4767	64.6500	-1.1829	-0.6877	56.5356	-0.0122	55.7400	48.0218	1.1607	80.3152	41.3608	1.9418	56.1110	31.4825	1.7823
Next Place: tense	-39.7711	120.8596	-0.3291	-33.9861	111.0099	-0.3062	-13.3341	100.0208	-0.1333	-11.1025	87.4185	-0.1270	19.1762	74.2191	0.2584	0.3923	63.9398	0.0061	-25.4064	48.6731	-0.5220
Next Manner: approximate	-96.9537	116.1895	-0.8344	-56.4201	106.7338	-0.5286	-13.5583	96.1417	-0.1410	17.0573	84.0147	0.2030	69.3391	71.3284	0.9721	50.0675	61.4644	0.8146	1.4147	46.8075	0.0302

Next Manner: flap	-204.0632	129.9553	-1.5703	-164.5969	119.5403	-1.3769	-118.3434	107.5062	-1.1008	-70.9034	93.9312	-0.7548	8.5795	79.7361	0.1076	10.8387	68.7261	0.1577	-16.6408	52.3301	-0.3180
Next Manner: fricative	-255.5427	111.4343	-2.2932	-190.4864	102.3721	-1.8607	-127.1438	92.1990	-1.3790	-66.7658	80.5646	-0.8287	22.1152	68.3991	0.3233	15.8485	58.9531	0.2688	-12.4372	44.9023	-0.2770
Next Manner: nasal	-195.6041	119.4709	-1.6373	-138.8215	109.7637	-1.2647	-76.1550	98.8660	-0.7703	-28.0629	86.3966	-0.3248	46.9239	73.3546	0.6397	37.1844	63.2177	0.5882	3.4985	48.1551	0.0726
Next Manner: stop	-164.1825	116.3509	-1.4111	-124.4787	106.8888	-1.1646	-79.5528	96.2722	-0.8263	-35.5967	84.1283	-0.4231	25.9302	71.4269	0.3630	2.4154	61.5516	0.0392	-33.8191	46.8771	-0.7214
Duration (log) x Frequency (log)	0.1352	0.0833	1.6221	0.0518	0.0775	0.6681	0.0057	0.0693	0.0821	-0.0157	0.0610	-0.2571	-0.0190	0.0522	-0.3640	-0.0147	0.0453	-0.3251	0.0074	0.0345	0.2145

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	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	-80.1822	162.9178	-0.4922	-104.8070	144.9753	-0.7229	-127.8085	133.3305	-0.9586	-156.2037	122.0956	-1.2794	-140.9026	112.7307	-1.2499	-136.8106	98.9764	-1.3823	-108.4243	77.5635	-1.3979
Tense: past	-38.0925	80.3438	-0.4741	-46.2700	73.1459	-0.6326	-21.7517	67.4294	-0.3226	-36.2970	62.4676	-0.5811	-15.7602	57.9445	-0.2720	-17.6982	50.5532	-0.3501	-27.8591	39.6446	-0.7027
NDL Cue Strength	-497.0982	476.7618	-1.0427	-508.8721	421.0572	-1.2086	-352.6007	386.1165	-0.9132	-253.3766	351.7984	-0.7202	-181.9072	323.4166	-0.5625	-160.8601	285.6087	-0.5632	-34.0767	223.6226	-0.1524
Duration (log)	0.7294	1.2214	0.5971	1.0707	1.1005	0.9730	1.2408	1.0128	1.2251	1.4853	0.9248	1.6060	1.4529	0.8519	1.7055	1.3572	0.7498	1.8100	0.8363	0.5878	1.4228
Frequency (log)	52.4125	45.6248	1.1488	48.8976	40.4249	1.2096	42.7405	37.1723	1.1498	43.1557	33.7371	1.2792	38.5377	30.9889	1.2436	35.6823	27.3736	1.3035	20.5056	21.4542	0.9558
Previous Voicing: voiceless	116.7599	133.1592	0.8768	106.7095	120.7739	0.8835	86.0856	111.1868	0.7742	100.9193	102.4649	0.9849	69.9784	94.9262	0.7372	69.5598	82.9927	0.8381	87.5682	65.0480	1.3462
Previous Place: glottal	-187.3394	153.2438	-1.2225	-173.9093	138.4228	-1.2564	-106.9883	127.5764	-0.8386	-71.1670	116.2321	-0.6123	-31.0650	106.9661	-0.2904	-32.9591	94.2102	-0.3498	-5.6811	73.8910	-0.0769
Previous Place: labial	114.3637	110.5505	1.0345	122.3486	100.6217	1.2159	94.5194	92.6669	1.0200	105.7027	85.5569	1.2355	72.2944	79.2709	0.9120	70.2872	69.2675	1.0147	85.3515	54.3124	1.5715
Previous Place: labio-dental	-120.9393	129.5193	-0.9338	-131.8014	117.0042	-1.1265	-78.7095	107.8073	-0.7301	-70.4820	98.6528	-0.7144	-48.3982	90.9644	-0.5321	-46.6137	79.9339	-0.5832	-17.5717	62.6884	-0.2803
Previous Place: palatal	162.2500	317.2332	0.5115	32.9645	282.5613	0.1167	-36.1228	259.9378	-0.1390	-8.3537	235.8709	-0.0354	-23.8570	216.3901	-0.1102	25.2812	191.3689	0.1321	16.4536	150.0249	0.1097
Previous Manner: fricative	-2.7627	112.3563	-0.0246	19.3677	100.1736	0.1933	3.8380	92.2333	0.0416	-12.7680	84.2924	-0.1515	-7.5562	77.8995	-0.0970	-6.6254	68.3290	-0.0970	-38.8215	53.5445	-0.7250
Next Voicing: voiceless	-251.5236	140.1298	-1.7949	-293.4062	129.0028	-2.2744	-306.3243	119.2028	-2.5698	-240.6804	110.6920	-2.1743	-206.5790	102.8775	-2.0080	-169.4493	89.4679	-1.8940	-120.0886	70.2345	-1.7098
Next Place: dental	-237.1728	145.4185	-1.6310	-264.6565	133.9434	-1.9759	-282.5531	123.7631	-2.2830	-212.9630	114.7084	-1.8566	-168.2229	106.4884	-1.5797	-130.8995	92.7331	-1.4116	-97.5124	72.7997	-1.3395
Next Place: glottal	46.8133	47.3176	0.9893	64.8800	43.8422	1.4799	50.1072	40.6146	1.2337	44.0159	38.4378	1.1451	48.8592	36.1702	1.3508	41.3693	30.9913	1.3349	7.3315	24.3320	0.3013
Next Place: labial	-2.7886	84.1327	-0.0331	16.9308	76.8347	0.2204	13.9518	70.8063	0.1970	20.9696	66.1841	0.3168	15.8624	61.5900	0.2575	9.9702	53.5320	0.1862	9.8413	41.9682	0.2345
Next Place: lax	4.8352	40.5456	0.1193	-1.6307	37.7874	-0.0432	4.4999	35.0295	0.1285	9.8494	33.2498	0.2962	0.7884	31.2436	0.0252	1.8691	26.8028	0.0697	12.5369	21.0495	0.5956
Next Place: tense	42.4253	65.2082	0.6506	35.5363	59.1766	0.6005	41.8424	54.4209	0.7689	54.7091	50.0178	1.0938	50.0460	46.1859	1.0836	44.5806	40.5382	1.0997	17.1556	31.7687	0.5400
Next Manner: fricative	227.5421	141.6009	1.6069	285.1891	129.9675	2.1943	333.6300	120.0065	2.7801	280.3683	110.9567	2.5268	228.7426	102.8962	2.2230	190.4403	89.7381	2.1222	152.3915	70.4335	2.1636
Next Manner: nasal	-29.3347	86.5996	-0.3387	-25.1436	78.3955	-0.3207	-13.1250	72.0662	-0.1821	6.1436	66.5938	0.0923	15.8340	61.6002	0.2570	42.3641	53.9590	0.7851	52.5172	42.2771	1.2422
Next Manner: stop	181.9758	106.2533	1.7127	215.1542	95.7511	2.2470	243.0392	87.9186	2.7644	188.1962	80.7761	2.3299	146.8433	74.5506	1.9697	111.0772	65.5083	1.6956	89.6232	51.3043	1.7469
Duration (log) x Frequency (log)	-0.1720	0.2969	-0.5794	-0.2089	0.2697	-0.7747	-0.2408	0.2487	-0.9681	-0.2906	0.2267	-1.2818	-0.2956	0.2086	-1.4170	-0.2826	0.1837	-1.5381	-0.1436	0.1441	-0.9961

ɔ F2

	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	127.7970	199.3657	0.6410	168.0361	193.5217	0.8683	186.9700	187.2258	0.9986	158.1181	175.4975	0.9010	123.1643	163.9460	0.7512	19.1011	141.5742	0.1349	15.8427	108.2692	0.1463
Tense: past	7.0041	109.7641	0.0638	23.2107	103.6395	0.2240	62.6564	101.4158	0.6178	81.4625	95.0166	0.8573	78.3424	88.1285	0.8890	3.8000	75.3079	0.0505	11.4499	58.0680	0.1972
NDL Cue Strength	2129.7072	634.4904	3.3566	2202.2004	597.6314	3.6849	2138.2606	560.4101	3.8155	1897.4894	517.6691	3.6654	1440.3806	467.2786	3.0825	1119.9585	385.6426	2.9041	361.3758	302.8214	1.1934
Duration (log)	0.6377	1.4663	0.4349	0.3297	1.4519	0.2271	0.0468	1.4042	0.0333	-0.0790	1.3198	-0.0598	-0.0978	1.2356	-0.0792	0.8729	1.0719	0.8144	0.6286	0.8128	0.7733
Frequency (log)	-110.3982	57.6955	-1.9135	-127.9486	55.4442	-2.3077	-131.2735	52.7628	-2.4880	-118.9682	48.9900	-2.4284	-100.3236	45.0905	-2.2249	-68.0006	38.3737	-1.7721	-39.1984	29.8230	-1.3144
Previous Voicing: voiceless	169.7970	168.4539	1.0080	159.1403	164.6657	0.9664	135.6765	159.3013	0.8517	108.0471	149.9378	0.7206	62.4792	140.3268	0.4452	128.6510	121.7386	1.0568	48.1748	91.6910	0.5254
Previous Place: glottal	443.6966	201.0082	2.2074	471.7575	190.3950	2.4778	524.2125	183.0842	2.8632	522.2666	169.7107	3.0774	443.1714	157.8369	2.8078	295.9318	137.7209	2.1488	110.8315	105.1829	1.0537
Previous Place: labial	164.5537	130.1934	1.2639	120.0638	127.6203	0.9408	57.3157	127.2264	0.4505	26.8446	121.8942	0.2202	21.3323	116.6388	0.1829	75.2717	102.5273	0.7342	23.6641	75.4743	0.3135
Previous Place: labio-dental	379.1953	170.0029	2.2305	432.0956	158.7683	2.7215	454.0213	152.9477	2.9685	435.8913	142.1080	3.0673	356.1315	132.5150	2.6875	229.5078	114.8979	1.9975	90.4625	87.4057	1.0350
Previous Place: palatal	-589.0389	410.4948	-1.4349	-552.9844	381.3594	-1.4500	-508.1976	363.4106	-1.3984	-497.8093	334.7320	-1.4872	-417.9725	309.3689	-1.3510	-238.4958	267.3620	-0.8920	-140.4051	205.3756	-0.6837
Previous Manner: fricative	-389.7399	154.5828	-2.5212	-415.0686	147.1026	-2.8216	-422.9754	137.4274	-3.0778	-389.6018	125.0012	-3.1168	-285.7068	113.9656	-2.5070	-238.3701	97.8395	-2.4363	-70.9896	76.8058	-0.9243
Next Voicing: voiceless	176.9092	173.0056	1.0226	155.9072	176.3221	0.8842	14.7925	180.8454	0.0818	-18.9369	172.7207	-0.1096	-8.9085	164.9721	-0.0540	-28.7486	147.4023	-0.1950	-91.7979	110.6367	-0.8297
Next Place: dental	129.7961	179.4627	0.7232	85.2670	182.6638	0.4668	-60.1501	186.6522	-0.3223	-79.5456	178.1035	-0.4466	-52.8845	169.9660	-0.3111	-56.0308	151.8084	-0.3691	-102.2915	113.8091	-0.8988
Next Place: glottal	-0.8903	59.2670	-0.0150	27.7670	57.7571	0.4808	37.1720	59.8373	0.6212	44.6534	57.9265	0.7709	62.7123	56.1303	1.1173	101.4644	49.4787	2.0507	125.7770	36.4183	3.4537
Next Place: labial	390.1744	95.0802	4.1036	332.7747	92.0891	3.6136	186.1537	93.4358	1.9923	126.3138	90.1654	1.4009	89.5559	87.4370	1.0242	97.0221	77.8100	1.2469	44.3295	55.8642	0.7935
Next Place: lax	-6.2289	49.7910	-0.1251	21.9350	49.0700	0.4470	20.8316	50.9410	0.4089	33.4366	49.5589	0.6747	41.2999	48.1289	0.8581	52.4170	42.6289	1.2296	44.3397	30.8938	1.4352
Next Place: tense	151.9942	72.0274	2.1102	142.3474	69.9619	2.0346	106.3937	68.7422	1.5477	78.5932	65.7083	1.1961	70.3749	63.6342	1.1059	75.6617	56.8649	1.3306	74.4139	40.7003	1.8283
Next Manner: fricative	-118.8478	174.5211	-0.6810	-75.6615	176.8598	-0.4278	64.1736	179.9603	0.3566	92.2307	171.2626	0.5385	77.2835	163.2514	0.4734	89.3088	145.8630	0.6123	124.2294	109.6277	1.1332
Next Manner: nasal	-292.6608	95.4909	-3.0648	-240.8190	91.7023	-2.6261	-97.3398	91.5417	-1.0633	-39.8220	87.6472	-0.4543	2.6928	84.7977	0.0318	7.8035	75.7102	0.1031	42.0936	54.4047	0.7737
Next Manner: stop	-299.8784	116.1189	-2.5825	-272.1492	110.6000	-2.4607	-151.9864	108.6274	-1.3992	-107.6577	103.2860	-1.0423	-71.4789	99.9434	-0.7152	-64.1872	89.4726	-0.7174	-5.7343	64.2217	-0.0893
Duration (log) x Frequency (log)	0.0128	0.3678	0.0347	0.0928	0.3632	0.2554	0.1725	0.3509	0.4917	0.2240	0.3282	0.6825	0.2414	0.3064	0.7876	-0.0062	0.2663	-0.0234	0.0185	0.2030	0.0914

a F1

	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	148.7995	260.9550	0.5702	24.6873	259.5556	0.0951	-108.5625	225.2919	-0.4819	-75.4255	224.9224	-0.3353	21.7709	215.0674	0.1012	101.8485	174.8882	0.5824	110.9128	139.4179	0.7955
Tense: past	-4.7797	45.2248	-0.1057	-19.9134	42.2489	-0.4713	24.1677	37.3417	0.6472	59.5680	35.7395	1.6667	72.5501	34.2400	2.1189	64.7484	29.4297	2.2001	29.9285	24.0414	1.2449

NDL Cue Strength	-19.2354	151.4501	-0.1270	10.0435	144.6104	0.0695	-9.4092	125.3671	-0.0751	50.5689	122.5970	0.4125	20.4924	116.9330	0.1752	-21.4237	97.6288	-0.2194	15.1423	79.2924	0.1910
Duration (log)	0.5795	0.7458	0.7770	0.3045	0.7652	0.3979	-0.0838	0.7024	-0.1194	-0.5258	0.6840	-0.7688	-0.9058	0.6631	-1.3660	-1.1813	0.5533	-2.1350	-0.4308	0.4318	-0.9975
Frequency (log)	10.4054	79.5632	0.1308	15.0095	77.6119	0.1934	30.5131	66.9938	0.4555	1.1685	66.3392	0.0176	-20.7495	63.3158	-0.3277	-15.3336	52.0077	-0.2948	5.3818	41.8786	0.1285
Previous Voicing: voiceless	-36.9169	23.1768	-1.5928	-10.2259	20.7381	-0.4931	9.2486	18.6220	0.4967	14.7978	17.1605	0.8623	8.1372	16.3842	0.4966	4.7872	14.6088	0.3277	5.9193	12.0924	0.4895
Previous Place: diphthong	-179.8459	234.7529	-0.7661	-109.0782	226.5738	-0.4814	-119.3709	193.9505	-0.6155	-39.2186	191.9765	-0.2043	7.8099	182.9152	0.0427	-72.5680	150.5541	-0.4820	-218.5139	122.0290	-1.7907
Previous Place: labial	-245.4521	125.2333	-1.9600	-128.0017	125.0934	-1.0232	-42.8264	103.8512	-0.4124	110.6776	106.7235	1.0370	109.7555	101.1916	1.0846	18.3468	79.3973	0.2311	-58.1330	63.6313	-0.9136
Previous Place: labio-dental	-44.0679	57.6503	-0.7644	-89.3603	55.6804	-1.6049	-20.5369	48.4375	-0.4240	49.2813	47.7857	1.0313	77.4019	45.8152	1.6894	55.5998	38.0679	1.4605	24.7026	30.7803	0.8025
Previous Place: palatal	-160.4867	229.3885	-0.6996	-94.8945	222.1739	-0.4271	-89.4881	189.7202	-0.4717	5.4832	188.4035	0.0291	65.0160	179.4610	0.3623	-21.3109	147.0889	-0.1449	-170.8839	119.0822	-1.4350
Previous Place: palato-alveolar	-43.2770	93.9163	-0.4608	-52.4733	91.1347	-0.5758	6.9867	77.5539	0.0901	20.6138	77.3988	0.2663	34.8023	73.8274	0.4714	56.9515	60.2425	0.9454	71.8994	48.7190	1.4758
Previous Place: tense	-146.6114	237.1027	-0.6183	-110.3655	228.5065	-0.4830	-82.4706	195.8282	-0.4211	-0.2643	193.5773	-0.0014	44.1765	184.4422	0.2395	-45.4766	152.0377	-0.2991	-198.4449	123.2840	-1.6097
Previous Manner: fricative	-120.7562	126.6507	-0.9535	3.5332	123.2124	0.0287	28.3385	104.4276	0.2714	61.8834	104.6972	0.5911	47.6671	99.7135	0.4780	-31.8477	80.9911	-0.3932	-157.4000	65.5376	-2.4017
Previous Manner: nasal	-146.6381	338.7461	-0.4329	-80.2436	325.7447	-0.2463	-58.9125	279.8037	-0.2105	99.9086	275.6514	0.3624	160.0620	262.7336	0.6092	28.6154	217.3208	0.1317	-158.8546	176.2954	-0.9011
Previous Manner: stop	26.4207	34.3912	0.7682	26.8106	30.8645	0.8687	20.0450	27.6108	0.7260	4.7410	25.4250	0.1865	-7.8272	24.3344	-0.3217	-11.2971	21.7456	-0.5195	-10.0125	18.0142	-0.5558
Next Voicing: voiceless	27.6016	16.0104	1.7240	14.9458	14.4045	1.0376	-4.4691	12.9108	-0.3462	-12.3756	11.8983	-1.0401	-18.8352	11.3885	-1.6539	-20.8387	10.1741	-2.0482	-16.8113	8.4186	-1.9969
Next Place: dental	-52.4594	86.7787	-0.6045	-95.8572	79.1578	-1.2110	-135.8854	73.3375	-1.8529	-184.0199	67.9583	-2.7078	-197.5897	65.4165	-3.0205	-218.5548	58.3813	-3.7436	-174.8879	47.6535	-3.6700
Next Place: diphthong	57.5953	44.2355	1.3020	3.6907	40.0483	0.0922	-50.6901	35.7990	-1.4160	-75.0344	33.0801	-2.2683	-83.3881	31.6892	-2.6314	-76.2604	28.1995	-2.7043	-57.5337	23.2900	-2.4703
Next Place: glottal	62.0411	16.3145	3.8028	23.8500	14.6542	1.6275	-21.3342	13.1781	-1.6189	-45.7222	12.1580	-3.7607	-56.8782	11.6307	-4.8904	-55.9809	10.3885	-5.3888	-41.0785	8.5918	-4.7811
Next Place: labial	1.0357	19.2411	0.0538	-13.0185	17.2902	-0.7529	-11.1726	15.5474	-0.7186	-5.0566	14.3427	-0.3526	0.5889	13.7217	0.0429	-0.5083	12.2519	-0.0415	5.2157	10.1293	0.5149
Next Place: labio-dental	-10.8107	57.8646	-0.1868	-48.5916	52.1114	-0.9325	-82.2274	46.4510	-1.7702	-94.0253	42.8645	-2.1935	-97.9596	41.0282	-2.3876	-79.1189	36.5537	-2.1645	-56.0878	30.2612	-1.8535
Next Place: lax	45.2636	35.5418	1.2735	12.1332	32.3127	0.3755	-21.1702	29.0098	-0.7298	-47.1755	26.8728	-1.7555	-49.3405	25.7379	-1.9170	-47.1277	22.8364	-2.0637	-31.2151	18.8139	-1.6592
Next Place: palatal	53.3844	32.7843	1.6284	78.2562	29.6841	2.6363	78.4114	26.5752	2.9505	81.9229	24.4788	3.3467	71.8500	23.4768	3.0605	34.8501	20.9575	1.6629	-5.5982	17.3190	-0.3232
Next Manner: flap	2.1119	33.8310	0.0624	-12.6218	30.7473	-0.4105	-27.8324	27.5280	-1.0111	-35.3615	25.4758	-1.3880	-31.6943	24.4121	-1.2983	-24.9770	21.6855	-1.1518	-12.7738	17.8829	-0.7143
Next Manner: fricative	23.6909	53.3639	0.4440	37.8626	48.1799	0.7859	44.9302	43.1960	1.0401	32.8403	39.8638	0.8238	32.9665	38.1701	0.8637	39.3132	34.0359	1.1551	38.5446	28.1295	1.3703
Next Manner: nasal	47.1541	42.1749	1.1181	45.0557	38.0451	1.1843	-3.6937	34.1305	-0.1082	-15.8102	31.4996	-0.5019	-10.3356	30.1539	-0.3428	-0.1886	26.8811	-0.0070	4.4395	22.2175	0.1998
Next Manner: stop	-19.5394	35.5395	-0.5498	-4.8665	32.2325	-0.1510	2.8205	28.8902	0.0976	2.5691	26.7125	0.0962	9.1587	25.5944	0.3578	11.7736	22.7741	0.5170	12.1083	18.7934	0.6443
Duration (log) x Frequency (log)	-0.0731	0.1155	-0.6329	0.0026	0.1181	0.0224	0.0942	0.1084	0.8692	0.1922	0.1054	1.8230	0.2611	0.1022	2.5563	0.3017	0.0853	3.5364	0.1609	0.0667	2.4116

a F2

	20			30			40			50			60			70			80		
Predictor	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue	Estimate	StdError	tValue
(Intercept)	-493.6494	512.1415	-0.9639	-447.4286	453.7684	-0.9860	-590.7052	410.3387	-1.4396	-580.8308	359.2340	-1.6169	-430.6758	316.0874	-1.3625	-247.1703	248.4142	-0.9950	-254.8188	172.7937	-1.4747
Tense: past	41.4029	87.5818	0.4727	23.5328	78.9553	0.2981	37.8198	71.0726	0.5321	53.5966	62.2291	0.8613	55.3566	54.2619	1.0202	29.7684	42.6205	0.6985	30.6908	29.2195	1.0504
NDL Cue Strength	-617.3641	296.8596	-2.0796	-467.4620	265.5861	-1.7601	-446.0209	238.0207	-1.8739	-337.4586	208.1899	-1.6209	-274.2554	181.4210	-1.5117	-154.1291	142.5001	-1.0816	-106.9002	98.2531	-1.0880
Duration (log)	-1.0679	1.5508	-0.6886	-0.4924	1.3713	-0.3591	0.1839	1.2639	0.1455	0.3563	1.0950	0.3254	0.0542	0.9733	0.0556	0.0672	0.7516	0.0894	0.2907	0.5186	0.5605
Frequency (log)	322.7451	155.8779	2.0705	262.2680	138.6764	1.8912	268.3468	124.7103	2.1518	229.7879	109.2158	2.1040	173.9423	95.6151	1.8192	121.3274	75.2146	1.6131	91.0193	52.1161	1.7465
Previous Voicing: voiceless	-17.7452	47.1787	-0.3761	-4.0955	42.5503	-0.0963	-3.2406	37.4962	-0.0864	-7.0419	32.4441	-0.2170	-6.1997	27.9252	-0.2220	1.2502	21.6055	0.0579	-1.7718	14.5321	-0.1219
Previous Place: diphthong	-792.5036	456.5091	-1.7360	-597.3437	407.3855	-1.4663	-571.3801	364.7475	-1.5665	-505.2524	319.8405	-1.5797	-402.7009	279.1215	-1.4427	-344.5944	220.1821	-1.5650	-216.9535	152.4649	-1.4230
Previous Place: labial	563.6522	240.5770	2.3429	584.8154	212.6292	2.7504	519.7800	189.9312	2.7367	252.2477	167.2192	1.5085	137.3121	146.3448	0.9383	-3.3015	116.2642	-0.0284	-51.4337	81.5636	-0.6306
Previous Place: labio-dental	-4.6077	112.6417	-0.0409	16.8871	101.3503	0.1666	7.1445	92.2546	0.0774	-18.4948	80.9401	-0.2285	-57.8636	70.9304	-0.8158	-52.7508	55.9953	-0.9421	-39.0157	39.0057	-1.0003
Previous Place: palatal	-830.2618	445.4549	-1.8639	-660.7978	397.2535	-1.6634	-638.7226	355.8935	-1.7947	-543.7345	312.2070	-1.7416	-391.5664	272.5638	-1.4366	-317.1409	215.1312	-1.4742	-186.7521	149.1364	-1.2522
Previous Place: palato-alveolar	395.7679	181.4706	2.1809	370.3930	162.3253	2.2818	404.1033	146.1397	2.7652	384.6729	128.4568	2.9946	332.2943	112.1752	2.9623	247.5639	88.7939	2.7881	166.9655	61.7564	2.7036
Previous Place: tense	-894.8552	461.6177	-1.9385	-650.0259	412.1037	-1.5773	-575.3430	369.0614	-1.5589	-465.4180	323.5550	-1.4385	-362.6894	282.2982	-1.2848	-354.1750	222.5998	-1.5911	-232.6247	154.0680	-1.5099
Previous Manner: fricative	-374.4000	243.9447	-1.5348	-302.5734	218.1226	-1.3872	-269.2606	195.7600	-1.3755	-194.2796	172.1308	-1.1287	-126.5444	150.3743	-0.8415	-124.5257	119.1832	-1.0448	-68.3994	83.0329	-0.8238
Previous Manner: nasal	-1261.4503	661.2895	-1.9076	-959.6849	590.3443	-1.6256	-930.6224	528.2493	-1.7617	-787.8900	462.7654	-1.7026	-611.8552	403.5936	-1.5160	-471.5076	317.8659	-1.4834	-308.9528	219.6321	-1.4067
Previous Manner: stop	89.7628	68.5671	1.3091	91.4820	61.9883	1.4758	83.3353	54.7037	1.5234	60.6401	47.5185	1.2761	28.3563	41.0288	0.6911	9.0478	31.8895	0.2837	-11.8174	21.4506	-0.5509
Next Voicing: voiceless	22.0668	32.0976	0.6875	21.9116	28.9495	0.7569	23.8436	25.4935	0.9353	31.9480	22.1154	1.4446	28.4220	19.1165	1.4868	28.0181	14.8452	1.8874	18.8896	9.9906	1.8907
Next Place: dental	-29.3351	175.5873	-0.1671	-69.8530	155.7598	-0.4485	-103.7013	135.4907	-0.7654	-85.3796	116.9954	-0.7298	-88.6178	102.4261	-0.8652	-57.0102	79.2994	-0.7189	-32.6090	53.6083	-0.6083
Next Place: diphthong	-244.5581	88.3075	-2.7694	-174.0734	79.6765	-2.1848	-145.3052	70.4072	-2.0638	-135.1910	61.1474	-2.2109	-145.4665	52.9251	-2.7485	-109.0514	41.1395	-2.6508	-56.8908	27.7293	-2.0516
Next Place: glottal	58.6186	32.7718	1.7887	62.4838	29.5219	2.1165	58.3866	25.9635	2.2488	58.5385	22.5037	2.6013	48.3710	19.4466	2.4874	40.3491	15.0862	2.6746	25.8858	10.1538	2.5494
Next Place: labial	133.0461	38.5972	3.4470	141.8843	34.7978	4.0774	111.9929	30.6560	3.6532	89.3722	26.5939	3.3606	70.5594	22.9851	3.0698	58.1632	17.8406	3.2602	35.7937	12.0089	2.9806
Next Place: labio-dental	159.6046	115.2652	1.3847	160.2224	104.1279	1.5387	135.4008	91.7626	1.4756	126.4451	79.6961	1.5866	99.9370	68.8031	1.4525	78.8573	53.4785	1.4746	56.4437	35.9600	1.5696
Next Place: lax	-250.5991	70.9181	-3.5336	-187.6659	63.9016	-2.9368	-179.0834	56.7088	-3.1579	-155.5719	49.2636	-3.1580	-148.7975	42.7362	-3.4818	-130.5760	33.2116	-3.9316	-88.5620	22.4314	-3.9481
Next Place: palatal	-12.3286	65.6224	-0.1879	30.4569	59.0818	0.5155	87.8944	51.9205	1.6929	130.3182	45.0137	2.8951	159.9630	39.0392	4.0975	120.9981	30.3199	3.9907	81.6809	20.4125	4.0015
Next Manner: flap	-292.2514	67.3924	-4.3366	-230.3422	60.7658	-3.7907	-215.3361	53.8576	-3.9982	-178.9423	46.7992	-3.8236	-162.8345	40.5747	-4.0132	-135.1486	31.5514	-4.2834	-89.8411	21.2906	-4.2198
Next Manner: fricative	-478.5192	106.7967	-4.4807	-379.5514	96.2783	-3.9422	-303.9672	84.9613	-3.5777	-244.5881	73.7279	-3.3174	-202.1164	63.8215	-3.1669	-176.4606	49.5698	-3.5598	-113.0544	33.3973	-3.3851
Next Manner: nasal	-388.0727	84.2878	-4.6041	-331.9802	76.1095	-4.3619	-305.6709	67.4093	-4.5346	-235.9320	58.5507	-4.0295	-190.7595	50.6499	-3.7662	-146.4599	39.3541	-3.7216	-76.9547	26.5294	-2.9007
Next Manner: stop	-353.2648	70.7883	-4.9904	-291.6687	63.8372	-4.5689	-270.8119	56.5515	-4.7888	-238.5772	49.1372	-4.8553	-210.6229	42.5898	-4.9454	-175.1863	33.1177	-5.2898	-113.9896	22.3426	-5.1019
Duration (log) x Frequency (log)	0.2010	0.2398	0.8381	0.0898	0.2118	0.4242	-0.0085	0.1942	-0.0438	-0.0100	0.1684	-0.0592	0.0534	0.1499	0.3560	0.0489	0.1159	0.4220	0.0013	0.0799	0.0166

Table A.17: Coefficients for the F1 and F2 global (all vowels pooled) GAM models of formant movement.

	F1				F2			
Parametric Coefficients								
Predictor	edf	Ref.edf	F	p	edf	Ref.edf	F	p
(Intercept)	6.0419	0.2615	23.1068	0.0000	7.4215	0.1745	42.5337	0.0000
Tense: present	0.0109	0.0099	1.1006	0.2711	-0.0143	0.0066	-2.1487	0.0317
NDL Cue Strength	0.0924	0.0250	3.6981	0.0002	-0.0885	0.0170	-5.2206	0.0000
Vowel: æ	-0.0485	0.1429	-0.3397	0.7341	0.0428	0.0903	0.4740	0.6355
Vowel: ʌ	0.2632	0.2338	1.1261	0.2601	-0.3274	0.1560	-2.0985	0.0359
Vowel: ɔ	-0.3316	0.1450	-2.2866	0.0222	-0.6278	0.1623	-3.8683	0.0001
Vowel: ɜ	-0.1923	0.1296	-1.4841	0.1378	0.1252	0.0865	1.4466	0.1480
Vowel: ɪ	-0.4626	0.2987	-1.5488	0.1214	0.5070	0.1995	2.5414	0.0110
Vowel: i	-0.3184	0.1706	-1.8662	0.0620	0.2509	0.1141	2.1989	0.0279
Vowel: o	0.1112	0.2712	0.4098	0.6819	-0.1215	0.1814	-0.6701	0.5028
Vowel: ʊ	-0.5709	0.1714	-3.3300	0.0009	-0.4208	0.1369	-3.0743	0.0021
Vowel: u	-0.2043	0.0896	-2.2808	0.0226	0.2573	0.0595	4.3268	0.0000
Previous Manner: approximate	0.4122	0.2218	1.8588	0.0631	0.2441	0.1482	1.6475	0.0995
Previous Manner: diphthong	0.2062	0.2134	0.9667	0.3337	0.4029	0.1430	2.8181	0.0048
Previous Manner: diphthong-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Previous Manner: flap	0.4623	0.1037	4.4585	0.0000	-0.2621	0.0696	-3.7645	0.0002
Previous Manner: fricative	0.4184	0.2001	2.0912	0.0365	0.0967	0.1338	0.7226	0.4699
Previous Manner: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Previous Manner: lax-nasal	-0.3447	0.2400	-1.4364	0.1509	-0.1289	0.1607	-0.8026	0.4222
Previous Manner: nasal	0.1765	0.2037	0.8661	0.3864	-0.1687	0.1361	-1.2394	0.2152
Previous Manner: rhotic	0.1286	0.2167	0.5933	0.5530	0.0000	0.0000	NA	NA
Previous Manner: stop	0.4785	0.2178	2.1971	0.0280	0.2426	0.1455	1.6670	0.0955
Previous Manner: tense	0.0000	0.0000	NA	NA	0.1584	0.1377	1.1504	0.2500
Previous Voicing: voiceless	-0.0223	0.0265	-0.8420	0.3998	-0.0760	0.0177	-4.2935	0.0000
Previous Place: dental	0.2295	0.1236	1.8577	0.0632	0.3593	0.0824	4.3576	0.0000
Previous Place: diphthong	-0.0638	0.1100	-0.5802	0.5618	-0.2659	0.0742	-3.5855	0.0003
Previous Place: glottal	-0.0865	0.0836	-1.0351	0.3006	-0.2477	0.0584	-4.2397	0.0000
Previous Place: labial	-0.0826	0.1448	-0.5701	0.5686	-0.2934	0.0966	-3.0380	0.0024
Previous Place: labio-dental	-0.0965	0.0612	-1.5764	0.1149	-0.0187	0.0411	-0.4559	0.6485
Previous Place: lax	0.1590	0.2298	0.6918	0.4891	0.0624	0.1535	0.4063	0.6845
Previous Place: palatal	-0.2996	0.1006	-2.9775	0.0029	-0.0880	0.0672	-1.3089	0.1906
Previous Place: palato-alveolar	-0.1593	0.0526	-3.0255	0.0025	-0.0006	0.0358	-0.0169	0.9865
Previous Place: tense	0.0870	0.2061	0.4223	0.6728	0.0000	0.0000	NA	NA
Next Manner: approximate	0.1094	0.1727	0.6336	0.5264	-0.2237	0.1151	-1.9424	0.0521
Next Manner: diphthong	-0.0034	0.1741	-0.0193	0.9846	0.0000	0.0000	NA	NA
Next Manner: flap	0.1431	0.1705	0.8390	0.4015	-0.1081	0.1137	-0.9512	0.3415
Next Manner: fricative	0.0466	0.1772	0.2627	0.7928	-0.1264	0.1181	-1.0704	0.2845
Next Manner: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Next Manner: lax-nasal	0.0973	0.1664	0.5851	0.5585	0.0779	0.1109	0.7030	0.4821
Next Manner: nasal	0.1834	0.1668	1.0993	0.2716	-0.0906	0.1112	-0.8148	0.4152
Next Manner: rhotic	0.0000	0.0000	NA	NA	-0.0040	0.1596	-0.0248	0.9802
Next Manner: stop	0.1199	0.1707	0.7026	0.4823	-0.1356	0.1138	-1.1917	0.2334
Next Manner: tense	-0.0187	0.1013	-0.1842	0.8538	0.0437	0.0676	0.6468	0.5177
Next Voicing: voiceless	0.0281	0.0198	1.4195	0.1558	0.0427	0.0132	3.2392	0.0012
Next Place: dental	0.2282	0.1057	2.1602	0.0308	0.0517	0.0705	0.7343	0.4628

Next Place: diphthong	0.0000	0.0000	NA	NA	-0.0412	0.1160	-0.3549	0.7227
Next Place: glottal	0.0663	0.0202	3.2856	0.0010	0.0205	0.0134	1.5278	0.1266
Next Place: labial	0.0327	0.0237	1.3767	0.1686	-0.0158	0.0158	-0.9995	0.3175
Next Place: labio-dental	0.0737	0.0715	1.0313	0.3024	-0.0561	0.0476	-1.1781	0.2387
Next Place: lax	0.1202	0.1712	0.7022	0.4825	-0.1086	0.1141	-0.9513	0.3414
Next Place: palatal	-0.1210	0.0397	-3.0459	0.0023	-0.0349	0.0265	-1.3188	0.1872
Next Place: palato-alveolar	-0.0561	0.0889	-0.6308	0.5282	-0.1112	0.0593	-1.8752	0.0608
Next Place: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Previous Manner: approximate	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Manner: approximate	-0.2028	0.1657	-1.2243	0.2209	0.0313	0.1107	0.2829	0.7773
Vowel: ɔ x Previous Manner: approximate	0.1583	0.0997	1.5881	0.1123	-0.0087	0.0682	-0.1281	0.8981
Vowel: ɜ x Previous Manner: approximate	-0.0486	0.1533	-0.3171	0.7512	-0.1982	0.1024	-1.9360	0.0529
Vowel: ɪ x Previous Manner: approximate	0.0783	0.2446	0.3200	0.7490	-0.5003	0.1635	-3.0598	0.0022
Vowel: i x Previous Manner: approximate	-0.2696	0.1288	-2.0941	0.0363	-0.2299	0.0864	-2.6616	0.0078
Vowel: o x Previous Manner: approximate	-0.5975	0.2298	-2.6001	0.0093	-0.2928	0.1538	-1.9036	0.0570
Vowel: ʊ x Previous Manner: approximate	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Manner: approximate	-0.0778	0.1225	-0.6353	0.5253	-0.2417	0.0817	-2.9570	0.0031
Vowel: æ x Previous Manner: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Manner: diphthong	0.1152	0.2411	0.4778	0.6328	-0.4720	0.1614	-2.9249	0.0034
Vowel: ɔ x Previous Manner: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Previous Manner: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Previous Manner: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: i x Previous Manner: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: o x Previous Manner: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʊ x Previous Manner: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Manner: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Previous Manner: diphthong-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Manner: diphthong-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɔ x Previous Manner: diphthong-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Previous Manner: diphthong-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Previous Manner: diphthong-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: i x Previous Manner: diphthong-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: o x Previous Manner: diphthong-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʊ x Previous Manner: diphthong-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Manner: diphthong-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Previous Manner: flap	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Manner: flap	-0.3648	0.2690	-1.3559	0.1751	0.3829	0.1797	2.1304	0.0331
Vowel: ɔ x Previous Manner: flap	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Previous Manner: flap	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Previous Manner: flap	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: i x Previous Manner: flap	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: o x Previous Manner: flap	-0.5979	0.1607	-3.7203	0.0002	0.1981	0.1084	1.8279	0.0676
Vowel: ʊ x Previous Manner: flap	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Manner: flap	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Previous Manner: fricative	-0.1401	0.0970	-1.4434	0.1489	0.1295	0.0595	2.1755	0.0296
Vowel: ʌ x Previous Manner: fricative	-0.7319	0.1478	-4.9511	0.0000	0.2412	0.0990	2.4369	0.0148
Vowel: ɔ x Previous Manner: fricative	0.2452	0.1331	1.8413	0.0656	0.2895	0.0902	3.2088	0.0013
Vowel: ɜ x Previous Manner: fricative	-0.1685	0.1258	-1.3398	0.1803	-0.0544	0.0841	-0.6461	0.5182

Vowel: ɪ x Previous Manner: fricative	-0.0081	0.2210	-0.0366	0.9708	-0.3161	0.1480	-2.1361	0.0327
Vowel: i x Previous Manner: fricative	-0.2714	0.0992	-2.7361	0.0062	-0.0934	0.0669	-1.3966	0.1625
Vowel: o x Previous Manner: fricative	-0.9936	0.2897	-3.4294	0.0006	-0.5868	0.1942	-3.0217	0.0025
Vowel: ʊ x Previous Manner: fricative	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Manner: fricative	-0.4294	0.1561	-2.7500	0.0060	-0.2198	0.1045	-2.1023	0.0355
Vowel: æ x Previous Manner: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Manner: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɔ x Previous Manner: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Previous Manner: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Previous Manner: lax	0.2834	0.2526	1.1220	0.2619	0.0000	0.0000	NA	NA
Vowel: i x Previous Manner: lax	-0.1437	0.1385	-1.0377	0.2994	0.1169	0.0925	1.2643	0.2061
Vowel: o x Previous Manner: lax	-0.3388	0.2386	-1.4203	0.1555	-0.1455	0.1597	-0.9111	0.3623
Vowel: ʊ x Previous Manner: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Manner: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Previous Manner: lax-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Manner: lax-nasal	0.7478	0.2611	2.8640	0.0042	-0.0106	0.1747	-0.0605	0.9518
Vowel: ɔ x Previous Manner: lax-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Previous Manner: lax-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Previous Manner: lax-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: i x Previous Manner: lax-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: o x Previous Manner: lax-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʊ x Previous Manner: lax-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Manner: lax-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Previous Manner: nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Manner: nasal	-0.1162	0.1366	-0.8506	0.3950	0.3565	0.0914	3.9013	0.0001
Vowel: ɔ x Previous Manner: nasal	0.6274	0.1473	4.2588	0.0000	0.4660	0.0995	4.6828	0.0000
Vowel: ɜ x Previous Manner: nasal	0.2535	0.1212	2.0918	0.0365	0.2542	0.0809	3.1427	0.0017
Vowel: ɪ x Previous Manner: nasal	0.5331	0.2288	2.3303	0.0198	-0.0963	0.1529	-0.6298	0.5288
Vowel: i x Previous Manner: nasal	-0.1446	0.0858	-1.6850	0.0920	0.3152	0.0575	5.4793	0.0000
Vowel: o x Previous Manner: nasal	-0.2632	0.2119	-1.2419	0.2143	0.1562	0.1420	1.0998	0.2714
Vowel: ʊ x Previous Manner: nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Manner: nasal	0.0267	0.0780	0.3428	0.7318	0.4099	0.0523	7.8370	0.0000
Vowel: æ x Previous Manner: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Manner: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɔ x Previous Manner: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Previous Manner: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Previous Manner: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: i x Previous Manner: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: o x Previous Manner: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʊ x Previous Manner: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Manner: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Previous Manner: stop	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Manner: stop	-0.3925	0.1647	-2.3835	0.0172	0.1048	0.1101	0.9518	0.3412
Vowel: ɔ x Previous Manner: stop	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Previous Manner: stop	-0.1946	0.1510	-1.2884	0.1976	-0.1844	0.1009	-1.8280	0.0676
Vowel: ɪ x Previous Manner: stop	-0.1027	0.2392	-0.4293	0.6677	-0.4552	0.1599	-2.8458	0.0044
Vowel: i x Previous Manner: stop	-0.3821	0.1281	-2.9837	0.0028	-0.1478	0.0856	-1.7259	0.0844
Vowel: o x Previous Manner: stop	-0.7153	0.2337	-3.0606	0.0022	-0.4490	0.1565	-2.8690	0.0041

Vowel: ʊ x Previous Manner: stop	0.2194	0.1401	1.5669	0.1171	0.3405	0.1480	2.3005	0.0214
Vowel: u x Previous Manner: stop	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Previous Manner: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Manner: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɔ x Previous Manner: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Previous Manner: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Previous Manner: tense	0.2378	0.2312	1.0284	0.3038	-0.2202	0.1546	-1.4245	0.1543
Vowel: i x Previous Manner: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: o x Previous Manner: tense	0.0000	0.0000	NA	NA	-0.2374	0.1479	-1.6049	0.1085
Vowel: ʊ x Previous Manner: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Manner: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Previous Voicing: voiceless	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Voicing: voiceless	0.1507	0.0429	3.5163	0.0004	0.0194	0.0286	0.6776	0.4980
Vowel: ɔ x Previous Voicing: voiceless	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Previous Voicing: voiceless	0.0757	0.0451	1.6788	0.0932	0.1480	0.0301	4.9102	0.0000
Vowel: ɪ x Previous Voicing: voiceless	0.0270	0.0321	0.8420	0.3998	0.0880	0.0214	4.1214	0.0000
Vowel: i x Previous Voicing: voiceless	-0.0757	0.0572	-1.3248	0.1852	0.1260	0.0383	3.2943	0.0010
Vowel: o x Previous Voicing: voiceless	0.1522	0.0803	1.8950	0.0581	0.3104	0.0537	5.7784	0.0000
Vowel: ʊ x Previous Voicing: voiceless	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Voicing: voiceless	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Previous Place: consonant	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Place: consonant	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɔ x Previous Place: consonant	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Previous Place: consonant	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Previous Place: consonant	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: i x Previous Place: consonant	-0.0122	0.0662	-0.1847	0.8535	0.1087	0.0442	2.4584	0.0140
Vowel: o x Previous Place: consonant	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʊ x Previous Place: consonant	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Place: consonant	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Previous Place: dental	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Place: dental	0.0699	0.1591	0.4391	0.6606	-0.3629	0.1063	-3.4134	0.0006
Vowel: ɔ x Previous Place: dental	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Previous Place: dental	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Previous Place: dental	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: i x Previous Place: dental	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: o x Previous Place: dental	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʊ x Previous Place: dental	-0.2480	0.1954	-1.2690	0.2045	0.1339	0.1307	1.0242	0.3058
Vowel: u x Previous Place: dental	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Previous Place: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Place: diphthong	0.0391	0.2531	0.1544	0.8773	0.4115	0.1697	2.4246	0.0153
Vowel: ɔ x Previous Place: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Previous Place: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Previous Place: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: i x Previous Place: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: o x Previous Place: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʊ x Previous Place: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Place: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Previous Place: glottal	-0.0108	0.1026	-0.1055	0.9160	0.3060	0.0691	4.4256	0.0000

Vowel: ʌ x Previous Place: glottal	0.6590	0.1088	6.0585	0.0000	0.3112	0.0746	4.1710	0.0000
Vowel: ɔ x Previous Place: glottal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Previous Place: glottal	0.3970	0.0991	4.0042	0.0001	0.2338	0.0685	3.4144	0.0006
Vowel: ɪ x Previous Place: glottal	0.0310	0.0988	0.3137	0.7537	0.2953	0.0682	4.3304	0.0000
Vowel: i x Previous Place: glottal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: o x Previous Place: glottal	0.3794	0.1336	2.8388	0.0045	0.1114	0.0908	1.2269	0.2199
Vowel: ʊ x Previous Place: glottal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Place: glottal	0.0819	0.1951	0.4197	0.6747	0.3069	0.1314	2.3359	0.0195
Vowel: æ x Previous Place: labial	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Place: labial	0.0775	0.1477	0.5248	0.5997	0.0306	0.0985	0.3106	0.7561
Vowel: ɔ x Previous Place: labial	-0.0712	0.1609	-0.4423	0.6582	0.0759	0.1079	0.7033	0.4819
Vowel: ɜ x Previous Place: labial	0.1176	0.1470	0.7998	0.4239	0.3122	0.0980	3.1848	0.0014
Vowel: ɪ x Previous Place: labial	0.1796	0.1527	1.1761	0.2396	0.1710	0.1019	1.6783	0.0933
Vowel: i x Previous Place: labial	0.1395	0.1476	0.9452	0.3446	0.2147	0.0985	2.1809	0.0292
Vowel: o x Previous Place: labial	-0.1306	0.1553	-0.8410	0.4004	0.0745	0.1040	0.7157	0.4742
Vowel: ʊ x Previous Place: labial	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Place: labial	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Previous Place: labio-dental	0.5196	0.1658	3.1350	0.0017	0.0385	0.1068	0.3601	0.7188
Vowel: ʌ x Previous Place: labio-dental	0.4824	0.0995	4.8455	0.0000	-0.0112	0.0666	-0.1675	0.8670
Vowel: ɔ x Previous Place: labio-dental	0.0754	0.0850	0.8872	0.3750	-0.1792	0.0580	-3.0910	0.0020
Vowel: ɜ x Previous Place: labio-dental	0.2657	0.0780	3.4067	0.0007	0.0277	0.0523	0.5295	0.5965
Vowel: ɪ x Previous Place: labio-dental	0.1468	0.1052	1.3953	0.1629	-0.1107	0.0703	-1.5734	0.1156
Vowel: i x Previous Place: labio-dental	0.1155	0.0719	1.6056	0.1084	0.1255	0.0484	2.5960	0.0094
Vowel: o x Previous Place: labio-dental	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʊ x Previous Place: labio-dental	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Place: labio-dental	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Previous Place: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Place: lax	-0.5409	0.1806	-2.9943	0.0028	0.2249	0.1208	1.8623	0.0626
Vowel: ɔ x Previous Place: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Previous Place: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Previous Place: lax	0.0000	0.0000	NA	NA	-0.1513	0.1687	-0.8969	0.3698
Vowel: i x Previous Place: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: o x Previous Place: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʊ x Previous Place: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Place: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Previous Place: palatal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Place: palatal	0.2148	0.1035	2.0748	0.0380	0.1798	0.0691	2.6031	0.0092
Vowel: ɔ x Previous Place: palatal	0.1404	0.2038	0.6891	0.4908	0.3883	0.1381	2.8119	0.0049
Vowel: ɜ x Previous Place: palatal	0.2506	0.1068	2.3461	0.0190	0.1908	0.0714	2.6741	0.0075
Vowel: ɪ x Previous Place: palatal	0.3267	0.1050	3.1126	0.0019	0.1322	0.0702	1.8842	0.0595
Vowel: i x Previous Place: palatal	0.2867	0.1157	2.4780	0.0132	-0.0138	0.0772	-0.1790	0.8580
Vowel: o x Previous Place: palatal	0.2349	0.1024	2.2937	0.0218	0.1002	0.0683	1.4669	0.1424
Vowel: ʊ x Previous Place: palatal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Place: palatal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Previous Place: palato-alveolar	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Place: palato-alveolar	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɔ x Previous Place: palato-alveolar	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Previous Place: palato-alveolar	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA

Vowel: ɪ x Previous Place: palato-alveolar	0.2720	0.0832	3.2673	0.0011	-0.0726	0.0559	-1.2973	0.1945
Vowel: i x Previous Place: palato-alveolar	0.0793	0.1000	0.7928	0.4279	-0.1054	0.0670	-1.5719	0.1160
Vowel: o x Previous Place: palato-alveolar	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʊ x Previous Place: palato-alveolar	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Place: palato-alveolar	0.2359	0.1631	1.4463	0.1481	0.3947	0.1093	3.6123	0.0003
Vowel: æ x Previous Place: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Place: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɔ x Previous Place: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Previous Place: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Previous Place: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: i x Previous Place: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: o x Previous Place: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʊ x Previous Place: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Place: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Previous Place: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Place: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɔ x Previous Place: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Previous Place: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Previous Place: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: i x Previous Place: tense	-0.0925	0.0961	-0.9632	0.3355	0.0320	0.0642	0.4994	0.6175
Vowel: o x Previous Place: tense	-0.2340	0.2208	-1.0596	0.2893	0.0000	0.0000	NA	NA
Vowel: ʊ x Previous Place: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Place: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Next Manner: approximate	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Next Manner: approximate	-0.2981	0.1978	-1.5070	0.1318	0.2720	0.1320	2.0609	0.0393
Vowel: ɔ x Next Manner: approximate	-0.0479	0.0928	-0.5157	0.6061	0.3183	0.1430	2.2264	0.0260
Vowel: ɜ x Next Manner: approximate	-0.0966	0.0861	-1.1212	0.2622	-0.0218	0.0575	-0.3795	0.7043
Vowel: ɪ x Next Manner: approximate	-0.0994	0.2055	-0.4835	0.6287	0.0594	0.1370	0.4338	0.6645
Vowel: i x Next Manner: approximate	-0.0451	0.1570	-0.2874	0.7738	0.1908	0.1047	1.8234	0.0683
Vowel: o x Next Manner: approximate	0.0273	0.1792	0.1521	0.8791	0.1419	0.1195	1.1878	0.2349
Vowel: ʊ x Next Manner: approximate	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Next Manner: approximate	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Next Manner: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Next Manner: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɔ x Next Manner: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Next Manner: diphthong	0.1336	0.0889	1.5020	0.1331	0.0000	0.0000	NA	NA
Vowel: ɪ x Next Manner: diphthong	0.0000	0.0000	NA	NA	-0.1175	0.1385	-0.8485	0.3961
Vowel: i x Next Manner: diphthong	0.1861	0.1605	1.1593	0.2463	0.0000	0.0000	NA	NA
Vowel: o x Next Manner: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʊ x Next Manner: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Next Manner: diphthong	-0.0264	0.0974	-0.2712	0.7862	-0.2938	0.0650	-4.5219	0.0000
Vowel: æ x Next Manner: flap	-0.1016	0.1267	-0.8019	0.4226	-0.0110	0.0836	-0.1317	0.8952
Vowel: ʌ x Next Manner: flap	-0.1593	0.1957	-0.8138	0.4158	0.0696	0.1305	0.5332	0.5939
Vowel: ɔ x Next Manner: flap	0.0000	0.0000	NA	NA	0.1564	0.1545	1.0124	0.3113
Vowel: ɜ x Next Manner: flap	-0.0341	0.0755	-0.4521	0.6512	-0.0170	0.0504	-0.3370	0.7361
Vowel: ɪ x Next Manner: flap	-0.0272	0.2020	-0.1348	0.8927	-0.0502	0.1347	-0.3730	0.7092
Vowel: i x Next Manner: flap	-0.0989	0.1554	-0.6366	0.5244	0.1271	0.1036	1.2269	0.2199
Vowel: o x Next Manner: flap	-0.0169	0.1787	-0.0947	0.9246	0.1457	0.1191	1.2229	0.2214

Vowel: ʊ x Next Manner: flap	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Next Manner: flap	-0.2709	0.0743	-3.6477	0.0003	-0.1900	0.0496	-3.8332	0.0001
Vowel: æ x Next Manner: fricative	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Next Manner: fricative	-0.1578	0.1958	-0.8061	0.4202	0.1294	0.1306	0.9911	0.3217
Vowel: ɔ x Next Manner: fricative	0.1385	0.1937	0.7150	0.4746	0.1667	0.1844	0.9041	0.3660
Vowel: ɜ x Next Manner: fricative	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Next Manner: fricative	0.0487	0.2088	0.2332	0.8156	-0.0793	0.1392	-0.5699	0.5688
Vowel: i x Next Manner: fricative	-0.0659	0.1638	-0.4021	0.6876	0.0706	0.1092	0.6464	0.5180
Vowel: o x Next Manner: fricative	-0.0002	0.1831	-0.0013	0.9990	0.1760	0.1221	1.4416	0.1494
Vowel: ʊ x Next Manner: fricative	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Next Manner: fricative	-0.1222	0.1226	-0.9967	0.3189	-0.1506	0.0818	-1.8398	0.0658
Vowel: æ x Next Manner: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Next Manner: lax	0.0000	0.0000	NA	NA	0.0869	0.1295	0.6708	0.5024
Vowel: ɔ x Next Manner: lax	-0.1314	0.1006	-1.3060	0.1916	0.0000	0.0000	NA	NA
Vowel: ɜ x Next Manner: lax	-0.0630	0.0797	-0.7899	0.4296	0.0000	0.0000	NA	NA
Vowel: ɪ x Next Manner: lax	0.0047	0.2031	0.0229	0.9817	-0.0774	0.1354	-0.5720	0.5673
Vowel: i x Next Manner: lax	-0.0228	0.1554	-0.1469	0.8832	0.1169	0.1036	1.1283	0.2592
Vowel: o x Next Manner: lax	0.1160	0.1775	0.6532	0.5136	0.0000	0.0000	NA	NA
Vowel: ʊ x Next Manner: lax	0.0000	0.0000	NA	NA	0.1753	0.1090	1.6081	0.1078
Vowel: u x Next Manner: lax	-0.2377	0.0839	-2.8327	0.0046	-0.3204	0.0560	-5.7223	0.0000
Vowel: æ x Next Manner: lax-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Next Manner: lax-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɔ x Next Manner: lax-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Next Manner: lax-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Next Manner: lax-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: i x Next Manner: lax-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: o x Next Manner: lax-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʊ x Next Manner: lax-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Next Manner: lax-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Next Manner: nasal	-0.2890	0.1796	-1.6090	0.1076	-0.0380	0.1173	-0.3236	0.7462
Vowel: ʌ x Next Manner: nasal	-0.3156	0.1916	-1.6468	0.0996	0.1155	0.1278	0.9038	0.3661
Vowel: ɔ x Next Manner: nasal	0.0186	0.1373	0.1356	0.8921	0.1133	0.1559	0.7269	0.4673
Vowel: ɜ x Next Manner: nasal	-0.2298	0.0829	-2.7731	0.0056	-0.0254	0.0553	-0.4592	0.6461
Vowel: ɪ x Next Manner: nasal	-0.1579	0.1998	-0.7905	0.4293	0.0106	0.1332	0.0797	0.9365
Vowel: i x Next Manner: nasal	-0.1102	0.1492	-0.7384	0.4603	0.1239	0.0995	1.2457	0.2129
Vowel: o x Next Manner: nasal	-0.0239	0.1740	-0.1371	0.8909	0.1161	0.1160	1.0008	0.3169
Vowel: ʊ x Next Manner: nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Next Manner: nasal	-0.2367	0.0838	-2.8246	0.0047	-0.1404	0.0559	-2.5108	0.0121
Vowel: æ x Next Manner: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Next Manner: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɔ x Next Manner: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Next Manner: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Next Manner: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: i x Next Manner: rhotic	-0.0139	0.1585	-0.0878	0.9300	0.0000	0.0000	NA	NA
Vowel: o x Next Manner: rhotic	-0.0099	0.1526	-0.0652	0.9480	0.0000	0.0000	NA	NA
Vowel: ʊ x Next Manner: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Next Manner: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Next Manner: stop	-0.1067	0.1243	-0.8585	0.3906	0.0574	0.0826	0.6947	0.4872

Vowel: ʌ x Next Manner: stop	-0.3044	0.1912	-1.5917	0.1115	0.1445	0.1275	1.1332	0.2572
Vowel: ɔ x Next Manner: stop	0.1231	0.1507	0.8166	0.4141	0.1283	0.1644	0.7804	0.4351
Vowel: ɜ x Next Manner: stop	-0.0021	0.0597	-0.0352	0.9719	0.0568	0.0398	1.4261	0.1538
Vowel: ɪ x Next Manner: stop	-0.0498	0.2017	-0.2469	0.8050	0.0093	0.1345	0.0691	0.9449
Vowel: i x Next Manner: stop	-0.1434	0.1551	-0.9245	0.3552	0.1700	0.1034	1.6442	0.1002
Vowel: o x Next Manner: stop	0.0052	0.1773	0.0291	0.9767	0.1394	0.1182	1.1796	0.2382
Vowel: ʊ x Next Manner: stop	-0.0396	0.1370	-0.2894	0.7723	0.2078	0.0915	2.2706	0.0232
Vowel: u x Next Manner: stop	-0.1523	0.0643	-2.3689	0.0178	-0.0936	0.0429	-2.1818	0.0291
Vowel: æ x Next Manner: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Next Manner: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɔ x Next Manner: tense	-0.0032	0.2288	-0.0140	0.9889	0.0000	0.0000	NA	NA
Vowel: ɜ x Next Manner: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Next Manner: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: i x Next Manner: tense	0.1051	0.1271	0.8271	0.4082	0.0000	0.0000	NA	NA
Vowel: o x Next Manner: tense	0.2186	0.1129	1.9360	0.0529	0.0000	0.0000	NA	NA
Vowel: ʊ x Next Manner: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Next Manner: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Next Voicing: voiceless	-0.0545	0.1180	-0.4620	0.6441	-0.0605	0.0774	-0.7811	0.4348
Vowel: ʌ x Next Voicing: voiceless	0.0627	0.0397	1.5791	0.1143	-0.0048	0.0265	-0.1814	0.8561
Vowel: ɔ x Next Voicing: voiceless	-0.2526	0.1701	-1.4847	0.1376	0.0581	0.1165	0.4986	0.6181
Vowel: ɜ x Next Voicing: voiceless	-0.0446	0.0296	-1.5065	0.1319	-0.0667	0.0198	-3.3728	0.0007
Vowel: ɪ x Next Voicing: voiceless	-0.0084	0.0234	-0.3579	0.7204	-0.0687	0.0156	-4.4031	0.0000
Vowel: i x Next Voicing: voiceless	-0.0096	0.0259	-0.3724	0.7096	-0.0036	0.0173	-0.2088	0.8346
Vowel: o x Next Voicing: voiceless	0.0283	0.0242	1.1699	0.2421	-0.0865	0.0162	-5.3508	0.0000
Vowel: ʊ x Next Voicing: voiceless	-0.1129	0.0444	-2.5430	0.0110	-0.0876	0.0297	-2.9480	0.0032
Vowel: u x Next Voicing: voiceless	-0.0655	0.0423	-1.5484	0.1215	-0.0252	0.0283	-0.8916	0.3726
Vowel: æ x Next Place: dental	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Next Place: dental	-0.2220	0.1218	-1.8235	0.0682	0.0219	0.0812	0.2693	0.7877
Vowel: ɔ x Next Place: dental	-0.5277	0.2041	-2.5854	0.0097	-0.0109	0.1388	-0.0789	0.9371
Vowel: ɜ x Next Place: dental	-0.2674	0.1215	-2.2016	0.0277	-0.1079	0.0810	-1.3315	0.1830
Vowel: ɪ x Next Place: dental	-0.3998	0.1120	-3.5683	0.0004	0.0212	0.0747	0.2837	0.7766
Vowel: i x Next Place: dental	-0.1569	0.1088	-1.4422	0.1492	-0.0057	0.0725	-0.0792	0.9369
Vowel: o x Next Place: dental	-0.1065	0.1079	-0.9876	0.3234	-0.0797	0.0719	-1.1081	0.2678
Vowel: ʊ x Next Place: dental	-0.0538	0.2899	-0.1855	0.8529	0.0000	0.0000	NA	NA
Vowel: u x Next Place: dental	-0.2723	0.1357	-2.0072	0.0447	0.0059	0.0905	0.0651	0.9481
Vowel: æ x Next Place: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Next Place: diphthong	0.0397	0.1987	0.1999	0.8416	-0.0048	0.1325	-0.0365	0.9709
Vowel: ɔ x Next Place: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Next Place: diphthong	0.0000	0.0000	NA	NA	-0.1308	0.0593	-2.2047	0.0275
Vowel: ɪ x Next Place: diphthong	0.1493	0.2077	0.7188	0.4723	0.0000	0.0000	NA	NA
Vowel: i x Next Place: diphthong	0.0000	0.0000	NA	NA	0.0085	0.1070	0.0798	0.9364
Vowel: o x Next Place: diphthong	0.3290	0.1804	1.8233	0.0683	0.0137	0.1203	0.1137	0.9094
Vowel: ʊ x Next Place: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Next Place: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Next Place: glottal	0.1847	0.1072	1.7227	0.0850	0.0692	0.0663	1.0437	0.2966
Vowel: ʌ x Next Place: glottal	0.0538	0.0382	1.4076	0.1593	-0.0321	0.0255	-1.2568	0.2088
Vowel: ɔ x Next Place: glottal	0.0845	0.0648	1.3031	0.1925	-0.0445	0.0453	-0.9830	0.3256
Vowel: ɜ x Next Place: glottal	-0.0634	0.0299	-2.1208	0.0339	-0.0459	0.0200	-2.2971	0.0216

Vowel: ɪ x Next Place: glottal	-0.0130	0.0243	-0.5353	0.5925	-0.0338	0.0162	-2.0889	0.0367
Vowel: i x Next Place: glottal	0.0095	0.0283	0.3346	0.7379	0.0131	0.0189	0.6922	0.4888
Vowel: o x Next Place: glottal	0.0944	0.0262	3.6029	0.0003	-0.0593	0.0175	-3.3979	0.0007
Vowel: ʊ x Next Place: glottal	0.0000	0.0000	NA	NA	0.2556	0.1946	1.3135	0.1890
Vowel: u x Next Place: glottal	-0.1158	0.0717	-1.6143	0.1065	-0.0470	0.0478	-0.9826	0.3258
Vowel: æ x Next Place: labial	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Next Place: labial	0.0784	0.0370	2.1162	0.0343	-0.1553	0.0247	-6.2837	0.0000
Vowel: ɔ x Next Place: labial	-0.2282	0.1043	-2.1890	0.0286	0.0285	0.0703	0.4048	0.6856
Vowel: ɜ x Next Place: labial	0.0237	0.0436	0.5428	0.5873	-0.0289	0.0291	-0.9922	0.3211
Vowel: ɪ x Next Place: labial	-0.0639	0.0316	-2.0244	0.0429	-0.0386	0.0211	-1.8339	0.0667
Vowel: i x Next Place: labial	-0.0219	0.0296	-0.7400	0.4593	0.0180	0.0198	0.9101	0.3628
Vowel: o x Next Place: labial	0.0204	0.0268	0.7610	0.4467	-0.0591	0.0178	-3.3128	0.0009
Vowel: ʊ x Next Place: labial	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Next Place: labial	-0.1681	0.0730	-2.3045	0.0212	-0.1309	0.0487	-2.6897	0.0072
Vowel: æ x Next Place: labio-dental	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Next Place: labio-dental	-0.3277	0.0959	-3.4168	0.0006	-0.0936	0.0639	-1.4638	0.1433
Vowel: ɔ x Next Place: labio-dental	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Next Place: labio-dental	-0.1108	0.1101	-1.0066	0.3141	0.1776	0.0735	2.4144	0.0158
Vowel: ɪ x Next Place: labio-dental	-0.1654	0.0784	-2.1107	0.0348	0.1935	0.0523	3.6978	0.0002
Vowel: i x Next Place: labio-dental	-0.0933	0.0803	-1.1621	0.2452	0.0974	0.0536	1.8189	0.0689
Vowel: o x Next Place: labio-dental	0.1102	0.0747	1.4752	0.1402	0.0337	0.0498	0.6768	0.4985
Vowel: ʊ x Next Place: labio-dental	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Next Place: labio-dental	-0.1763	0.1105	-1.5964	0.1104	0.1449	0.0736	1.9688	0.0490
Vowel: æ x Next Place: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Next Place: lax	-0.1863	0.1942	-0.9592	0.3375	0.0000	0.0000	NA	NA
Vowel: ɔ x Next Place: lax	0.0000	0.0000	NA	NA	0.1441	0.1397	1.0315	0.3023
Vowel: ɜ x Next Place: lax	0.0000	0.0000	NA	NA	-0.0514	0.0532	-0.9661	0.3340
Vowel: ɪ x Next Place: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: i x Next Place: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: o x Next Place: lax	0.0000	0.0000	NA	NA	0.0633	0.1184	0.5348	0.5928
Vowel: ʊ x Next Place: lax	0.1124	0.2426	0.4634	0.6430	0.0000	0.0000	NA	NA
Vowel: u x Next Place: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Next Place: palatal	0.4297	0.1624	2.6457	0.0082	0.2605	0.1048	2.4866	0.0129
Vowel: ʌ x Next Place: palatal	0.0726	0.0522	1.3906	0.1644	0.0693	0.0349	1.9857	0.0471
Vowel: ɔ x Next Place: palatal	-0.0009	0.1189	-0.0078	0.9938	0.2803	0.0848	3.3061	0.0009
Vowel: ɜ x Next Place: palatal	0.0269	0.0622	0.4324	0.6654	0.0443	0.0415	1.0671	0.2859
Vowel: ɪ x Next Place: palatal	0.0989	0.0478	2.0688	0.0386	0.1179	0.0319	3.6901	0.0002
Vowel: i x Next Place: palatal	0.1234	0.0445	2.7741	0.0055	0.0322	0.0297	1.0841	0.2783
Vowel: o x Next Place: palatal	0.1087	0.0426	2.5504	0.0108	0.1156	0.0284	4.0680	0.0000
Vowel: ʊ x Next Place: palatal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Next Place: palatal	-0.0566	0.0867	-0.6524	0.5142	-0.0867	0.0579	-1.4969	0.1344
Vowel: æ x Next Place: palato-alveolar	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Next Place: palato-alveolar	-0.1620	0.1060	-1.5288	0.1263	0.0930	0.0707	1.3151	0.1885
Vowel: ɔ x Next Place: palato-alveolar	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Next Place: palato-alveolar	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Next Place: palato-alveolar	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: i x Next Place: palato-alveolar	0.1167	0.1031	1.1316	0.2578	0.0875	0.0688	1.2717	0.2035
Vowel: o x Next Place: palato-alveolar	0.1668	0.0945	1.7646	0.0776	0.1846	0.0631	2.9268	0.0034

Vowel: ʊ x Next Place: palato-alveolar	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Next Place: palato-alveolar	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Next Place: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Next Place: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɔ x Next Place: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Next Place: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Next Place: tense	0.1889	0.1703	1.1092	0.2673	-0.0012	0.1136	-0.0107	0.9914
Vowel: i x Next Place: tense	0.0000	0.0000	NA	NA	-0.0447	0.0848	-0.5268	0.5983
Vowel: o x Next Place: tense	0.0000	0.0000	NA	NA	-0.1122	0.0753	-1.4893	0.1364
Vowel: ʊ x Next Place: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Next Place: tense	-0.0630	0.2160	-0.2918	0.7704	-0.4233	0.1441	-2.9380	0.0033
Smooth Terms								
Predictor	edf	Ref.edf	F	p	edf	Ref.edf	F	p
s(Time Step)	8.3309	8.8554	53.3082	0.0000	6.5498	7.7354	6.4663	0.0000
ti(Time Step) x Tense: past	1.3796	1.9124	3.8190	0.0241	1.0040	1.0050	0.5010	0.4796
ti(Time Step) x Tense: present	1.0158	1.0214	1.4789	0.2232	2.1664	2.4716	8.7526	0.0001
ti(Time Step,NDL Cue Strength)	7.8264	9.0248	41.1962	0.0000	11.2998	12.4096	58.9209	0.0000
te(Duration (log), Frequency (log))	13.8764	16.0228	25.3339	0.0000	16.2401	18.1581	91.0332	0.0000
ti(Time Step) x Vowel: a	3.5382	3.8506	14.8823	0.0000	3.4833	3.7845	6.6146	0.0000
ti(Time Step) x Vowel: æ	0.0020	0.0039	0.6606	0.9594	1.7931	2.1385	13.3914	0.0000
ti(Time Step) x Vowel: ʌ	2.1052	2.5750	2.8603	0.0441	3.4768	3.7853	8.7078	0.0000
ti(Time Step) x Vowel: ɔ	1.0024	1.0046	3.7859	0.0515	2.5222	3.0496	3.4376	0.0157
ti(Time Step) x Vowel: ɜ	3.5054	3.8380	15.1666	0.0000	1.0033	1.0052	1.5360	0.2150
ti(Time Step) x Vowel: ɪ	1.0004	1.0008	5.4227	0.0199	2.0432	2.4867	1.6453	0.1813
ti(Time Step) x Vowel: i	3.6136	3.9025	12.9208	0.0000	3.8667	3.9406	42.3087	0.0000
ti(Time Step) x Vowel: o	1.0007	1.0013	0.6262	0.4289	3.1729	3.4755	1.8712	0.1215
ti(Time Step) x Vowel: ʊ	1.0001	1.0003	7.4338	0.0064	1.8292	2.1253	3.2682	0.0355
ti(Time Step) x Vowel: u	1.0007	1.0014	0.1649	0.6850	3.2931	3.6499	4.4290	0.0022
s(Time Step, Speaker) x Vowel: a	37.0603	39.0000	17.3184	0.0000	36.5572	39.0000	10.9882	0.0000
s(Time Step, Speaker) x Vowel: æ	20.8736	25.0000	4.2108	0.0000	14.2595	25.0000	1.2247	0.0000
s(Time Step, Speaker) x Vowel: ʌ	35.1676	37.0000	7.7642	0.0000	35.1513	37.0000	7.1888	0.0000
s(Time Step, Speaker) x Vowel: ɔ	16.5750	32.0000	1.0861	0.0000	20.8947	32.0000	1.6271	0.0000
s(Time Step, Speaker) x Vowel: ɜ	35.5184	39.0000	6.7917	0.0000	36.1762	39.0000	6.0333	0.0000
s(Time Step, Speaker) x Vowel: ɪ	37.3672	39.0000	9.7843	0.0000	37.8747	39.0000	16.3753	0.0000
s(Time Step, Speaker) x Vowel: i	35.7047	39.0000	5.9639	0.0000	37.3951	39.0000	12.8315	0.0000
s(Time Step, Speaker) x Vowel: o	38.1623	39.0000	28.9540	0.0000	38.3501	39.0000	26.4541	0.0000
s(Time Step, Speaker) x Vowel: ʊ	26.0562	33.0000	2.5833	0.0000	31.5760	33.0000	8.7190	0.0000
s(Time Step, Speaker) x Vowel: u	31.3823	36.0000	4.1848	0.0000	30.4589	36.0000	4.6108	0.0000

Table A.18: Coefficients for the F1 and F2 by vowel GAM models of formant movement.

	F1				F2			
Parametric Coefficients								
Predictor	edf	Ref.edf	F	p	edf	Ref.edf	F	p
(Intercept)	6.0124	0.2603	23.1011	0.0000	7.3108	0.1697	43.0926	0.0000
Tense: present	0.0111	0.0100	1.1159	0.2645	-0.0065	0.0070	-0.9324	0.3511
NDL Cue Strength	0.1003	0.0256	3.9148	0.0001	-0.0661	0.0173	-3.8217	0.0001
Vowel: æ	0.0040	0.1420	0.0279	0.9777	0.0159	0.0889	0.1789	0.8580
Vowel: ʌ	-0.0878	0.3072	-0.2858	0.7750	0.1532	0.2007	0.7632	0.4454
Vowel: ɔ	-0.3064	0.1444	-2.1223	0.0338	-0.1814	0.1479	-1.2266	0.2200
Vowel: ɜ	0.6992	0.2494	2.8039	0.0051	0.1261	0.0857	1.4713	0.1412
Vowel: ɪ	-0.4394	0.2972	-1.4782	0.1394	0.5993	0.1953	3.0695	0.0021
Vowel: i	-0.2918	0.1699	-1.7173	0.0859	0.2939	0.1129	2.6040	0.0092
Vowel: o	0.2475	0.2705	0.9147	0.3604	-0.1073	0.1579	-0.6799	0.4966
Vowel: ʊ	-0.5920	0.1976	-2.9960	0.0027	-0.0257	0.0737	-0.3491	0.7270
Vowel: u	-0.1929	0.0893	-2.1599	0.0308	-0.1472	0.1387	-1.0612	0.2886
Previous Manner: approximate	0.4038	0.2209	1.8278	0.0676	0.3541	0.1463	2.4210	0.0155
Previous Manner: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Previous Manner: diphthong-nasal	-0.3386	0.2131	-1.5886	0.1122	-0.4110	0.1128	-3.6432	0.0003
Previous Manner: flap	0.4586	0.1034	4.4370	0.0000	-0.2903	0.0690	-4.2041	0.0000
Previous Manner: fricative	0.4398	0.1993	2.2064	0.0274	0.1775	0.1252	1.4171	0.1564
Previous Manner: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Previous Manner: lax-nasal	0.4196	0.1044	4.0173	0.0001	-0.1457	0.0693	-2.1029	0.0355
Previous Manner: nasal	0.1855	0.2028	0.9145	0.3605	-0.0728	0.1319	-0.5521	0.5809
Previous Manner: rhotic	0.1392	0.2158	0.6452	0.5188	0.0000	0.0000	NA	NA
Previous Manner: stop	0.4700	0.2169	2.1667	0.0303	0.3539	0.1438	2.4620	0.0138
Previous Manner: tense	0.1031	0.2052	0.5023	0.6155	0.0000	0.0000	NA	NA
Previous Voicing: voiceless	-0.0203	0.0264	-0.7678	0.4426	-0.0738	0.0175	-4.2169	0.0000
Previous Place: consonant	-0.0108	0.0659	-0.1638	0.8699	0.1032	0.0437	2.3612	0.0182
Previous Place: dental	0.2285	0.1229	1.8588	0.0631	0.4440	0.1626	2.7307	0.0063
Previous Place: diphthong	0.1614	0.2010	0.8029	0.4220	0.2203	0.1304	1.6892	0.0912
Previous Place: glottal	-0.0639	0.0834	-0.7661	0.4436	-0.2101	0.0588	-3.5710	0.0004
Previous Place: labial	-0.1031	0.1442	-0.7148	0.4747	-0.2874	0.0955	-3.0099	0.0026
Previous Place: labio-dental	-0.0894	0.0619	-1.4442	0.1487	0.0063	0.0409	0.1550	0.8769
Previous Place: lax	-0.7165	0.1502	-4.7708	0.0000	0.1550	0.1001	1.5484	0.1215
Previous Place: palatal	-0.2751	0.1005	-2.7382	0.0062	-0.1138	0.0666	-1.7071	0.0878
Previous Place: palato-alveolar	-0.2006	0.0532	-3.7684	0.0002	0.0266	0.0356	0.7477	0.4547
Previous Place: rhotic	0.0000	0.0000	NA	NA	0.1656	0.1399	1.1836	0.2366
Previous Place: tense	0.0000	0.0000	NA	NA	0.2446	0.1204	2.0316	0.0422
Next Manner: approximate	0.1203	0.1719	0.6998	0.4841	-0.2222	0.1138	-1.9521	0.0509
Next Manner: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Next Manner: flap	0.1497	0.1697	0.8823	0.3776	-0.1020	0.1124	-0.9081	0.3638
Next Manner: fricative	0.0405	0.1763	0.2296	0.8184	-0.1210	0.1168	-1.0367	0.2999
Next Manner: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Next Manner: lax-nasal	0.0000	0.0000	NA	NA	0.0724	0.1096	0.6608	0.5088
Next Manner: nasal	0.1852	0.1660	1.1159	0.2645	-0.0855	0.1099	-0.7781	0.4365
Next Manner: rhotic	-0.1546	0.2498	-0.6188	0.5361	0.0004	0.1567	0.0023	0.9982
Next Manner: stop	0.1263	0.1698	0.7441	0.4568	-0.1311	0.1124	-1.1661	0.2436
Next Manner: syllabic	0.0563	0.1273	0.4422	0.6583	-0.0908	0.0843	-1.0764	0.2817
Next Manner: tense	0.0035	0.1008	0.0352	0.9720	0.0000	0.0000	NA	NA
Next Voicing: voiceless	0.0283	0.0197	1.4387	0.1502	0.0439	0.0130	3.3708	0.0008
Next Place: consonant	0.0419	0.0949	0.4416	0.6588	-0.0346	0.0628	-0.5514	0.5813
Next Place: dental	0.2414	0.1051	2.2957	0.0217	0.0510	0.0696	0.7323	0.4640

Next Place: diphthong	0.0190	0.1732	0.1098	0.9125	-0.0426	0.1147	-0.3716	0.7102
Next Place: glottal	0.0668	0.0201	3.3289	0.0009	0.0227	0.0133	1.7081	0.0876
Next Place: labial	0.0338	0.0236	1.4295	0.1529	-0.0136	0.0156	-0.8705	0.3840
Next Place: labio-dental	0.0578	0.0711	0.8124	0.4166	-0.0449	0.0471	-0.9525	0.3408
Next Place: lax	0.1260	0.1703	0.7396	0.4595	-0.1016	0.1128	-0.9010	0.3676
Next Place: palatal	-0.1175	0.0395	-2.9726	0.0030	-0.0315	0.0262	-1.2030	0.2290
Next Place: palato-alveolar	-0.0509	0.0886	-0.5743	0.5658	-0.0934	0.0588	-1.5893	0.1120
Next Place: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Next Place: tense	0.0000	0.0000	NA	NA	0.0488	0.0669	0.7291	0.4660
Vowel: æ x Previous Manner: approximate	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Manner: approximate	0.1683	0.2589	0.6498	0.5158	-0.4456	0.1724	-2.5847	0.0097
Vowel: ɔ x Previous Manner: approximate	0.1389	0.1003	1.3841	0.1663	-0.4619	0.0912	-5.0649	0.0000
Vowel: ɜ x Previous Manner: approximate	-0.8994	0.2585	-3.4784	0.0005	-0.2007	0.1013	-1.9809	0.0476
Vowel: ɪ x Previous Manner: approximate	0.0746	0.2438	0.3061	0.7595	-0.6242	0.1618	-3.8579	0.0001
Vowel: i x Previous Manner: approximate	-0.2560	0.1285	-1.9924	0.0463	-0.2782	0.0856	-3.2523	0.0011
Vowel: o x Previous Manner: approximate	-0.7031	0.2293	-3.0658	0.0022	-0.3110	0.1282	-2.4263	0.0153
Vowel: ʊ x Previous Manner: approximate	0.0000	0.0000	NA	NA	-0.3496	0.1467	-2.3829	0.0172
Vowel: u x Previous Manner: approximate	-0.0420	0.1222	-0.3438	0.7310	-0.2733	0.0810	-3.3746	0.0007
Vowel: æ x Previous Manner: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Manner: diphthong	-0.0243	0.2406	-0.1012	0.9194	-0.4842	0.1342	-3.6091	0.0003
Vowel: ɔ x Previous Manner: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Previous Manner: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Previous Manner: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: i x Previous Manner: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: o x Previous Manner: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʊ x Previous Manner: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Manner: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Previous Manner: diphthong-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Manner: diphthong-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɔ x Previous Manner: diphthong-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Previous Manner: diphthong-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Previous Manner: diphthong-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: i x Previous Manner: diphthong-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: o x Previous Manner: diphthong-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʊ x Previous Manner: diphthong-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Manner: diphthong-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Previous Manner: flap	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Manner: flap	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɔ x Previous Manner: flap	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Previous Manner: flap	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Previous Manner: flap	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: i x Previous Manner: flap	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: o x Previous Manner: flap	-0.7006	0.1612	-4.3456	0.0000	0.3137	0.1081	2.9031	0.0037
Vowel: ʊ x Previous Manner: flap	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Manner: flap	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Previous Manner: fricative	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Manner: fricative	-0.4171	0.2470	-1.6887	0.0913	-0.1825	0.1614	-1.1305	0.2583
Vowel: ɔ x Previous Manner: fricative	0.1970	0.1338	1.4724	0.1409	-0.1404	0.0609	-2.3034	0.0213
Vowel: ɜ x Previous Manner: fricative	-1.0662	0.2530	-4.2147	0.0000	-0.0695	0.0834	-0.8333	0.4047
Vowel: ɪ x Previous Manner: fricative	-0.0317	0.2201	-0.1439	0.8856	-0.4021	0.1402	-2.8678	0.0041
Vowel: i x Previous Manner: fricative	-0.2936	0.0993	-2.9572	0.0031	-0.1526	0.0663	-2.3024	0.0213
Vowel: o x Previous Manner: fricative	-1.1363	0.2890	-3.9319	0.0001	-0.6539	0.1518	-4.3081	0.0000

Vowel: ʊ x Previous Manner: fricative	0.0000	0.0000	NA	NA	-0.3002	0.1950	-1.5392	0.1238
Vowel: u x Previous Manner: fricative	-0.4374	0.1556	-2.8118	0.0049	-0.3006	0.1451	-2.0718	0.0383
Vowel: æ x Previous Manner: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Manner: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɔ x Previous Manner: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Previous Manner: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Previous Manner: lax	1.1624	0.1828	6.3594	0.0000	0.0000	0.0000	NA	NA
Vowel: i x Previous Manner: lax	0.0000	0.0000	NA	NA	0.0875	0.0915	0.9567	0.3387
Vowel: o x Previous Manner: lax	0.4252	0.1109	3.8342	0.0001	-0.1623	0.0735	-2.2064	0.0274
Vowel: ʊ x Previous Manner: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Manner: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Previous Manner: lax-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Manner: lax-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɔ x Previous Manner: lax-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Previous Manner: lax-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Previous Manner: lax-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: i x Previous Manner: lax-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: o x Previous Manner: lax-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʊ x Previous Manner: lax-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Manner: lax-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Previous Manner: nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Manner: nasal	0.2519	0.2429	1.0370	0.2998	-0.1083	0.1590	-0.6811	0.4958
Vowel: ɔ x Previous Manner: nasal	0.5865	0.1477	3.9720	0.0001	0.0000	0.0000	NA	NA
Vowel: ɜ x Previous Manner: nasal	-0.6187	0.2441	-2.5341	0.0113	0.2456	0.0802	3.0611	0.0022
Vowel: ɪ x Previous Manner: nasal	0.5277	0.2278	2.3165	0.0205	-0.2232	0.1488	-1.5000	0.1336
Vowel: i x Previous Manner: nasal	-0.1498	0.0858	-1.7460	0.0808	0.2920	0.0571	5.1108	0.0000
Vowel: o x Previous Manner: nasal	-0.3845	0.2117	-1.8161	0.0694	0.1364	0.1116	1.2226	0.2215
Vowel: ʊ x Previous Manner: nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Manner: nasal	0.0303	0.0778	0.3886	0.6976	0.3989	0.0520	7.6771	0.0000
Vowel: æ x Previous Manner: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Manner: rhotic	0.0000	0.0000	NA	NA	-0.4153	0.1772	-2.3437	0.0191
Vowel: ɔ x Previous Manner: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Previous Manner: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Previous Manner: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: i x Previous Manner: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: o x Previous Manner: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʊ x Previous Manner: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Manner: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Previous Manner: stop	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Manner: stop	-0.0180	0.2571	-0.0702	0.9440	-0.3731	0.1717	-2.1727	0.0298
Vowel: ɔ x Previous Manner: stop	0.0000	0.0000	NA	NA	-0.4216	0.0996	-4.2339	0.0000
Vowel: ɜ x Previous Manner: stop	-1.0452	0.2569	-4.0676	0.0000	-0.1913	0.0999	-1.9157	0.0554
Vowel: ɪ x Previous Manner: stop	-0.0960	0.2383	-0.4029	0.6870	-0.5758	0.1585	-3.6338	0.0003
Vowel: i x Previous Manner: stop	-0.3684	0.1278	-2.8816	0.0040	-0.2022	0.0848	-2.3838	0.0171
Vowel: o x Previous Manner: stop	-0.8217	0.2332	-3.5233	0.0004	-0.4981	0.1312	-3.7954	0.0001
Vowel: ʊ x Previous Manner: stop	0.2199	0.1447	1.5204	0.1284	0.0000	0.0000	NA	NA
Vowel: u x Previous Manner: stop	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Previous Manner: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Manner: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɔ x Previous Manner: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Previous Manner: tense	-0.8869	0.2605	-3.4042	0.0007	0.0000	0.0000	NA	NA
Vowel: ɪ x Previous Manner: tense	0.2271	0.2302	0.9868	0.3237	0.0000	0.0000	NA	NA

Vowel: i x Previous Manner: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: o x Previous Manner: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʊ x Previous Manner: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Manner: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Previous Voicing: voiceless	-0.0716	0.0983	-0.7290	0.4660	0.1838	0.0584	3.1454	0.0017
Vowel: ʌ x Previous Voicing: voiceless	0.1479	0.0428	3.4529	0.0006	0.0124	0.0284	0.4365	0.6625
Vowel: ɔ x Previous Voicing: voiceless	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Previous Voicing: voiceless	0.0856	0.0449	1.9047	0.0568	0.1762	0.0299	5.9024	0.0000
Vowel: ɪ x Previous Voicing: voiceless	0.0248	0.0319	0.7768	0.4373	0.0880	0.0212	4.1582	0.0000
Vowel: i x Previous Voicing: voiceless	-0.0779	0.0571	-1.3632	0.1728	0.1511	0.0379	3.9871	0.0001
Vowel: o x Previous Voicing: voiceless	0.1625	0.0800	2.0318	0.0422	0.3656	0.0533	6.8538	0.0000
Vowel: ʊ x Previous Voicing: voiceless	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Voicing: voiceless	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Previous Place: consonant	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Place: consonant	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɔ x Previous Place: consonant	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Previous Place: consonant	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Previous Place: consonant	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: i x Previous Place: consonant	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: o x Previous Place: consonant	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʊ x Previous Place: consonant	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Place: consonant	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Previous Place: dental	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Place: dental	0.1258	0.1585	0.7936	0.4274	-0.4629	0.1756	-2.6355	0.0084
Vowel: ɔ x Previous Place: dental	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Previous Place: dental	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Previous Place: dental	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: i x Previous Place: dental	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: o x Previous Place: dental	0.0000	0.0000	NA	NA	-0.0694	0.1732	-0.4005	0.6888
Vowel: ʊ x Previous Place: dental	-0.2824	0.1948	-1.4495	0.1472	0.0000	0.0000	NA	NA
Vowel: u x Previous Place: dental	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Previous Place: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Place: diphthong	0.5358	0.1855	2.8875	0.0039	-0.0120	0.1238	-0.0968	0.9229
Vowel: ɔ x Previous Place: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Previous Place: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Previous Place: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: i x Previous Place: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: o x Previous Place: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʊ x Previous Place: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Place: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Previous Place: glottal	-0.2240	0.1065	-2.1039	0.0354	0.2544	0.0703	3.6203	0.0003
Vowel: ʌ x Previous Place: glottal	0.6683	0.1092	6.1187	0.0000	0.2242	0.0751	2.9858	0.0028
Vowel: ɔ x Previous Place: glottal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Previous Place: glottal	0.3772	0.0991	3.8067	0.0001	0.1959	0.0688	2.8460	0.0044
Vowel: ɪ x Previous Place: glottal	0.0082	0.0988	0.0825	0.9342	0.2185	0.0685	3.1892	0.0014
Vowel: i x Previous Place: glottal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: o x Previous Place: glottal	0.3592	0.1331	2.6982	0.0070	0.0864	0.0905	0.9546	0.3398
Vowel: ʊ x Previous Place: glottal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Place: glottal	0.0493	0.1943	0.2539	0.7996	0.3628	0.1680	2.1591	0.0309
Vowel: æ x Previous Place: labial	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Place: labial	0.1238	0.1471	0.8420	0.3998	0.0415	0.0975	0.4253	0.6706
Vowel: ɔ x Previous Place: labial	-0.0427	0.1604	-0.2664	0.7900	0.0924	0.1070	0.8634	0.3879

Vowel: ɜ x Previous Place: labial	0.1430	0.1464	0.9772	0.3285	0.3379	0.0969	3.4850	0.0005
Vowel: ɪ x Previous Place: labial	0.2000	0.1520	1.3158	0.1882	0.1609	0.1008	1.5965	0.1104
Vowel: i x Previous Place: labial	0.1606	0.1469	1.0931	0.2744	0.1910	0.0973	1.9616	0.0498
Vowel: o x Previous Place: labial	-0.0923	0.1546	-0.5972	0.5504	0.0585	0.1029	0.5684	0.5698
Vowel: ʊ x Previous Place: labial	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Place: labial	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Previous Place: labio-dental	0.3869	0.1667	2.3211	0.0203	-0.0425	0.1072	-0.3965	0.6918
Vowel: ʌ x Previous Place: labio-dental	0.5327	0.1001	5.3235	0.0000	-0.0372	0.0664	-0.5604	0.5752
Vowel: ɔ x Previous Place: labio-dental	0.0699	0.0854	0.8186	0.4130	-0.1823	0.0580	-3.1451	0.0017
Vowel: ɜ x Previous Place: labio-dental	0.2639	0.0786	3.3575	0.0008	0.0186	0.0522	0.3561	0.7218
Vowel: ɪ x Previous Place: labio-dental	0.1485	0.1053	1.4100	0.1585	-0.1644	0.0698	-2.3552	0.0185
Vowel: i x Previous Place: labio-dental	0.1113	0.0725	1.5351	0.1248	0.1111	0.0482	2.3070	0.0211
Vowel: o x Previous Place: labio-dental	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʊ x Previous Place: labio-dental	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Place: labio-dental	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Previous Place: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Place: lax	0.6913	0.1958	3.5307	0.0004	-0.2496	0.1306	-1.9108	0.0560
Vowel: ɔ x Previous Place: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Previous Place: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Previous Place: lax	0.0000	0.0000	NA	NA	-0.2851	0.1219	-2.3395	0.0193
Vowel: i x Previous Place: lax	0.7398	0.2432	3.0418	0.0024	0.0000	0.0000	NA	NA
Vowel: o x Previous Place: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʊ x Previous Place: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Place: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Previous Place: palatal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Place: palatal	0.2005	0.1033	1.9405	0.0523	0.1726	0.0684	2.5224	0.0117
Vowel: ɔ x Previous Place: palatal	0.0901	0.2035	0.4429	0.6578	0.4763	0.1399	3.4036	0.0007
Vowel: ɜ x Previous Place: palatal	0.2208	0.1066	2.0708	0.0384	0.2008	0.0707	2.8401	0.0045
Vowel: ɪ x Previous Place: palatal	0.3099	0.1049	2.9552	0.0031	0.1355	0.0696	1.9460	0.0517
Vowel: i x Previous Place: palatal	0.2609	0.1155	2.2588	0.0239	0.0482	0.0766	0.6300	0.5287
Vowel: o x Previous Place: palatal	0.2124	0.1022	2.0784	0.0377	0.1098	0.0677	1.6229	0.1046
Vowel: ʊ x Previous Place: palatal	0.0608	0.2943	0.2067	0.8362	0.0000	0.0000	NA	NA
Vowel: u x Previous Place: palatal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Previous Place: palato-alveolar	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Place: palato-alveolar	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɔ x Previous Place: palato-alveolar	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Previous Place: palato-alveolar	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Previous Place: palato-alveolar	0.3134	0.0834	3.7570	0.0002	-0.1152	0.0554	-2.0777	0.0377
Vowel: i x Previous Place: palato-alveolar	0.1218	0.0999	1.2195	0.2226	-0.1321	0.0663	-1.9912	0.0465
Vowel: o x Previous Place: palato-alveolar	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʊ x Previous Place: palato-alveolar	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Place: palato-alveolar	0.2788	0.1626	1.7147	0.0864	0.4732	0.1414	3.3457	0.0008
Vowel: æ x Previous Place: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Previous Place: rhotic	0.3720	0.2679	1.3887	0.1649	0.0000	0.0000	NA	NA
Vowel: ɔ x Previous Place: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Previous Place: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Previous Place: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: i x Previous Place: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: o x Previous Place: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʊ x Previous Place: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Place: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Previous Place: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA

Vowel: ʌ x Previous Place: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɔ x Previous Place: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Previous Place: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Previous Place: tense	0.0000	0.0000	NA	NA	-0.3352	0.1392	-2.4088	0.0160
Vowel: i x Previous Place: tense	-0.0917	0.0956	-0.9594	0.3374	0.0237	0.0634	0.3741	0.7084
Vowel: o x Previous Place: tense	-0.3642	0.2205	-1.6515	0.0986	-0.2489	0.1038	-2.3979	0.0165
Vowel: ʊ x Previous Place: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Previous Place: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Next Manner: approximate	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Next Manner: approximate	-0.2960	0.1969	-1.5035	0.1327	0.2817	0.1305	2.1584	0.0309
Vowel: ɔ x Next Manner: approximate	-0.0304	0.0929	-0.3268	0.7438	0.3082	0.1415	2.1782	0.0294
Vowel: ɜ x Next Manner: approximate	-0.1130	0.0859	-1.3150	0.1885	-0.0175	0.0569	-0.3070	0.7589
Vowel: ɪ x Next Manner: approximate	-0.1088	0.2046	-0.5319	0.5948	0.0971	0.1355	0.7163	0.4738
Vowel: i x Next Manner: approximate	-0.0554	0.1562	-0.3543	0.7231	0.1890	0.1035	1.8271	0.0677
Vowel: o x Next Manner: approximate	0.0200	0.1783	0.1123	0.9106	0.1440	0.1181	1.2188	0.2229
Vowel: ʊ x Next Manner: approximate	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Next Manner: approximate	0.0000	0.0000	NA	NA	0.4106	0.1425	2.8816	0.0040
Vowel: æ x Next Manner: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Next Manner: diphthong	0.0252	0.1977	0.1274	0.8986	0.0000	0.0000	NA	NA
Vowel: ɔ x Next Manner: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Next Manner: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Next Manner: diphthong	0.1289	0.2067	0.6234	0.5330	0.0000	0.0000	NA	NA
Vowel: i x Next Manner: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: o x Next Manner: diphthong	0.0000	0.0000	NA	NA	0.0174	0.1189	0.1461	0.8839
Vowel: ʊ x Next Manner: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Next Manner: diphthong	-0.0528	0.0970	-0.5444	0.5862	0.1489	0.1369	1.0879	0.2766
Vowel: æ x Next Manner: flap	-0.1475	0.1262	-1.1691	0.2424	0.0040	0.0825	0.0489	0.9610
Vowel: ʌ x Next Manner: flap	-0.1477	0.1948	-0.7581	0.4484	0.0758	0.1290	0.5874	0.5569
Vowel: ɔ x Next Manner: flap	0.0000	0.0000	NA	NA	0.1854	0.1532	1.2096	0.2264
Vowel: ɜ x Next Manner: flap	-0.0421	0.0752	-0.5592	0.5760	-0.0223	0.0499	-0.4467	0.6551
Vowel: ɪ x Next Manner: flap	-0.0381	0.2011	-0.1895	0.8497	-0.0242	0.1332	-0.1815	0.8560
Vowel: i x Next Manner: flap	-0.1065	0.1546	-0.6890	0.4908	0.1305	0.1024	1.2753	0.2022
Vowel: o x Next Manner: flap	-0.0165	0.1778	-0.0929	0.9260	0.1457	0.1177	1.2378	0.2158
Vowel: ʊ x Next Manner: flap	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Next Manner: flap	-0.2736	0.0739	-3.7004	0.0002	0.2180	0.1392	1.5659	0.1174
Vowel: æ x Next Manner: fricative	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Next Manner: fricative	-0.1583	0.1948	-0.8126	0.4165	0.0993	0.1291	0.7690	0.4419
Vowel: ɔ x Next Manner: fricative	0.1580	0.1927	0.8201	0.4121	0.1262	0.1825	0.6913	0.4894
Vowel: ɜ x Next Manner: fricative	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Next Manner: fricative	0.0535	0.2078	0.2577	0.7967	-0.0599	0.1376	-0.4354	0.6633
Vowel: i x Next Manner: fricative	-0.0630	0.1629	-0.3867	0.6990	0.0612	0.1079	0.5676	0.5703
Vowel: o x Next Manner: fricative	0.0080	0.1821	0.0440	0.9649	0.1700	0.1206	1.4097	0.1586
Vowel: ʊ x Next Manner: fricative	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Next Manner: fricative	-0.1027	0.1222	-0.8404	0.4007	0.2516	0.1477	1.7037	0.0884
Vowel: æ x Next Manner: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Next Manner: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɔ x Next Manner: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Next Manner: lax	-0.0719	0.0794	-0.9059	0.3650	-0.0587	0.0526	-1.1157	0.2646
Vowel: ɪ x Next Manner: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: i x Next Manner: lax	-0.0295	0.1547	-0.1909	0.8486	0.1107	0.1024	1.0810	0.2797
Vowel: o x Next Manner: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʊ x Next Manner: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA

Vowel: u x Next Manner: lax	0.0000	0.0000	NA	NA	0.0942	0.1336	0.7050	0.4808
Vowel: æ x Next Manner: lax-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Next Manner: lax-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɔ x Next Manner: lax-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Next Manner: lax-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Next Manner: lax-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: i x Next Manner: lax-nasal	0.0908	0.1655	0.5487	0.5832	0.0000	0.0000	NA	NA
Vowel: o x Next Manner: lax-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʊ x Next Manner: lax-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Next Manner: lax-nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Next Manner: nasal	-0.2678	0.1792	-1.4947	0.1350	-0.0027	0.1159	-0.0231	0.9815
Vowel: ʌ x Next Manner: nasal	-0.3176	0.1907	-1.6657	0.0958	0.1141	0.1264	0.9031	0.3665
Vowel: ɔ x Next Manner: nasal	0.0430	0.1370	0.3140	0.7535	0.1085	0.1544	0.7024	0.4824
Vowel: ɜ x Next Manner: nasal	-0.2327	0.0826	-2.8156	0.0049	-0.0493	0.0548	-0.8989	0.3687
Vowel: ɪ x Next Manner: nasal	-0.1585	0.1988	-0.7972	0.4254	0.0392	0.1317	0.2979	0.7658
Vowel: i x Next Manner: nasal	-0.1123	0.1485	-0.7561	0.4496	0.1170	0.0983	1.1902	0.2340
Vowel: o x Next Manner: nasal	-0.0226	0.1731	-0.1304	0.8962	0.1140	0.1146	0.9944	0.3201
Vowel: ʊ x Next Manner: nasal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Next Manner: nasal	-0.2298	0.0835	-2.7526	0.0059	0.2782	0.1360	2.0456	0.0408
Vowel: æ x Next Manner: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Next Manner: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɔ x Next Manner: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Next Manner: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Next Manner: rhotic	0.2703	0.2846	0.9496	0.3423	-0.1270	0.1809	-0.7022	0.4826
Vowel: i x Next Manner: rhotic	0.0000	0.0000	NA	NA	-0.0710	0.1511	-0.4701	0.6383
Vowel: o x Next Manner: rhotic	0.0000	0.0000	NA	NA	-0.2447	0.1629	-1.5022	0.1331
Vowel: ʊ x Next Manner: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Next Manner: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Next Manner: stop	-0.1681	0.1243	-1.3524	0.1763	0.0667	0.0819	0.8151	0.4150
Vowel: ʌ x Next Manner: stop	-0.3026	0.1903	-1.5902	0.1118	0.1356	0.1260	1.0758	0.2820
Vowel: ɔ x Next Manner: stop	0.1409	0.1503	0.9374	0.3486	0.1225	0.1628	0.7524	0.4518
Vowel: ɜ x Next Manner: stop	-0.0117	0.0595	-0.1973	0.8436	0.0573	0.0395	1.4522	0.1464
Vowel: ɪ x Next Manner: stop	-0.0582	0.2007	-0.2897	0.7720	0.0352	0.1330	0.2644	0.7915
Vowel: i x Next Manner: stop	-0.1498	0.1543	-0.9709	0.3316	0.1749	0.1022	1.7120	0.0869
Vowel: o x Next Manner: stop	0.0030	0.1764	0.0169	0.9865	0.1400	0.1168	1.1983	0.2308
Vowel: ʊ x Next Manner: stop	0.0099	0.2216	0.0446	0.9644	0.1340	0.0924	1.4506	0.1469
Vowel: u x Next Manner: stop	-0.1501	0.0640	-2.3444	0.0191	0.3207	0.1406	2.2808	0.0226
Vowel: æ x Next Manner: syllabic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Next Manner: syllabic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɔ x Next Manner: syllabic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Next Manner: syllabic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Next Manner: syllabic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: i x Next Manner: syllabic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: o x Next Manner: syllabic	0.0778	0.1626	0.4783	0.6325	0.1080	0.1077	1.0031	0.3158
Vowel: ʊ x Next Manner: syllabic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Next Manner: syllabic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Next Manner: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Next Manner: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɔ x Next Manner: tense	0.0007	0.2282	0.0029	0.9977	0.0000	0.0000	NA	NA
Vowel: ɜ x Next Manner: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Next Manner: tense	0.0000	0.0000	NA	NA	0.0187	0.1124	0.1661	0.8681
Vowel: i x Next Manner: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA

Vowel: o x Next Manner: tense	0.1989	0.1124	1.7699	0.0768	0.0000	0.0000	NA	NA
Vowel: ʊ x Next Manner: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Next Manner: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Next Voicing: voiceless	-0.0920	0.1179	-0.7804	0.4352	-0.0619	0.0763	-0.8110	0.4174
Vowel: ʌ x Next Voicing: voiceless	0.0775	0.0396	1.9566	0.0504	0.0148	0.0263	0.5643	0.5726
Vowel: ɔ x Next Voicing: voiceless	-0.2400	0.1692	-1.4183	0.1561	0.0999	0.1155	0.8651	0.3870
Vowel: ɜ x Next Voicing: voiceless	-0.0437	0.0294	-1.4827	0.1382	-0.0727	0.0195	-3.7227	0.0002
Vowel: ɪ x Next Voicing: voiceless	-0.0109	0.0233	-0.4684	0.6395	-0.0678	0.0154	-4.3992	0.0000
Vowel: i x Next Voicing: voiceless	-0.0076	0.0258	-0.2955	0.7676	-0.0035	0.0171	-0.2075	0.8356
Vowel: o x Next Voicing: voiceless	0.0260	0.0241	1.0792	0.2805	-0.0868	0.0160	-5.4357	0.0000
Vowel: ʊ x Next Voicing: voiceless	-0.1137	0.0441	-2.5762	0.0100	-0.0916	0.0294	-3.1182	0.0018
Vowel: u x Next Voicing: voiceless	-0.0709	0.0421	-1.6831	0.0924	-0.0237	0.0279	-0.8498	0.3954
Vowel: æ x Next Place: consonant	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Next Place: consonant	0.5151	0.1398	3.6853	0.0002	-0.0742	0.0926	-0.8009	0.4232
Vowel: ɔ x Next Place: consonant	-0.2485	0.1716	-1.4481	0.1476	0.1029	0.1147	0.8974	0.3695
Vowel: ɜ x Next Place: consonant	0.1039	0.1158	0.8972	0.3696	0.0732	0.0767	0.9542	0.3400
Vowel: ɪ x Next Place: consonant	-0.0327	0.1063	-0.3075	0.7584	-0.0674	0.0705	-0.9564	0.3389
Vowel: i x Next Place: consonant	0.0811	0.1285	0.6306	0.5283	0.0451	0.0851	0.5299	0.5962
Vowel: o x Next Place: consonant	-0.0099	0.1004	-0.0984	0.9216	-0.0228	0.0664	-0.3433	0.7314
Vowel: ʊ x Next Place: consonant	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Next Place: consonant	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Next Place: dental	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Next Place: dental	-0.2187	0.1212	-1.8044	0.0712	0.0439	0.0803	0.5463	0.5848
Vowel: ɔ x Next Place: dental	-0.5258	0.2030	-2.5899	0.0096	0.0358	0.1375	0.2604	0.7946
Vowel: ɜ x Next Place: dental	-0.2763	0.1209	-2.2851	0.0223	-0.0825	0.0801	-1.0296	0.3032
Vowel: ɪ x Next Place: dental	-0.4101	0.1115	-3.6779	0.0002	0.0300	0.0739	0.4060	0.6848
Vowel: i x Next Place: dental	-0.1683	0.1082	-1.5548	0.1200	-0.0043	0.0717	-0.0603	0.9519
Vowel: o x Next Place: dental	-0.1203	0.1073	-1.1207	0.2624	-0.0752	0.0711	-1.0578	0.2901
Vowel: ʊ x Next Place: dental	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Next Place: dental	-0.2958	0.1350	-2.1901	0.0285	0.0278	0.0895	0.3110	0.7558
Vowel: æ x Next Place: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Next Place: diphthong	0.0000	0.0000	NA	NA	-0.0069	0.1310	-0.0527	0.9580
Vowel: ɔ x Next Place: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Next Place: diphthong	0.1077	0.0886	1.2152	0.2243	-0.1285	0.0587	-2.1881	0.0287
Vowel: ɪ x Next Place: diphthong	0.0000	0.0000	NA	NA	-0.0772	0.1369	-0.5640	0.5728
Vowel: i x Next Place: diphthong	0.1615	0.1597	1.0110	0.3120	0.0060	0.1058	0.0565	0.9549
Vowel: o x Next Place: diphthong	0.3075	0.1795	1.7126	0.0868	0.0000	0.0000	NA	NA
Vowel: ʊ x Next Place: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Next Place: diphthong	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Next Place: glottal	0.1839	0.1080	1.7025	0.0887	0.0464	0.0652	0.7125	0.4761
Vowel: ʌ x Next Place: glottal	0.0637	0.0381	1.6714	0.0946	-0.0232	0.0253	-0.9188	0.3582
Vowel: ɔ x Next Place: glottal	0.0912	0.0643	1.4183	0.1561	-0.0414	0.0447	-0.9263	0.3543
Vowel: ɜ x Next Place: glottal	-0.0625	0.0298	-2.1006	0.0357	-0.0532	0.0198	-2.6908	0.0071
Vowel: ɪ x Next Place: glottal	-0.0154	0.0242	-0.6385	0.5232	-0.0352	0.0160	-2.1991	0.0279
Vowel: i x Next Place: glottal	0.0084	0.0282	0.2968	0.7666	0.0108	0.0187	0.5794	0.5623
Vowel: o x Next Place: glottal	0.0951	0.0261	3.6483	0.0003	-0.0587	0.0173	-3.3985	0.0007
Vowel: ʊ x Next Place: glottal	0.0000	0.0000	NA	NA	0.3002	0.2199	1.3650	0.1723
Vowel: u x Next Place: glottal	-0.1209	0.0714	-1.6932	0.0904	-0.0423	0.0473	-0.8928	0.3720
Vowel: æ x Next Place: labial	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Next Place: labial	0.0785	0.0369	2.1295	0.0332	-0.1632	0.0244	-6.6777	0.0000
Vowel: ɔ x Next Place: labial	-0.2283	0.1040	-2.1956	0.0281	0.0396	0.0700	0.5663	0.5712
Vowel: ɜ x Next Place: labial	0.0293	0.0435	0.6743	0.5001	-0.0075	0.0289	-0.2581	0.7963

Vowel: ɪ x Next Place: labial	-0.0663	0.0314	-2.1112	0.0348	-0.0401	0.0209	-1.9198	0.0549
Vowel: i x Next Place: labial	-0.0238	0.0295	-0.8073	0.4195	0.0158	0.0195	0.8112	0.4172
Vowel: o x Next Place: labial	0.0168	0.0266	0.6321	0.5273	-0.0627	0.0176	-3.5525	0.0004
Vowel: ʊ x Next Place: labial	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Next Place: labial	-0.1757	0.0726	-2.4200	0.0155	-0.1234	0.0482	-2.5622	0.0104
Vowel: æ x Next Place: labio-dental	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Next Place: labio-dental	-0.2859	0.0955	-2.9932	0.0028	-0.0762	0.0633	-1.2048	0.2283
Vowel: ɔ x Next Place: labio-dental	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Next Place: labio-dental	-0.0852	0.1097	-0.7767	0.4374	0.2020	0.0728	2.7743	0.0055
Vowel: ɪ x Next Place: labio-dental	-0.1428	0.0781	-1.8286	0.0675	0.1973	0.0518	3.8095	0.0001
Vowel: i x Next Place: labio-dental	-0.0780	0.0799	-0.9766	0.3288	0.0813	0.0530	1.5341	0.1250
Vowel: o x Next Place: labio-dental	0.1286	0.0744	1.7281	0.0840	0.0255	0.0493	0.5177	0.6047
Vowel: ʊ x Next Place: labio-dental	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Next Place: labio-dental	-0.1724	0.1100	-1.5680	0.1169	0.1543	0.0728	2.1178	0.0342
Vowel: æ x Next Place: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Next Place: lax	-0.1746	0.1933	-0.9033	0.3663	0.0915	0.1281	0.7142	0.4751
Vowel: ɔ x Next Place: lax	-0.1082	0.1014	-1.0678	0.2856	0.1482	0.1381	1.0732	0.2832
Vowel: ɜ x Next Place: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Next Place: lax	-0.0011	0.2021	-0.0056	0.9955	-0.0486	0.1339	-0.3632	0.7165
Vowel: i x Next Place: lax	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: o x Next Place: lax	0.1104	0.1766	0.6249	0.5321	0.0585	0.1170	0.5002	0.6169
Vowel: ʊ x Next Place: lax	0.1996	0.1612	1.2378	0.2158	0.1027	0.1080	0.9515	0.3414
Vowel: u x Next Place: lax	-0.2396	0.0836	-2.8679	0.0041	0.0000	0.0000	NA	NA
Vowel: æ x Next Place: palatal	0.3597	0.1620	2.2199	0.0264	0.2454	0.1032	2.3776	0.0174
Vowel: ʌ x Next Place: palatal	0.0757	0.0520	1.4566	0.1452	0.0701	0.0345	2.0302	0.0423
Vowel: ɔ x Next Place: palatal	-0.0302	0.1188	-0.2539	0.7996	0.2972	0.0842	3.5302	0.0004
Vowel: ɜ x Next Place: palatal	0.0107	0.0620	0.1727	0.8629	0.0232	0.0411	0.5654	0.5718
Vowel: ɪ x Next Place: palatal	0.1030	0.0477	2.1604	0.0307	0.1112	0.0317	3.5099	0.0004
Vowel: i x Next Place: palatal	0.1164	0.0443	2.6271	0.0086	0.0154	0.0294	0.5260	0.5989
Vowel: o x Next Place: palatal	0.0998	0.0424	2.3534	0.0186	0.1117	0.0281	3.9755	0.0001
Vowel: ʊ x Next Place: palatal	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Next Place: palatal	-0.0699	0.0864	-0.8094	0.4183	-0.0913	0.0573	-1.5934	0.1111
Vowel: æ x Next Place: palato-alveolar	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Next Place: palato-alveolar	-0.1535	0.1056	-1.4538	0.1460	0.0891	0.0700	1.2726	0.2032
Vowel: ɔ x Next Place: palato-alveolar	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Next Place: palato-alveolar	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Next Place: palato-alveolar	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: i x Next Place: palato-alveolar	0.1119	0.1027	1.0893	0.2760	0.0703	0.0681	1.0318	0.3022
Vowel: o x Next Place: palato-alveolar	0.1622	0.0942	1.7217	0.0851	0.1697	0.0625	2.7168	0.0066
Vowel: ʊ x Next Place: palato-alveolar	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Next Place: palato-alveolar	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Next Place: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Next Place: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɔ x Next Place: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Next Place: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Next Place: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: i x Next Place: rhotic	0.2507	0.2418	1.0368	0.2998	0.0000	0.0000	NA	NA
Vowel: o x Next Place: rhotic	0.2576	0.2587	0.9959	0.3193	0.0000	0.0000	NA	NA
Vowel: ʊ x Next Place: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Next Place: rhotic	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: æ x Next Place: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ʌ x Next Place: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA

Vowel: ɔ x Next Place: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɜ x Next Place: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: ɪ x Next Place: tense	0.1746	0.1695	1.0300	0.3030	0.0000	0.0000	NA	NA
Vowel: i x Next Place: tense	0.0812	0.1265	0.6414	0.5213	-0.0508	0.0839	-0.6057	0.5447
Vowel: o x Next Place: tense	0.0000	0.0000	NA	NA	-0.1126	0.0746	-1.5095	0.1312
Vowel: ʊ x Next Place: tense	0.0000	0.0000	NA	NA	0.0000	0.0000	NA	NA
Vowel: u x Next Place: tense	-0.0865	0.2150	-0.4021	0.6876	0.0000	0.0000	NA	NA
Smooth Terms								
Predictor	edf	Ref.edf	F	p	edf	Ref.edf	F	p
s(Time Step)	8.3456	8.8408	54.0186	0.0000	7.6025	8.4649	12.1285	0.0000
ti(Time Step) x interaction(Tense, Vowel) past : a	1.0002	1.0002	17.5761	0.0000	3.2410	3.5753	3.3461	0.0132
ti(Time Step) x interaction(Tense, Vowel) present : a	0.0000	0.0001	0.0287	0.9987	0.7938	1.0814	1.0275	0.3109
ti(Time Step) x interaction(Tense, Vowel) past : æ	0.0002	0.0003	0.0088	0.9988	0.0001	0.0001	0.0955	0.9971
ti(Time Step) x interaction(Tense, Vowel) present : æ	1.0000	1.0000	16.7389	0.0000	1.0000	1.0000	9.3759	0.0022
ti(Time Step) x interaction(Tense, Vowel) past : ʌ	1.0001	1.0001	21.5859	0.0000	1.0001	1.0001	79.9313	0.0000
ti(Time Step) x interaction(Tense, Vowel) present : ʌ	0.0000	0.0001	0.3941	0.9953	0.0002	0.0003	0.1426	0.9948
ti(Time Step) x interaction(Tense, Vowel) past : ɔ	0.0000	0.0001	0.4390	0.9956	0.0004	0.0007	0.0248	0.9967
ti(Time Step) x interaction(Tense, Vowel) present : ɔ	1.0000	1.0001	0.0023	0.9618	1.0000	1.0001	5.6575	0.0174
ti(Time Step) x interaction(Tense, Vowel) past : ɜ	1.0001	1.0001	2.9852	0.0840	1.0001	1.0001	21.9894	0.0000
ti(Time Step) x interaction(Tense, Vowel) present : ɜ	0.0001	0.0001	0.0595	0.9981	0.0001	0.0002	0.0023	0.9995
ti(Time Step) x interaction(Tense, Vowel) past : ɪ	1.0000	1.0000	10.0147	0.0016	2.8611	3.0021	6.3655	0.0003
ti(Time Step) x interaction(Tense, Vowel) present : ɪ	1.0002	1.0004	14.6597	0.0001	1.0002	1.0003	0.6001	0.4385
ti(Time Step) x interaction(Tense, Vowel) past : i	1.0001	1.0001	11.4516	0.0007	1.0001	1.0001	0.7349	0.3913
ti(Time Step) x interaction(Tense, Vowel) present : i	1.0000	1.0000	12.3661	0.0004	1.0001	1.0001	0.6150	0.4329
ti(Time Step) x interaction(Tense, Vowel) past : o	0.0002	0.0004	0.4475	0.9900	1.0020	1.0037	0.1485	0.7010
ti(Time Step) x interaction(Tense, Vowel) present : o	1.0003	1.0005	15.9000	0.0001	1.0014	1.0023	0.0387	0.8446
ti(Time Step) x interaction(Tense, Vowel) past : ʊ	1.0000	1.0001	1.3605	0.2435	1.0002	1.0003	0.6506	0.4199
ti(Time Step) x interaction(Tense, Vowel) present : ʊ	1.0000	1.0000	0.1058	0.7450	1.0000	1.0001	2.8852	0.0894
ti(Time Step) x interaction(Tense, Vowel) past : u	0.0001	0.0001	0.1686	0.9960	2.0246	2.4423	9.0563	0.0000
ti(Time Step) x interaction(Tense, Vowel) present : u	1.0008	1.0014	0.0477	0.8275	1.0001	1.0002	12.2674	0.0005
ti(Time Step,NDL Cue Strength) x Vowelaa	5.0660	6.2648	2.4533	0.0210	2.6386	3.4558	4.2515	0.0036
ti(Time Step,NDL Cue Strength) x Vowelae	4.6062	5.8020	4.8858	0.0001	7.8079	8.8917	12.5061	0.0000
ti(Time Step,NDL Cue Strength) x Vowelah	7.8282	9.1501	23.7997	0.0000	6.6042	7.8754	55.6524	0.0000
ti(Time Step,NDL Cue Strength) x Vowelao	1.0005	1.0010	0.2531	0.6152	5.0540	6.5404	6.0971	0.0000
ti(Time Step,NDL Cue Strength) x Voweleh	5.9641	7.3657	9.5380	0.0000	7.0087	8.4898	44.9558	0.0000
ti(Time Step,NDL Cue Strength) x Vowelih	4.5025	5.5366	15.7206	0.0000	6.1318	7.4266	65.7360	0.0000
ti(Time Step,NDL Cue Strength) x Voweliy	5.0402	6.6642	5.2974	0.0000	5.7286	6.9988	11.4980	0.0000
ti(Time Step,NDL Cue Strength) x Vowelow	6.2244	7.6443	5.8289	0.0000	10.5544	11.4824	24.5982	0.0000
ti(Time Step,NDL Cue Strength) x Voweluh	0.3423	8.0000	0.1180	0.0686	0.0008	8.0000	0.0000	0.7873
ti(Time Step,NDL Cue Strength) x Voweluw	1.7787	12.0000	0.3954	0.0319	3.2701	12.0000	2.5342	0.0000
te(Duration (log), Frequency (log))	13.8118	15.9767	25.1458	0.0000	16.5027	18.3308	95.7426	0.0000
ti(Time Step) x Vowelaa	2.3295	2.6503	6.8357	0.0004	0.0013	0.0016	0.0000	1.0000
ti(Time Step) x Vowelae	1.0002	1.0002	13.9636	0.0002	1.0000	1.0000	3.2900	0.0697
ti(Time Step) x Vowelah	1.0000	1.0001	10.4374	0.0012	2.8453	3.1933	2.6029	0.0468
ti(Time Step) x Vowelao	1.0001	1.0001	14.0069	0.0002	1.0004	1.0007	0.3710	0.5426
ti(Time Step) x Voweleh	3.4391	3.7128	9.4088	0.0000	1.0001	1.0001	0.2418	0.6229
ti(Time Step) x Vowelih	0.0001	0.0001	0.2793	0.9957	0.0002	0.0003	0.2159	0.9940
ti(Time Step) x Voweliy	2.6514	2.8823	16.4521	0.0000	2.8753	2.9577	48.1089	0.0000
ti(Time Step) x Vowelow	1.0005	1.0008	11.9708	0.0005	0.0249	0.0304	0.0652	0.9645
ti(Time Step) x Voweluh	0.0000	0.0001	0.0272	0.9991	0.6369	0.9328	0.8159	0.3830
ti(Time Step) x Voweluw	1.0001	1.0001	8.2791	0.0040	1.0001	1.0002	0.5396	0.4626
s(Time Step, Speaker) x Vowelaa	37.0393	39.0000	16.2188	0.0000	36.5549	39.0000	12.3381	0.0000
s(Time Step, Speaker) x Vowelae	19.9724	25.0000	3.9641	0.0000	12.3729	25.0000	1.0093	0.0000
s(Time Step, Speaker) x Vowelah	35.3050	37.0000	8.0558	0.0000	35.2418	37.0000	7.9716	0.0000
s(Time Step, Speaker) x Vowelao	15.9404	32.0000	1.0476	0.0000	20.3417	32.0000	1.4172	0.0000
s(Time Step, Speaker) x Voweleh	35.5853	39.0000	6.7702	0.0000	36.1292	39.0000	5.3759	0.0000
s(Time Step, Speaker) x Vowelih	37.3747	39.0000	9.3783	0.0000	37.9099	39.0000	20.2732	0.0000
s(Time Step, Speaker) x Voweliy	35.8173	39.0000	5.9661	0.0000	37.4363	39.0000	13.1429	0.0000
s(Time Step, Speaker) x Vowelow	38.1849	39.0000	22.8954	0.0000	38.3750	39.0000	27.0447	0.0000
s(Time Step, Speaker) x Voweluh	25.9042	33.0000	2.7315	0.0000	31.6080	33.0000	8.5689	0.0000
s(Time Step, Speaker) x Voweluw	31.4147	36.0000	4.3508	0.0000	30.6172	36.0000	4.9993	0.0000

Table A.25: Coefficients for the F1 and F2 global (all vowels pooled) GAM models of formant movement for robust vowels.

	F1				F2			
Parametric Coefficients								
Predictor	edf	Ref.edf	F	p	edf	Ref.edf	F	p
(Intercept)	6.4468	0.0228	282.2044	0.0000	7.2649	0.0140	519.9614	0.0000
Tense: present	-0.0631	0.0068	-9.3332	0.0000	0.0124	0.0042	2.9440	0.0032
NDL Cue Strength	-0.1648	0.0146	-11.2823	0.0000	0.1181	0.0091	12.9638	0.0000
Vowel: ɛ	-0.1234	0.0259	-4.7568	0.0000	0.2165	0.0172	12.5971	0.0000
Vowel: ɪ	-0.2832	0.0262	-10.8184	0.0000	0.2750	0.0179	15.4010	0.0000
Vowel: i	-0.4669	0.0245	-19.0331	0.0000	0.3309	0.0168	19.7458	0.0000
Vowel: u	-0.4419	0.0290	-15.2619	0.0000	0.2346	0.0169	13.9160	0.0000
Smooth Terms								
Predictor	edf	Ref.edf	F	p	edf	Ref.edf	F	p
s(Time Step)	6.5989	7.7262	9.0277	0.0000	1.0019	1.0034	4.5408	0.0329
ti(Time Step) x Tense: past	2.6965	3.1086	7.7588	0.0000	1.0008	1.0015	20.6267	0.0000
ti(Time Step) x Tense: present	0.0002	0.0002	0.3420	0.9930	2.0954	2.5410	3.0100	0.1149
ti(Time Step,NDL Cue Strength)	4.8098	6.1673	12.3736	0.0000	3.5891	3.8805	48.3961	0.0000
te(Duration (log), Frequency (log))	16.5237	18.5192	13.2472	0.0000	17.7318	19.4183	45.0458	0.0000
ti(Time Step) x Vowel: ʌ	1.0001	1.0002	8.9198	0.0028	0.0011	0.0017	0.7616	0.9709
ti(Time Step) x Vowel: ɛ	1.0000	1.0001	0.2291	0.6323	0.0009	0.0014	0.0194	0.9958
ti(Time Step) x Vowel: ɪ	1.3531	1.7906	3.6057	0.0954	0.0006	0.0011	0.3971	0.9831
ti(Time Step) x Vowel: i	0.0002	0.0003	0.2802	0.9933	2.2057	2.5787	5.8619	0.0027
ti(Time Step) x Vowel: u	0.0002	0.0003	0.2172	0.9933	0.0030	0.0058	0.0035	0.9964
ti(Time Step) x interaction(Vowel, Prev_Voicing) ʌ.voiced	1.6377	2.0892	5.0175	0.0069	0.0002	0.0003	0.0013	0.9995
ti(Time Step) x interaction(Vowel, Prev_Voicing) ɛ.voiced	1.0000	1.0001	0.1252	0.7236	1.0008	1.0012	61.8123	0.0000
ti(Time Step) x interaction(Vowel, Prev_Voicing) ɪ.voiced	0.0606	0.0806	0.8042	0.7990	0.0005	0.0009	0.3701	0.9853
ti(Time Step) x interaction(Vowel, Prev_Voicing) i.voiced	1.3706	1.7773	6.1324	0.0187	1.5829	1.9710	7.2266	0.0013
ti(Time Step) x interaction(Vowel, Prev_Voicing) u.voiced	1.0001	1.0002	1.3639	0.2428	1.0010	1.0020	0.7384	0.3899
ti(Time Step) x interaction(Vowel, Prev_Voicing) ʌ.voiceless	1.0001	1.0002	0.2739	0.6007	1.0009	1.0015	94.3688	0.0000
ti(Time Step) x interaction(Vowel, Prev_Voicing) ɛ.voiceless	0.0000	0.0001	0.0788	0.9983	2.9487	2.9961	23.7945	0.0000
ti(Time Step) x interaction(Vowel, Prev_Voicing) ɪ.voiceless	2.9339	3.2501	5.0978	0.0016	3.3932	3.5127	11.8456	0.0000
ti(Time Step) x interaction(Vowel, Prev_Voicing) i.voiceless	1.0001	1.0001	1.4818	0.2235	1.0031	1.0038	0.5610	0.4537
ti(Time Step) x interaction(Vowel, Prev_Voicing) u.voiceless	0.0001	0.0002	0.0020	0.9995	0.0009	0.0017	0.0518	0.9925
ti(Time Step) x interaction(Vowel, PrevPlacegrp) ʌ.F2high	1.0001	1.0002	1.8091	0.1787	3.6359	3.9097	13.4617	0.0000
ti(Time Step) x interaction(Vowel, PrevPlacegrp) ɛ.F2high	3.3676	3.7145	21.0809	0.0000	3.1992	3.5826	36.2207	0.0000
ti(Time Step) x interaction(Vowel, PrevPlacegrp) ɪ.F2high	1.0001	1.0001	0.2519	0.6158	1.0006	1.0010	1.9114	0.1669
ti(Time Step) x interaction(Vowel, PrevPlacegrp) i.F2high	1.0001	1.0001	0.2648	0.6069	1.0010	1.0019	1.8085	0.1790
ti(Time Step) x interaction(Vowel, PrevPlacegrp) u.F2high	1.0001	1.0002	0.1736	0.6770	1.0009	1.0017	4.3172	0.0377
ti(Time Step) x interaction(Vowel, PrevPlacegrp) ʌ.F2low	0.0000	0.0001	0.0016	0.9998	3.0416	3.4964	6.9750	0.0000
ti(Time Step) x interaction(Vowel, PrevPlacegrp) ɛ.F2low	1.0000	1.0001	2.3531	0.1251	3.9659	3.9975	29.8698	0.0000
ti(Time Step) x interaction(Vowel, PrevPlacegrp) ɪ.F2low	1.0000	1.0000	0.7276	0.3937	3.8754	3.9846	15.5158	0.0000
ti(Time Step) x interaction(Vowel, PrevPlacegrp) i.F2low	1.0000	1.0001	0.4074	0.5233	2.0117	2.4382	4.7534	0.0071
ti(Time Step) x interaction(Vowel, PrevPlacegrp) ʌ.F2mid	2.4915	2.9189	10.4378	0.0000	1.0010	1.0016	0.4920	0.4823
ti(Time Step) x interaction(Vowel, PrevPlacegrp) ɛ.F2mid	2.6214	2.8805	4.5670	0.0041	0.0005	0.0008	0.1169	0.9921
ti(Time Step) x interaction(Vowel, PrevPlacegrp) ɪ.F2mid	1.0000	1.0000	0.1402	0.7081	1.0001	1.0002	0.6002	0.4386
ti(Time Step) x interaction(Vowel, PrevPlacegrp) i.F2mid	1.0001	1.0001	0.0103	0.9192	1.0011	1.0016	4.7505	0.0292
ti(Time Step) x interaction(Vowel, PrevPlacegrp) u.F2mid	0.0001	0.0002	0.4697	0.9929	0.0023	0.0045	0.0115	0.9943
ti(Time Step) x interaction(Vowel, Next_Voicing) ʌ.voiced	1.0000	1.0001	10.7837	0.0010	1.0005	1.0008	2.6846	0.1014
ti(Time Step) x interaction(Vowel, Next_Voicing) ɛ.voiced	1.0000	1.0000	10.8677	0.0010	3.1839	3.6710	5.4204	0.0004
ti(Time Step) x interaction(Vowel, Next_Voicing) ɪ.voiced	2.1159	2.5637	8.7457	0.0004	1.0003	1.0006	8.9062	0.0028
ti(Time Step) x interaction(Vowel, Next_Voicing) i.voiced	0.0001	0.0002	0.2191	0.9953	1.9271	2.4572	4.9362	0.0035
ti(Time Step) x interaction(Vowel, Next_Voicing) u.voiced	1.0001	1.0002	1.2338	0.2667	1.0008	1.0015	9.9760	0.0016
ti(Time Step) x interaction(Vowel, Next_Voicing) ʌ.voiceless	2.0424	2.3450	23.3599	0.0000	1.4222	1.8400	6.0838	0.0127
ti(Time Step) x interaction(Vowel, Next_Voicing) ɛ.voiceless	0.0000	0.0001	0.2680	0.9963	0.0002	0.0003	0.1149	0.9955

ti(Time Step) x interaction(Vowel, Next_Voicing) ɪ.voiceless	0.0001	0.0001	0.0015	0.9997	1.7290	2.0318	8.1498	0.0002
ti(Time Step) x interaction(Vowel, Next_Voicing) i.voiceless	1.0001	1.0001	10.7493	0.0010	1.0023	1.0031	36.7402	0.0000
ti(Time Step) x interaction(Vowel, Next_Voicing) u.voiceless	0.0000	0.0001	0.0020	0.9997	0.0007	0.0013	0.2437	0.9856
ti(Time Step) x interaction(Vowel, NextPlacegrp) ʌ.F2high	2.6152	2.9839	5.9011	0.0010	1.0004	1.0007	2.5808	0.1080
ti(Time Step) x interaction(Vowel, NextPlacegrp) ɛ.F2high	0.0000	0.0000	0.3368	0.9969	1.0002	1.0003	61.7554	0.0000
ti(Time Step) x interaction(Vowel, NextPlacegrp) ɪ.F2high	1.0000	1.0000	0.3629	0.5469	3.4461	3.5649	11.5842	0.0000
ti(Time Step) x interaction(Vowel, NextPlacegrp) i.F2high	2.0087	2.5530	1.1826	0.3900	0.0005	0.0009	0.0122	0.9973
ti(Time Step) x interaction(Vowel, NextPlacegrp) u.F2high	0.0007	0.0014	0.8111	0.9735	1.3674	1.9012	0.6949	0.4443
ti(Time Step) x interaction(Vowel, NextPlacegrp) ʌ.F2low	0.0001	0.0003	0.6850	0.9892	0.0006	0.0008	0.7646	0.9798
ti(Time Step) x interaction(Vowel, NextPlacegrp) ɛ.F2low	1.0000	1.0000	0.0607	0.8055	1.0003	1.0006	65.0800	0.0000
ti(Time Step) x interaction(Vowel, NextPlacegrp) ɪ.F2low	0.0000	0.0001	0.0015	0.9997	0.0004	0.0007	0.1917	0.9910
ti(Time Step) x interaction(Vowel, NextPlacegrp) i.F2low	1.0001	1.0001	0.3492	0.5546	1.0014	1.0025	37.3059	0.0000
ti(Time Step) x interaction(Vowel, NextPlacegrp) u.F2low	1.0000	1.0000	1.4249	0.2326	2.5977	2.8765	25.4829	0.0000
ti(Time Step) x interaction(Vowel, NextPlacegrp) ʌ.F2mid	1.0000	1.0001	0.4975	0.4806	2.8113	3.2071	11.6874	0.0000
ti(Time Step) x interaction(Vowel, NextPlacegrp) ɛ.F2mid	1.0001	1.0001	0.2649	0.6068	1.0005	1.0009	63.8407	0.0000
ti(Time Step) x interaction(Vowel, NextPlacegrp) ɪ.F2mid	1.0000	1.0000	2.0825	0.1490	2.2015	2.5266	5.6264	0.0028
ti(Time Step) x interaction(Vowel, NextPlacegrp) i.F2mid	1.0002	1.0004	0.8000	0.3709	3.3588	3.7450	5.5947	0.0003
ti(Time Step) x interaction(Vowel, NextPlacegrp) u.F2mid	1.0001	1.0001	0.0068	0.9341	1.0016	1.0032	0.2995	0.5844
s(Time Step, Speaker) x Vowel: ʌ	34.5677	36.0000	31.0782	0.0000	34.4755	36.0000	24.6681	0.0000
s(Time Step, Speaker) x Vowel: ɛ	35.1530	39.0000	13.1475	0.0000	36.4038	39.0000	18.9644	0.0000
s(Time Step, Speaker) x Vowel: ɪ	37.2238	39.0000	22.7403	0.0000	37.9765	39.0000	49.4769	0.0000
s(Time Step, Speaker) x Vowel: i	34.3833	39.0000	8.2036	0.0000	37.0068	39.0000	26.0224	0.0000
s(Time Step, Speaker) x Vowel: u	27.3519	31.0000	10.3384	0.0000	25.6568	31.0000	6.8442	0.0000

Table A.26: Coefficients for the F1 and F2 by vowel GAM models of formant movement for robust vowels.

	F1				F2			
Parametric Coefficients								
Predictor	edf	Ref.edf	F	p	edf	Ref.edf	F	p
(Intercept)	6.4486	0.0232	277.5160	0.0000	7.2590	0.0140	518.2553	0.0000
Tense: present	-0.0644	0.0068	-9.5338	0.0000	0.0166	0.0043	3.8919	0.0001
NDL Cue Strength	-0.1634	0.0146	-11.1668	0.0000	0.1130	0.0093	12.1060	0.0000
Vowel: ɛ	-0.1241	0.0264	-4.7010	0.0000	0.2127	0.0175	12.1223	0.0000
Vowel: ɪ	-0.2843	0.0266	-10.6990	0.0000	0.2775	0.0179	15.4750	0.0000
Vowel: i	-0.4680	0.0249	-18.7818	0.0000	0.3352	0.0168	19.9237	0.0000
Vowel: u	-0.4446	0.0294	-15.1062	0.0000	0.2453	0.0170	14.4534	0.0000
Smooth Terms								
Predictor	edf	Ref.edf	F	p	edf	Ref.edf	F	p
s(Time Step)	6.8837	7.9239	14.4017	0.0000	2.7531	3.7305	1.3333	0.2254
ti(Time Step) x interaction(Tense, Vowel) past : ʌ	1.0008	1.0015	11.3454	0.0008	1.0000	1.0001	14.2293	0.0002
ti(Time Step) x interaction(Tense, Vowel) present : ʌ	0.0003	0.0006	0.1827	0.9919	0.0000	0.0000	0.0351	0.9990
ti(Time Step) x interaction(Tense, Vowel) past : ɛ	0.0001	0.0002	0.2585	0.9941	0.0000	0.0000	0.1956	0.9980
ti(Time Step) x interaction(Tense, Vowel) present : ɛ	1.0002	1.0004	12.7940	0.0003	1.0000	1.0000	47.2357	0.0000
ti(Time Step) x interaction(Tense, Vowel) past : ɪ	0.0000	0.0001	0.0781	0.9982	0.0000	0.0000	0.2860	0.9980
ti(Time Step) x interaction(Tense, Vowel) present : ɪ	1.0002	1.0004	2.6339	0.1047	1.0000	1.0001	0.5194	0.4711
ti(Time Step) x interaction(Tense, Vowel) past : i	1.0002	1.0003	1.2822	0.2575	1.0001	1.0001	4.9942	0.0254
ti(Time Step) x interaction(Tense, Vowel) present : i	0.0006	0.0009	0.2639	0.9874	0.0001	0.0001	0.0594	0.9978
ti(Time Step) x interaction(Tense, Vowel) past : u	0.0003	0.0005	0.6432	0.9863	0.0002	0.0004	0.2265	0.9923
ti(Time Step) x interaction(Tense, Vowel) present : u	1.0003	1.0005	9.9119	0.0016	1.0001	1.0001	6.2199	0.0126
ti(Time Step,NDL Cue Strength) x Vowel: ʌ	2.7354	3.0044	17.4362	0.0000	8.7307	9.5739	12.4970	0.0000
ti(Time Step,NDL Cue Strength) x Vowel: ɛ	5.9822	7.4725	6.5133	0.0000	10.0172	11.3198	18.8192	0.0000
ti(Time Step,NDL Cue Strength) x Vowel: ɪ	1.0027	1.0053	22.3937	0.0000	2.8066	3.2448	14.2881	0.0000
ti(Time Step,NDL Cue Strength) x Vowel: i	3.7257	4.7237	2.1099	0.0455	3.0154	3.3703	2.7506	0.0191
ti(Time Step,NDL Cue Strength) x Vowel: u	1.0890	12.0000	0.4580	0.0343	0.9018	11.0000	1.6185	0.0012
te(Duration (log), Frequency (log))	16.2991	18.3479	12.8219	0.0000	17.4379	19.1991	44.1104	0.0000
ti(Time Step) x Vowel: ʌ	0.0009	0.0012	0.0159	0.9966	0.0000	0.0000	0.0425	0.9992
ti(Time Step) x Vowel: ɛ	2.6148	2.8207	19.9166	0.0000	0.0000	0.0000	0.2548	0.9974
ti(Time Step) x Vowel: ɪ	0.0004	0.0006	0.4410	0.9870	0.0000	0.0001	0.4783	0.9949
ti(Time Step) x Vowel: i	1.0324	1.3922	2.0956	0.2794	2.4329	2.7305	7.7498	0.0006
ti(Time Step) x Vowel: u	0.0002	0.0003	0.0825	0.9961	0.0001	0.0002	0.0032	0.9994
ti(Time Step) x interaction(Vowel, Prev_Voicing) ʌ.voiced	1.8720	2.3102	8.8679	0.0001	0.0000	0.0000	0.0695	0.9992
ti(Time Step) x interaction(Vowel, Prev_Voicing) ɛ.voiced	1.0001	1.0002	0.5958	0.4402	1.0000	1.0000	0.6569	0.4177
ti(Time Step) x interaction(Vowel, Prev_Voicing) ɪ.voiced	0.0005	0.0008	0.5216	0.9832	0.0000	0.0001	0.4553	0.9952
ti(Time Step) x interaction(Vowel, Prev_Voicing) i.voiced	0.8255	1.1738	1.4618	0.4069	1.6220	2.0087	9.5704	0.0001
ti(Time Step) x interaction(Vowel, Prev_Voicing) u.voiced	1.0003	1.0005	0.2991	0.5843	1.0002	1.0004	0.2469	0.6193
ti(Time Step) x interaction(Vowel, Prev_Voicing) ʌ.voiceless	2.7952	3.3298	4.5583	0.0040	1.0000	1.0000	30.4587	0.0000
ti(Time Step) x interaction(Vowel, Prev_Voicing) ɛ.voiceless	0.0001	0.0002	0.0082	0.9990	1.4643	1.8300	8.9376	0.0017
ti(Time Step) x interaction(Vowel, Prev_Voicing) ɪ.voiceless	2.9845	3.2975	6.0492	0.0004	3.4198	3.5322	12.2262	0.0000
ti(Time Step) x interaction(Vowel, Prev_Voicing) i.voiceless	1.0005	1.0006	0.1359	0.7127	1.0002	1.0002	0.0100	0.9202
ti(Time Step) x interaction(Vowel, Prev_Voicing) u.voiceless	0.0003	0.0006	0.1936	0.9917	0.0001	0.0001	0.1288	0.9969
ti(Time Step) x interaction(Vowel, PrevPlacegrp) ʌ.F2high	1.0002	1.0004	0.0023	0.9614	1.0000	1.0000	2.5196	0.1125
ti(Time Step) x interaction(Vowel, PrevPlacegrp) ɛ.F2high	1.0002	1.0003	29.2064	0.0000	1.0002	1.0003	45.7482	0.0000
ti(Time Step) x interaction(Vowel, PrevPlacegrp) ɪ.F2high	1.0001	1.0002	0.0195	0.8889	1.0000	1.0001	0.8409	0.3592
ti(Time Step) x interaction(Vowel, PrevPlacegrp) i.F2high	1.0002	1.0003	0.0027	0.9590	1.0000	1.0000	3.7202	0.0538
ti(Time Step) x interaction(Vowel, PrevPlacegrp) u.F2high	1.0003	1.0005	8.0234	0.0046	0.0001	0.0001	0.1221	0.9972
ti(Time Step) x interaction(Vowel, PrevPlacegrp) ʌ.F2low	0.0003	0.0005	0.0197	0.9975	2.9238	3.3794	6.3020	0.0001
ti(Time Step) x interaction(Vowel, PrevPlacegrp) ɛ.F2low	1.0001	1.0001	18.2029	0.0000	1.0000	1.0000	0.0067	0.9347
ti(Time Step) x interaction(Vowel, PrevPlacegrp) ɪ.F2low	1.0000	1.0001	0.0989	0.7532	3.8916	3.9882	17.1629	0.0000
ti(Time Step) x interaction(Vowel, PrevPlacegrp) i.F2low	1.0002	1.0004	0.2438	0.6218	1.9435	2.3679	2.3501	0.1004

ti(Time Step) x interaction(Vowel, PrevPlacegrp) ʌ.F2mid	1.0008	1.0015	4.5821	0.0322	1.0000	1.0000	1.0650	0.3021
ti(Time Step) x interaction(Vowel, PrevPlacegrp) ɛ.F2mid	0.0001	0.0002	0.0191	0.9984	0.0000	0.0000	0.0000	1.0000
ti(Time Step) x interaction(Vowel, PrevPlacegrp) ɪ.F2mid	1.0000	1.0000	0.1854	0.6668	1.0001	1.0002	0.1059	0.7449
ti(Time Step) x interaction(Vowel, PrevPlacegrp) i.F2mid	1.0004	1.0006	0.2170	0.6416	1.0000	1.0001	3.4429	0.0635
ti(Time Step) x interaction(Vowel, PrevPlacegrp) u.F2mid	0.0003	0.0005	0.6681	0.9857	1.0002	1.0003	1.3930	0.2378
ti(Time Step) x interaction(Vowel, Next_Voicing) ʌ.voiced	1.0006	1.0007	9.4372	0.0021	1.0000	1.0000	1.6820	0.1947
ti(Time Step) x interaction(Vowel, Next_Voicing) ɛ.voiced	1.0001	1.0002	8.6920	0.0032	1.0000	1.0000	3.7398	0.0531
ti(Time Step) x interaction(Vowel, Next_Voicing) ɪ.voiced	2.5157	3.0426	7.2382	0.0001	1.0000	1.0001	9.4403	0.0021
ti(Time Step) x interaction(Vowel, Next_Voicing) i.voiced	1.0003	1.0006	10.6482	0.0011	2.8830	3.4261	13.8514	0.0000
ti(Time Step) x interaction(Vowel, Next_Voicing) u.voiced	1.0003	1.0005	2.3028	0.1292	2.8187	3.2686	3.7848	0.0056
ti(Time Step) x interaction(Vowel, Next_Voicing) ʌ.voiceless	1.9046	2.2205	17.1122	0.0000	1.5518	1.9411	8.0564	0.0011
ti(Time Step) x interaction(Vowel, Next_Voicing) ɛ.voiceless	0.0001	0.0001	0.0260	0.9987	1.6404	2.0543	4.3079	0.0093
ti(Time Step) x interaction(Vowel, Next_Voicing) ɪ.voiceless	0.0001	0.0002	0.0658	0.9973	1.7758	2.0640	8.4764	0.0001
ti(Time Step) x interaction(Vowel, Next_Voicing) i.voiceless	0.0002	0.0004	0.0133	0.9981	0.0005	0.0007	0.1705	0.9914
ti(Time Step) x interaction(Vowel, Next_Voicing) u.voiceless	0.0001	0.0002	0.0662	0.9969	0.0000	0.0001	0.1675	0.9972
ti(Time Step) x interaction(Vowel, NextPlacegrp) ʌ.F2high	1.8010	2.1510	13.1578	0.0001	0.0000	0.0000	0.3246	0.9971
ti(Time Step) x interaction(Vowel, NextPlacegrp) ɛ.F2high	1.0001	1.0001	0.1773	0.6736	1.0000	1.0000	0.0213	0.8840
ti(Time Step) x interaction(Vowel, NextPlacegrp) ɪ.F2high	1.0000	1.0000	0.1585	0.6906	3.4443	3.5585	12.2281	0.0000
ti(Time Step) x interaction(Vowel, NextPlacegrp) i.F2high	2.9410	3.4740	0.6344	0.6980	1.0001	1.0001	32.7759	0.0000
ti(Time Step) x interaction(Vowel, NextPlacegrp) u.F2high	1.0328	1.0629	0.1155	0.7183	0.0001	0.0001	0.1000	0.9972
ti(Time Step) x interaction(Vowel, NextPlacegrp) ʌ.F2low	1.0002	1.0003	5.2615	0.0218	1.0000	1.0000	0.0907	0.7634
ti(Time Step) x interaction(Vowel, NextPlacegrp) ɛ.F2low	1.0001	1.0001	0.4563	0.4994	1.0000	1.0000	1.8800	0.1704
ti(Time Step) x interaction(Vowel, NextPlacegrp) ɪ.F2low	0.0001	0.0001	0.0000	1.0000	0.0000	0.0001	0.2223	0.9965
ti(Time Step) x interaction(Vowel, NextPlacegrp) i.F2low	0.0003	0.0006	0.0208	0.9973	0.0001	0.0001	0.2056	0.9960
ti(Time Step) x interaction(Vowel, NextPlacegrp) u.F2low	1.0001	1.0001	0.0002	0.9895	2.5609	2.8523	25.9225	0.0000
ti(Time Step) x interaction(Vowel, NextPlacegrp) ʌ.F2mid	1.0002	1.0003	6.2834	0.0122	3.2020	3.5388	23.8936	0.0000
ti(Time Step) x interaction(Vowel, NextPlacegrp) ɛ.F2mid	1.0001	1.0001	0.4479	0.5033	1.0000	1.0001	0.8365	0.3604
ti(Time Step) x interaction(Vowel, NextPlacegrp) ɪ.F2mid	1.0001	1.0002	0.5002	0.4794	1.9645	2.2759	4.8201	0.0076
ti(Time Step) x interaction(Vowel, NextPlacegrp) i.F2mid	1.8763	2.2899	1.2023	0.3734	3.3684	3.7524	17.0712	0.0000
ti(Time Step) x interaction(Vowel, NextPlacegrp) u.F2mid	1.0003	1.0005	0.0895	0.7650	1.0000	1.0001	1.0463	0.3064
s(Time Step, Speaker) x Vowel: ʌ	34.6087	36.0000	35.1737	0.0000	34.4689	36.0000	29.5862	0.0000
s(Time Step, Speaker) x Vowel: ɛ	35.2524	39.0000	15.8211	0.0000	36.6344	39.0000	19.4892	0.0000
s(Time Step, Speaker) x Vowel: ɪ	37.2553	39.0000	25.8293	0.0000	37.9965	39.0000	52.1229	0.0000
s(Time Step, Speaker) x Vowel: i	34.4078	39.0000	9.4207	0.0000	37.0231	39.0000	27.6693	0.0000
s(Time Step, Speaker) x Vowel: u	27.4720	31.0000	10.7382	0.0000	25.8226	31.0000	8.4128	0.0000

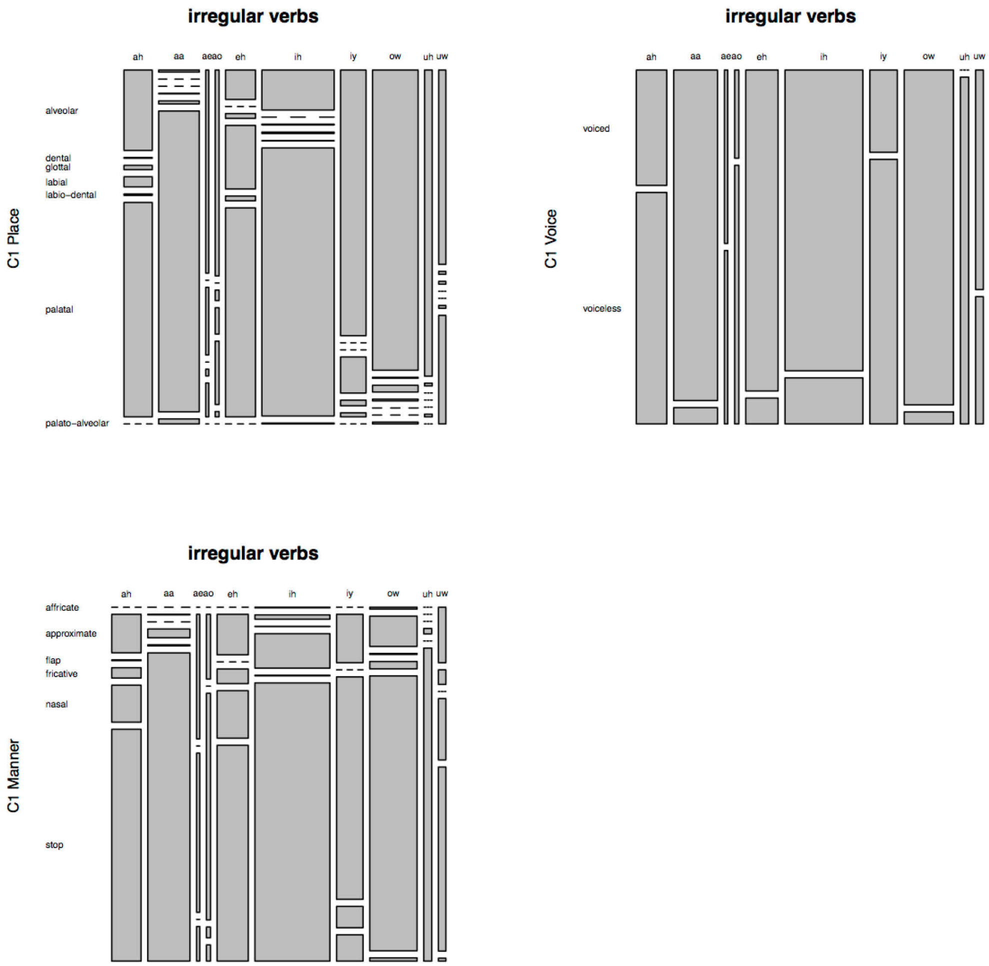

Figure A.5. Distributional plots for the voice, place, and manner of the context preceding each vowel.

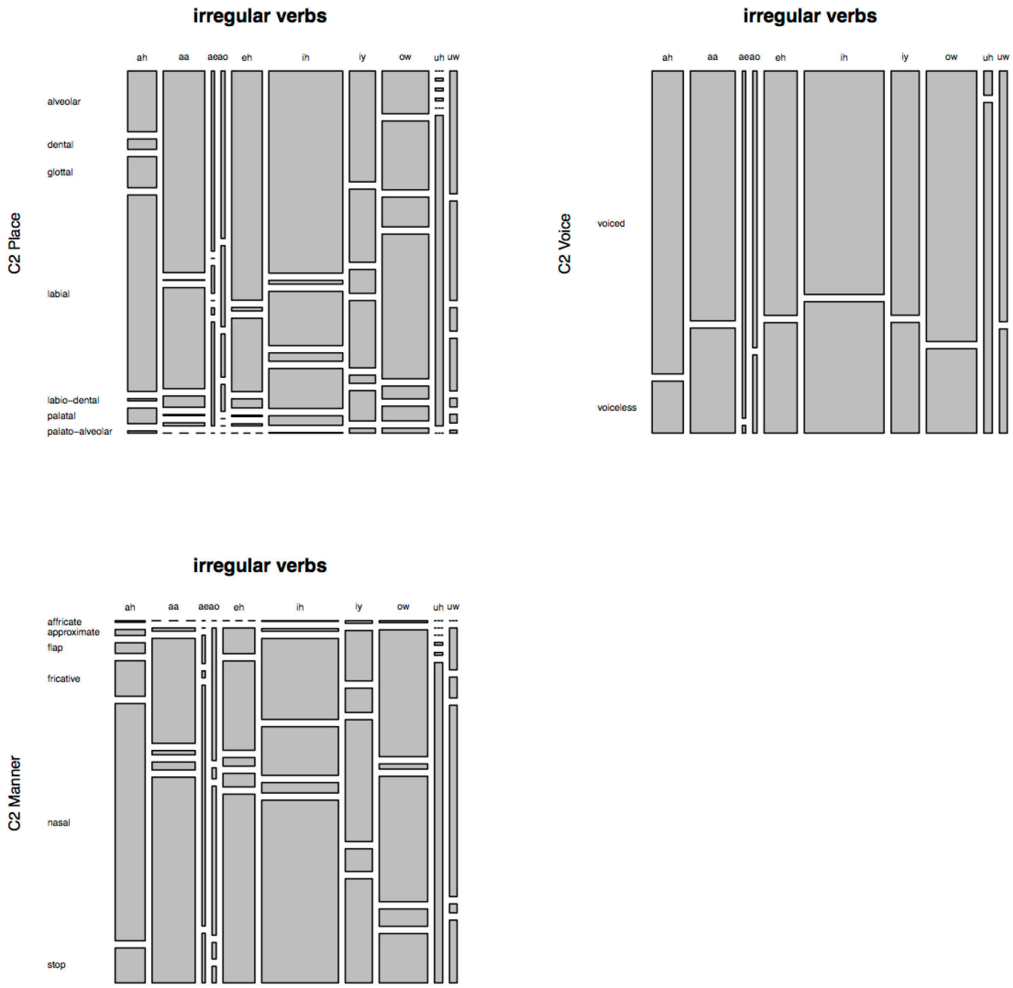

Figure A.6. Distributional plots for the voice, place, and manner of the context following each vowel.

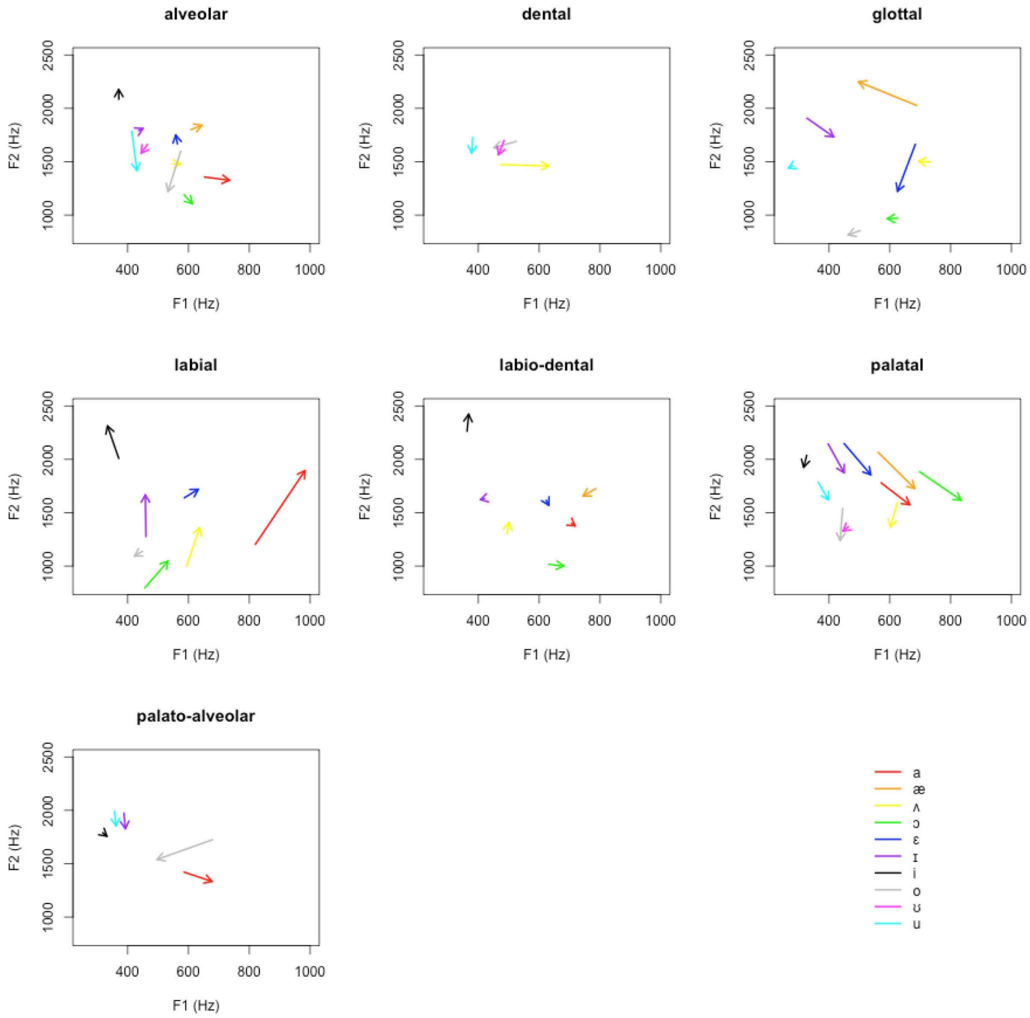

Figure A.7. Vowel plots by place of articulation for the consonant preceding each vowel. Arrowhead denotes vowel offset, blunt end denotes vowel onset.

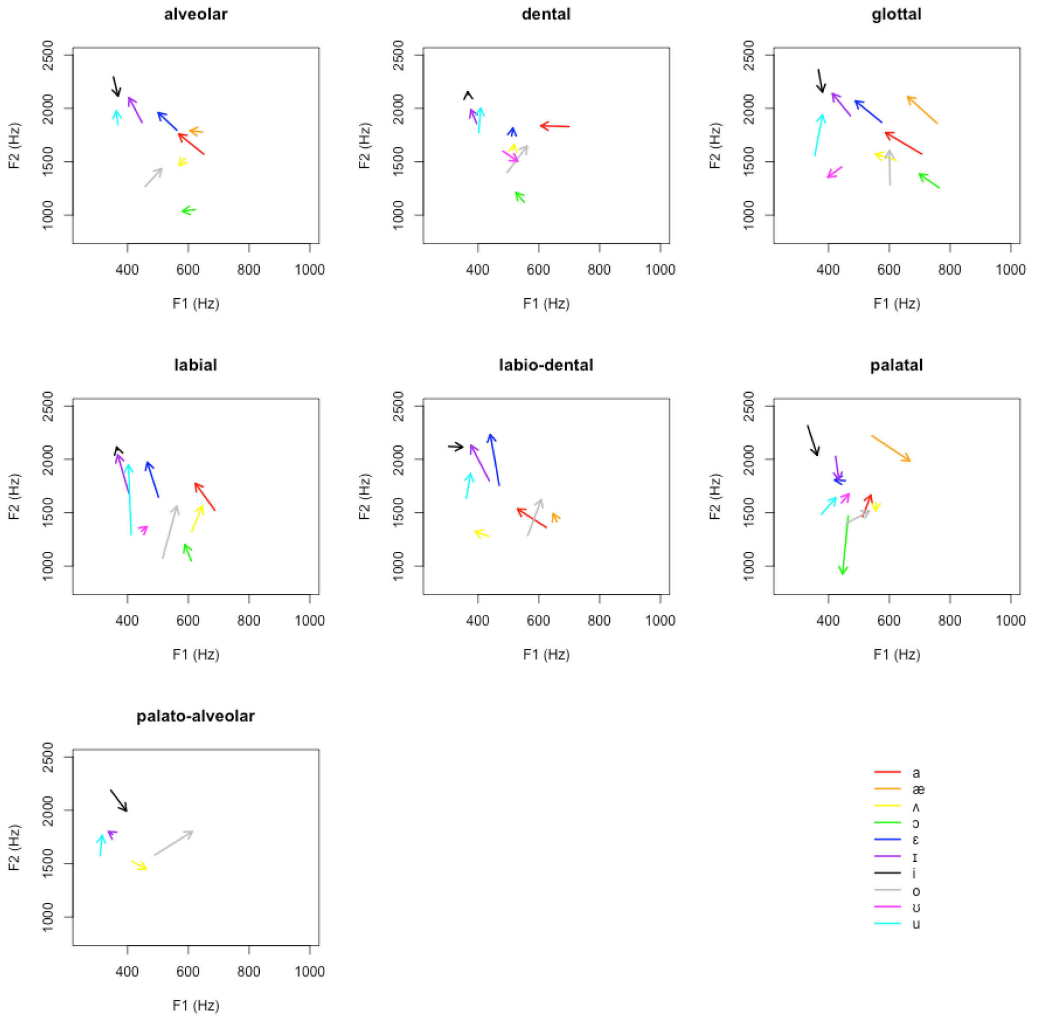

Figure A.8. Vowel plots by place of articulation for the consonant following each vowel. Arrowhead denotes vowel offset, blunt end denotes vowel onset.

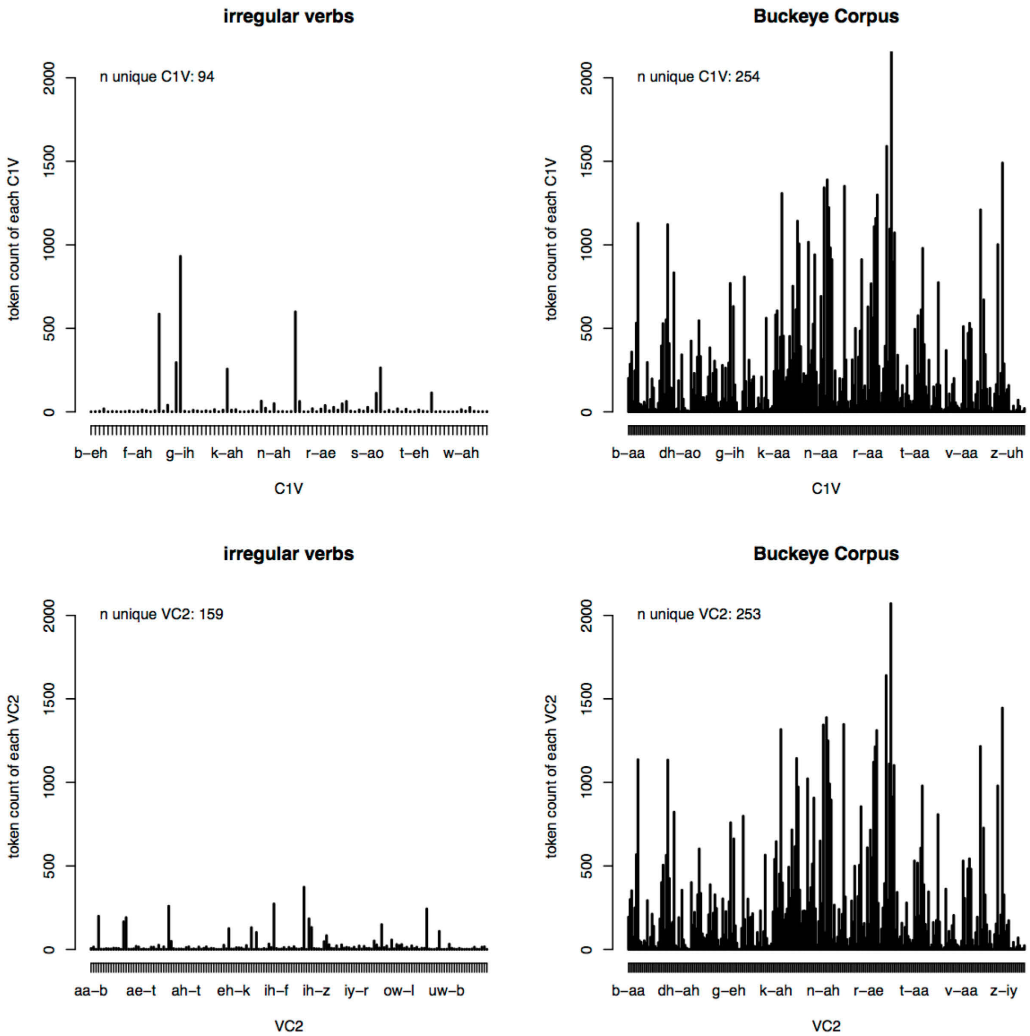

Figure A.9. Distributional plots for all the C1V and VC2 pairs in the dissertation's data (Buckeye Corpus irregular English verbs) compared to the entire Buckeye Corpus.

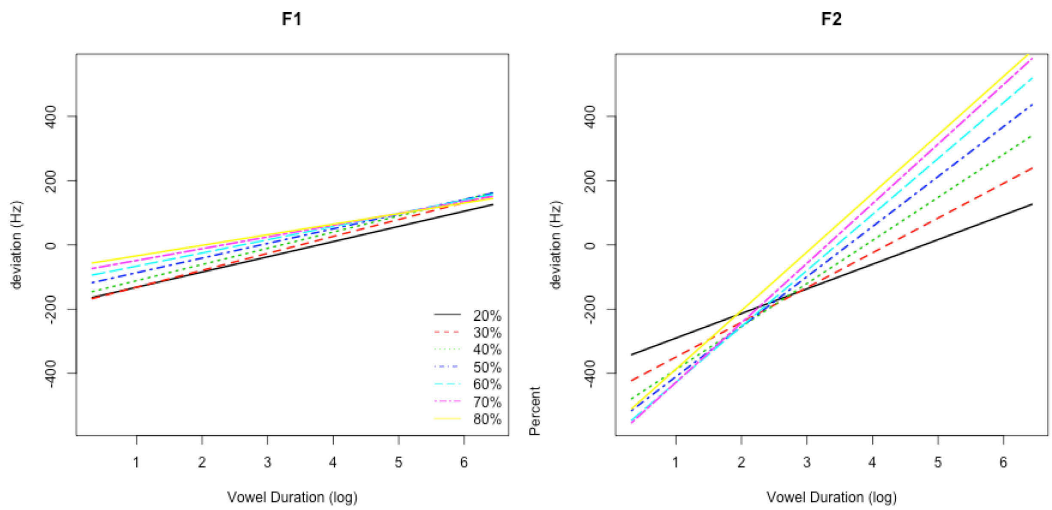

Figure A.10. LMER predictions in the formant deviation from vowel onset analysis. Interaction shown is between vowel duration (ms log) and percent time step.

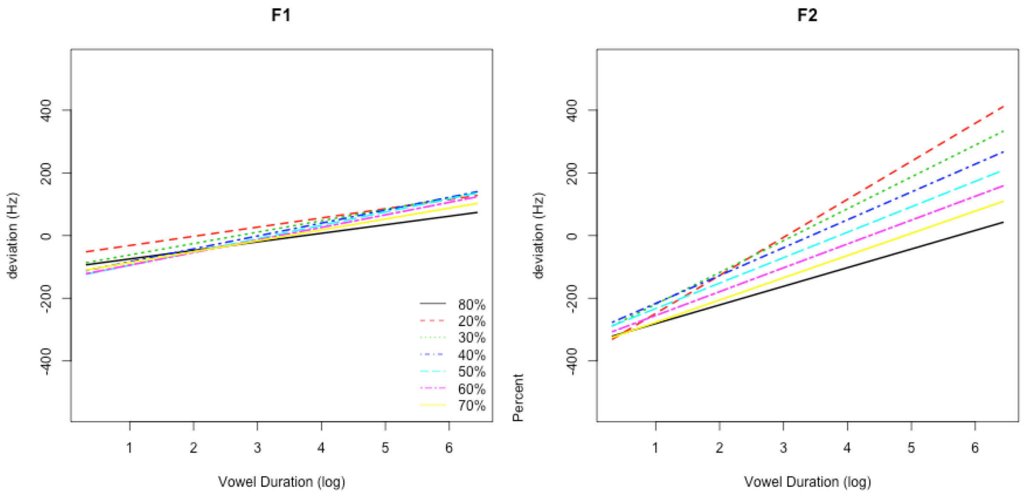

Figure A.11. LMER predictions in the formant deviation from vowel offset analysis. Interaction shown is between vowel duration (ms log) and percent time step.

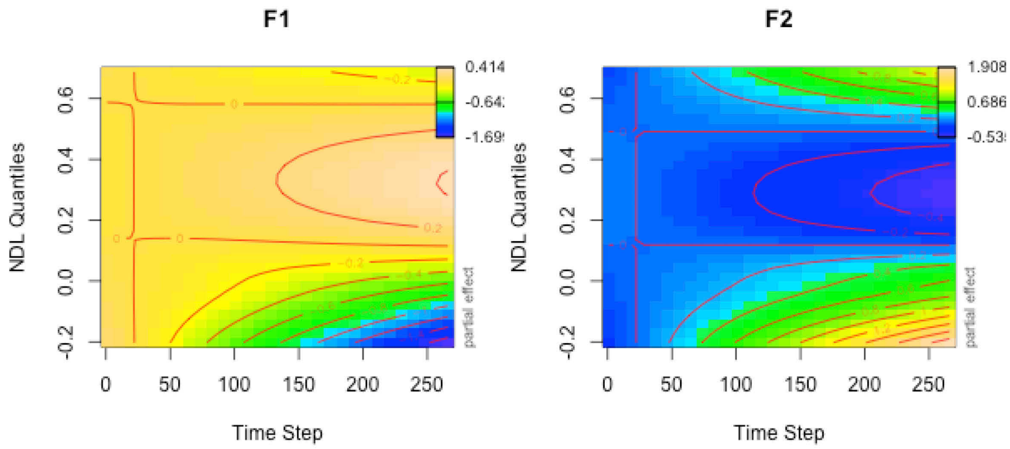

Figure A.12. F1 and F2 global GAM models' partial effects of NDL Cue Strength through Time. Time is shown on the x-axis. NDL Cue Strength is shown on the y-axis. Formant value is shown on the z-axis (in colours).

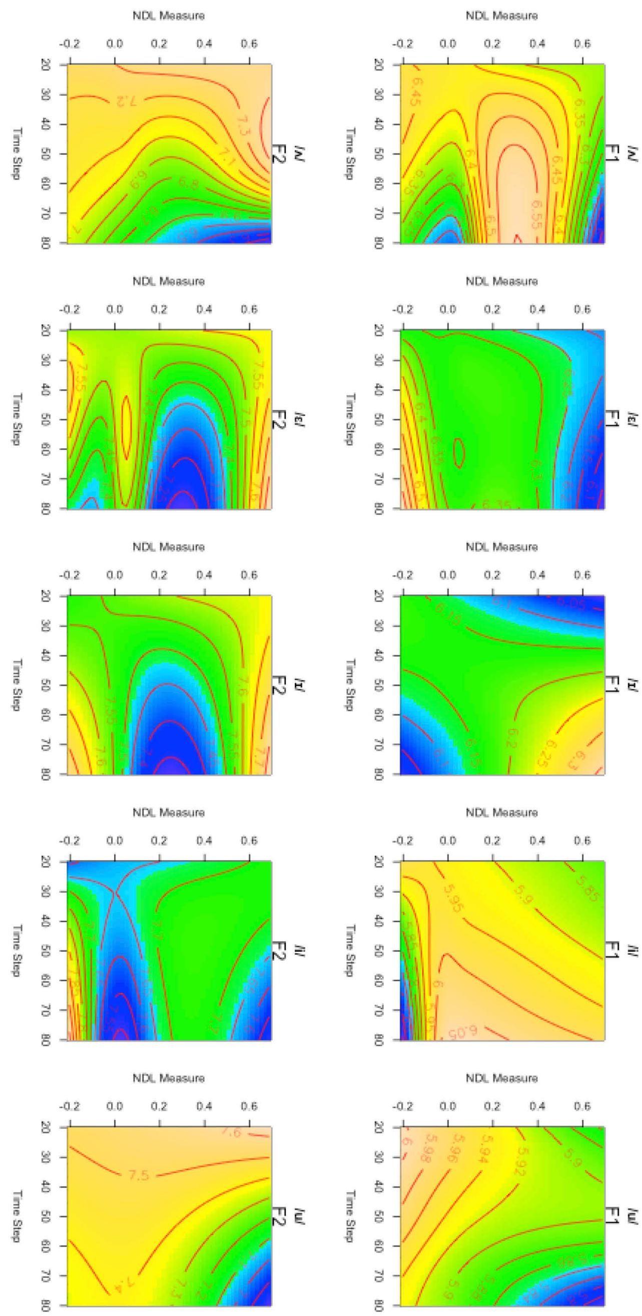

Figure A.13. F1 GAM model partial effects of NDL Cue Strength paired with Time for each vowel. Percent of vowel duration is shown on the x-axis. NDL Cue Strength is shown on the y-axis. Formant measures (in Hertz) is shown on the z-axis (in colours). F1 is shown on the top row, F2 is on the bottom row.

Discussion A.1: Phonetically relevant results to the onset analysis.

In the analysis of formant movement from the vowel edges (onset and offset), the interaction between the absolute length of a vowel's duration (log Duration) and relative time (Percent) is phonetically relevant. The phonetic relevance concerns the contribution of the surrounding phonetic environment on the formant trajectories. Lindblom (1963) proposes that more reduced (i.e. shorter) vowel durations will be produced with less formant movement because the contributions of the surrounding environment are too influential (context assimilation is strong). H&H Theory holds that hyper-articulated vowels (i.e. longer vowel durations) will show more formant movement away from the onset and offset edges, where there is less context assimilation. Broad and Clermont (1987) add to H&H Theory by quantifying the time domain of context assimilation. They propose that vowel trajectories will exponentially increase until it reaches an asymptote state, where context assimilation is at its weakest, at roughly 50% of the vowel's duration. Taken together, these two predictions entail that vowels with longer durations (H&H Theory's hyper-articulation) will display more movement away from the vowel edges (where assimilation to the phonetic context is strong) when compared to vowels with shorter durations (hypo-articulation). These predictions are discussed here with regards to vowel onset, where assimilation to the phonetic context preceding the vowel is strong.

On Table A.13 and for F1, the duration-time interaction is significant at the 30%, and 60%-80% time intervals, or the two tail ends of the vowel duration - close to onset, and close to offset (i.e. and not during Broad and Clermont's vowel asymptote state). For F2, however, this interaction is significant for every Percent time interval, with the magnitude of the effect gradually increasing until the 60%-70% time interval.

Figure A.10 shows positive trends for the duration-time interaction. For both F1 and F2, longer vowels are produced with more formant deviation from vowel onset compared to shorter vowels. The amount of deviation increases for each time step, from 20%-80%, indicating that deviation increases over time. The slopes of the interaction are steeper for F2 formant deviation than F1. This could be due to the effect the place of articulation that precedes the vowel, as place of articulation is known to strong affect F2 trajectories. Thus, there is strong support for the predictions made by H&H Theory and Broad and Clermont: more hyper-articulated vowels are produced with more dynamic formant dispersion compared to hypo-articulated vowels.

Discussion A.2: Phonetically relevant results to the offset analysis.

Similar to Discussion A.1, this section discusses the Lindblom (1963) and Broad and Clermont (1987) predictions of formant movement from vowel offset. On Table A.15 and for F1, the duration-time interaction is significant at the 70%-30% time intervals (80% serves as the reference level of vowel offset). For F2, this interaction is significant for every Percent time interval. The magnitude of the interaction effects in both the F1 and F2 data gradually increases as the trajectories progress backwards in time, away from the vowel offset. These effects are similar to the deviance from vowel onset models in Discussion A.1.

Figure A.11 shows positive trends for the duration-time interactions that are also similar to the onset models. For both F1 and F2, longer vowels are produced with more formant deviation from vowel onset compared to shorter vowels. The amount of deviation increases for each time step, from 80%-20%, indicating that deviation increases over time. Again, the slopes of the interaction is steeper for F2 formant deviation than F1 due to a possible confound with the place of articulation in the phonetic context that follows the vowel. Once again, there is strong support for the predictions made by H&H Theory and Broad and Clermont. Taken with Discussion A.1, the phonetic context that surrounds the vowel affects the formant trajectories in predictable ways: hyper-articulated vowels display more movement through time compared to hypo-articulated vowels.

Discussion A.3: Methods of gaining convergence in the GAM of formant movement.

Three methods were employed to attempt to gain convergence in the GAM models of formant movement. Methods 1 and 2 proved to be ineffective to solving the data sparsity issue. These methods and the issues of data sparsity are discussed below. Method 3 was effective in solving data sparsity, however it limits the generalizability of the predictions to other analyses in Chapter 3. This is discussed in more detail below.

Method 1: modelling each articulation feature (voice, place, and manner) for each C_1 and C_2 separately

Place of articulation is known to affect formant trajectories, particularly F2, and voicing is known to affect F1 trajectories (Lindblom, 1963). Each of these features for each C_1 and C_2 were placed in the GAM models individually; for example, one model with C_1 voicing only, another model with C_1 place only, etc. However, no factor level (e.g. C_1 voicing) was populated well enough across each vowel to gain model convergence. For example, /æ/ is disproportionally followed by voiceless consonants, with very few data for voiced consonants (see distributional plots in Figure A.5 and Figure A.6). For this data population sparsity issue, this method failed to reach model convergence.

Method 2: collapsing articulation features into locus equation groups to reduce factor levels

The places of articulation for the surrounding phonetic environment were collapsed into three groups according to Lindblom (1963): F2 decreasing (bilabial-like: labial and labio-dental), F2 mid (alveolar-like: dental and alveolar), and F2 increasing (velar-like: palatal-alveolar and palatal; phones such as /k/ are coded as 'palatal' in the Buckeye Corpus). However, these collapsed factor levels were still sparse for some vowels. For example, there is no F2 increasing consonants following the production of /ɔ / in the current data set (again, see distributional plots in Figure A.5 and Figure A.6).

Method 3: modelling data from robust vowels only

According to the distributional plots in Figure A.5 and Figure A.6, half of vowels (5/10) are robust for both each collapsed articulation feature (in Method 2 above) and voicing contrast in both phonetic environments (preceding and following): /ʌ /, /ɛ /, /ɪ /, /i/, and /u/. The ideal model of context assimilation (C_1V x Time + V x Time + VC_2 x Time) was run over data from these robust vowels only. All other predictors in the GAM model described in § 3.3.4.2, including the predictors of interest (morphological tense and NDL Cue Strength) were also included in the model. F1 and F2 were modelled separately.

Parametric coefficients and smooth terms for the global GAM model of robust vowels are given in Table A.25 and the same for the by vowel model in Table A.26. Partial effects for the NDL predictor in the global model are illustrated in Figure A.12 and Figure A.13.

In terms of model criticism, the current models with dynamic context contributions (smooth terms) are a better fit to the robust data when compared to models of the same robust data with fixed effect contract contributions (parametric terms). The R^2 scores of the dynamic context models are slightly better (by a difference in score of at most 0.037), and the ML scores are much lower (by a difference in score of at least 7880). A better model fit with dynamic context predictors is unsurprising given phonetic theory of context assimilation (discussed in §3.3.4.2).

In terms of NDL Cue Strength and Tense predictions, there is no difference in the predicted direction and statistical significance between the current model with dynamic context contributions and a model with fixed effects context contributions. The only difference between the two is seen in the partial effects plots for NDL in the global and by vowel models (Figure A.12 and Figure A.13). Compared to the GAM analysis in Chapter 3 (Figure 3.8 and Figure 3.10, the current model shows more formant movement in the robust vowels, overall.

The interaction pattern between NDL and formant movement is made more clear in the models of dynamic context contributions: vowels associated with high and low NDL Cue Strengths display similar patterns of dynamic movement compared to vowels associated with mid NDL Cue Strengths. The GAM analysis presented in Chapter 3 (§3.3.4) concluded that there was no discernible pattern between NDL Cue Strength and formant movement. It was suggested that this may be due to a proper lack of control over formants' context assimilations. This is supported here. In the models here with context assimilation properly controlled for its dynamic effects, there is a discernible pattern between NDL Cue Strength and formant movement.

However, this method of gaining model convergence limits the generalizability of the models' predictions for NDL Cue Strength and Tense. The three linear analyses in Chapter 3 are based on all irregular English verb vowels, whereas the GAM models here are based on a subset of those vowels. This subset was selected based out of statistical necessity, rather than a linguistic one. If anything, this statistical necessity highlights the issue of studying inherently unbalanced spontaneous speech. The goal of Chapter 3 is to present ecologically valid analyses and to represent the vowel data as it was produced by speakers, including it's inherent and unbalanced variation with phonetic context. Capturing actual language use was paramount. For this reason, the current models with more researcher imposed control over the data is not discussed in Chapter 3.

A.3 Supplementary Information for Chapter 4

Table A.19: Information about the Fillers and Nonwords for the morphological and lexical decision tasks. Stimuli items marked for containing distortions, glitches, and/or unnatural patterns in pitch and formant contours are shown in boldface.

shortest duration manipulation		short duration manipulation		normal duration manipulation		long duration manipulation		longest duration manipulation	
Word	Type	Word	Type	Word	Type	Word	Type	Word	Type
women	Filler	weeks	Filler	kite	Filler	**noses**	**Filler**	**meal**	**Filler**
apple	Filler	suggest	Filler	**movies**	**Filler**	cat	Filler	cities	Filler
intend	Filler	acted	Filler	counted	Filler	needed	Filler	accept	Filler
joined	Filler	live	Filler	close	Filler	saved	Filler	called	Filler
care	Filler	check	Filler	cooked	Filler	faced	Filler	hoped	Filler
ask	Filler	**dealt**	**Filler**	do	Filler	felt	Filler	walk	Filler
cut	Filler	weep	Filler	spent	Filler	send	Filler	forbade	Filler
was	**Filler**	bɪkiz	Nonword	gɪmən	Nonword	**kʌŋ**	**Nonword**	tɛz	Nonword
ɪndɑnd	Nonword	koɪt	Nonword	**jip**	**Nonword**	twu	Nonword	**heɪv**	**Nonword**
fɛft	Nonword	**hʌʒ**	**Nonword**	fiks	Nonword	swoʊ	Nonword	**dɪmiz**	**Nonword**
kwɛt	Nonword	**vəld**	**Nonword**	**wɛm**	**Nonword**	dæt	Nonword	sənspɛst	Nonword
sɛps	Nonword	**wiʃ**	**Nonword**	**wʌd**	**Nonword**	soʊvd	Nonword	**fʌt**	**Nonword**
dʒɔɪld	**Nonword**	**sɪθ**	**Nonword**	**ælk**	**Nonword**	**wɪd**	**Nonword**	**swɔg**	**Nonword**
gɑm	**Nonword**	dʒɪŋ	Nonword	kɔɪt	Nonword	gɛm	Nonword	**kukt**	**Nonword**
drɛt	**Nonword**	wɔm	Nonword	gɪθ	Nonword	fɛpt	Nonword	**ɪzəl**	**Nonword**
hæʒ	Nonword	foʊpt	Nonword	foʊst	Nonword	nɛld	Nonword	kwɑt	Nonword
kɛʃ	Nonword	fɑlk	Nonword	ɹaɪk	Nonword	dɛʃt	Nonword	læv	Nonword
ɛknəd	Nonword	ploʊ	Nonword	wʊks	Nonword	**ɹoʊk**	**Nonword**	gid	Nonword
swu	Nonword	vɛɹ	Nonword	slɔɹ	Nonword	stoʊm	Nonword	zaɪt	Nonword
tizəd	Nonword	tʃæk	Nonword	plu	Nonword	zoʊt	Nonword	kʊft	Nonword
pəgkɛst	Nonword	ɛksɛlt	Nonword	stɪm	Nonword	kwu	Nonword	dʒaɪnd	Nonword
fɛbaɪd	Nonword	dæ	Nonword	drit	Nonword	wɑlm	Nonword	goʊzɪz	Nonword
nim	Nonword	twoʊ	Nonword	grɪk	Nonword	ælsəd	Nonword	grʌk	Nonword
liz	Nonword	lɛz	Nonword	sæʒ	Nonword	feɪpt	Nonword	gɛd	Nonword
stʌm	Nonword	mivuz	Nonword	dʒæŋ	Nonword	hɛnt	Nonword	mʌpiz	Nonword
mɛm	Nonword	æksɛkt	Nonword	dɹoʊ	Nonword	tʃoʊl	Nonword	æʃk	Nonword
tɔz	Nonword	kæŋ	Nonword	bɪv	Nonword	kɔɪntəd	Nonword	**tɹoʊz**	**Nonword**
hoʊnt	Nonword	vɔɹ	Nonword	tɑmən	Nonword	tʃul	Nonword	wɚbeɪd	Nonword
tʃɛd	Nonword	lʌn	Nonword	kaɪb	Nonword	dɪ	Nonword	vɹoʊ	Nonword
dɪt	Nonword	hɪn	Nonword	stum	Nonword	dɛpt	Nonword	vɹu	Nonword
taɪzɪz	Nonword	keɪndəd	Nonword	kæʒ	Nonword	zɔɹ	Nonword	paɪt	Nonword
mʌz	Nonword	hɪv	Nonword	kɛnd	Nonword	kaɪɹ	Nonword	geɪθ	Nonword
zɛɹ	Nonword	sɪʒ	Nonword	seɪgd	Nonword	**skoʊ**	**Nonword**	**noʊld**	**Nonword**
sɹu	**Nonword**	givəd	Nonword	hoʊmp	Nonword	maɪp	Nonword	sæθ	Nonword
gil	Nonword	slɛɹ	Nonword	ɪndɛɹd	Nonword	spoʊz	Nonword	wɛz	Nonword
kɔdʒd	Nonword	ɛtəl	Nonword	spɛpt	Nonword	**blɛnt**	**Nonword**	**swɛg**	**Nonword**

Table A.20: Information about the Target stimuli for the morphological and lexical decision tasks.

Lemma	Word	Vowel	Tense	NDL Level	NDL Cue Association Strength	Phonological Neighbourhood Density	Buckeye Frequency	Duration Manipulation Level	Speaking Rate (bpm)	Vowel Duration (ms)	Frame Word Duration (ms)	Stimuli Word Duration (ms)	Frame Sentence Duration (ms)	Stimuli Sentence Duration (ms)
blow	blow	/o/	present	mid	0.0529	10	1.61	long	120	213.09	788.87	1001.96	1171.63	1384.72
								normal	130	204.26		993.12		1375.87
								short	140	121.01		967.76		1340.68
	blew	/u/	past	high	0.113	11	1.79	normal	130	128.89	823.73	952.62	1266.8	1395.69
								short	140	124.03		981.55		1429.71
								shortest	150	112.06		947.8		1378.07
choose	choose	/u/	present	mid	0.0085	17	3.09	long	120	173.56	1039.02	1212.58	1452.74	1605.15
								normal	130	152.39		1211.23		1605.15
								short	140	121.09		1180.56		1573.83
	chose	/o/	past	high	0.1383	18	1.61	normal	130	164.69	971.19	1135.88	1333.54	1498.23
								short	140	143.63		1119.22		1477.19
								shortest	150	130.22		1099.31		1463.74
get	get	/ɛ/	present	low	-0.039	18	7.03	longest	115	136.77	812.04	948.81	1257.77	1394.54
								long	120	122.75		934.77		1380.5
								normal	130	112.03		932.1		1369.77
	got	/ɑ/	past	high	0.2739	23	6.61	normal	130	168.2	779.18	947.38	1202.98	1371.18
								short	140	150.91		939.81		1353.9
								shortest	150	126.02		913.63		1329
give	give	/ɪ/	present	high	0.1042	6	5.04	normal	130	121.22	796.48	917.7	1185.56	1306.78
								short	140	111.01		908.25		1296.58
								shortest	150	93.76		890.24		1279.32
	gave	/e/	past	low	-0.0476	20	3.81	longest	115	212.44	843.78	1056.22	1234.16	1446.6
								long	120	194.43		1038.22		1428.59
								normal	130	172.12		1015.93		1406.3
grow	grow	/o/	present	high	0.1994	8	3.53	normal	130	101.46	870.37	971.83	1276.36	1377.82
								short	150	100.07		931.21		1342.61
								shortest	150	87.95		948.47		1354.47
	grew	/u/	past	mid	0.0235	12	3.97	long	120	104.87	841.52	946.39	1299.21	1404.08
								normal	130	92.56		914.06		1391.77
								short	140	61.21		893.67		1350.82
hang	hang	/æ/	present	low	-0.044	21	2.71	longest	115	154.41	860.27	1014.68	1296.2	1450.61
								long	120	132.85		993.12		1429.05
								normal	130	126.95		987.22		1423.15
	hung	/ʌ/	past	low	-0.0444	16	1.95	longest	115	111.77	845.67	957.44	1266.73	1378.5
								long	120	97.54		950.07		1371.13
								normal	130	83.64		930.59		1351.66
hold	hold	/o/	present	mid	0.0183	22	3.04	long	120	214.88	714.87	929.75	1126.12	1341
								normal	130	155.85		870.7		1281.95
								short	140	155.51		870.36		1281.61
	held	/ɛ/	past	mid	0.0053	19	2.08	long	120	109.53	883.51	993.04	1292.08	1401.61
								normal	130	79.87		997.15		1401.61
								short	140	46.04		969.4		1371.36
lead	lead	/i/	present	mid	0.0194	42	2.4	long	120	172.59	881.3	1053.89	1292.44	1465.03
								normal	130	156.36		1042.36		1448.8
								short	140	136.03		1022.06		1428.46
								long	115	141.36		1029.63		1420.91

	led	/ɛ/	past	low	-0.0359	25	1.1	longest	115	155.62	888.27	1043.89	1279.55	1435.17
								normal	130	124.99		1009.92		1404.56
meet	meet	/i/	present	mid	0.0547	27	3.3	long	115	133.58	858.26	991.84	1306.35	1439.93
								normal	130	129.04		987.21		1435.37
								short	140	92.09		952		1398.44
	met	/ɛ/	past	mid	-0.002	28	4.2	long	115	116.31	770.2	886.51	1263.4	1379.71
								normal	130	105.86		876.05		1369.25
								short	140	93		854.21		1349.07
sing	sing	/i/	present	high	0.1068	23	1.95	normal	130	72.83	946.98	1019.81	1367.87	1440.7
								short	140	67.92		1014.94		1435.78
								shortest	150	61.76		1008.77		1429.61
	sang	/æ/	past	high	0.0842	19	1.79	normal	130	142.87	875.56	1018.43	1311.26	1454.13
								short	140	132.03		1007.6		1443.29
								shortest	150	122.71		998.25		1433.95
sit	sit	/ɪ/	present	mid	0.0132	32	4.66	long	115	100.12	736.89	837.01	1173.19	1273.31
								normal	130	83.78		820.66		1256.96
								short	140	69.09		805.97		1242.27
	sat	/æ/	past	mid	0.0391	31	2.48	long	120	149.95	805.51	955.46	1220.59	1370.54
								normal	130	142.75		976.27		1391.18
								short	140	135.4		933.7		1317.8
stick	stick	/ɪ/	present	low	-0.0423	14	2.71	long	115	79.42	1008.96	1088.38	1429.85	1509.27
								longest	115	92.66		1101.6		1522.49
								normal	130	77.06		1086		1506.89
	stuck	/ʌ/	past	high	0.0897	12	2.83	normal	130	74.34	929.51	1003.85	1373.12	1447.46
								shortest	140	49.92		979.43		1423.04
								short	150	62.82		992.33		1435.94
swear	swear	/ɛ/	present	low	-0.0698	10	1.95	longest	115	173.26	875.48	1048.74	1274.9	1445.06
								long	120	153.92		1038.21		1428.82
								normal	130	142.95		1021.52		1417.85
	swore	/ɔ/	past	mid	-0.0271	5	0.69	long	120	108.69	900.46	1009.15	1256.75	1365.44
								normal	130	79.78		991.92		1346.21
								short	150	81.5		982.18		1339.55
tear	tear	/ɛ/	present	mid	0.0052	37	0.69	long	120	200.16	801.72	1001.88	1226.46	1426.62
								normal	130	177.04		973.36		1403.51
								short	150	155.09		956.82		1381.56
	tore	/o/	past	low	-0.062	38	1.61	long	115	95.83	912.53	1008.36	1325.94	1421.77
								longest	115	107.66		989.6		1405.46
								normal	130	81.21		1001.93		1419.27
throw	throw	/o/	present	high	0.0778	8	3.4	normal	130	107.05	819.15	926.2	1258.14	1365.19
								short	140	95.98		916.69		1354.49
								shortest	150	76.7		898.66		1335.26
	threw	/o/	past	mid	0.055	8	2.3	long	115	138.63	922.89	1061.52	1335.38	1474.01
								short	120	89.21		1012.09		1424.58
								normal	130	117.68		1025.95		1438.44
wear	wear	/ɛ/	present	mid	-0.029	30	3.76	long	120	164.66	791.83	956.49	1210.31	1374.97
								normal	130	150.38		942.22		1360.7
								short	140	114.2		906.03		1324.51
	wore	/ɔ/	past	mid	0.027	31	1.79	normal	120	99.72	860.89	960.61	1296.36	1396.08
								long	120	127.91		989.59		1419.86
								short	140	84.93		958.16		1388.44

win	win	/ɛ/	present	low	-0.1281	30	2.48	long	115	72.59	906.96	979.55	1350.11	1422.7
								longest	115	83.42		989		1432.15
								normal	130	66.99		970.82		1413.97
	won	/ʌ/	past	mid	-0.0243	20	3	long	120	115.08	915.39	1030.47	1338.14	1453.22
								normal	130	67		1000.85		1423.61
								short	140	51.07		970.28		1393.04
write	write	/ʌ/	present	mid	-0.0214	35	3.81	long	120	109.21	819.15	928.36	1269.34	1378.55
								normal	140	95.22		920.11		1365.8
								short	150	85.44		915.48		1365.67
	wrote	/o/	past	mid	0.0483	34	3.18	long	120	113.64	873.9	987.54	1365.75	1479.39
								normal	130	101.17		958.83		1457.26
								short	140	73.09		941.29		1438.87

Table A.21: LMER call and coefficients for the simple model of duration manipulation by vowel for the lexical decision data.

Model Call:

```
logRTWordOffset ~
  log(VowelDurationms) * TargetSegment
  + (1|Subject)
```

Predictor	Estimate	std.Error	t.value
(Intercept)	3.9548	1.8266	2.1651
log(VowelDurationms)	0.4934	0.3666	1.3459
TargetSegment: æ	-1.9761	2.4871	-0.7945
TargetSegment: ʌ	2.0077	1.8554	1.0821
TargetSegment: ɔ	3.6641	2.0445	1.7921
TargetSegment: ɛ	2.7828	1.8426	1.5102
TargetSegment: ɪ	2.3358	1.8387	1.2703
TargetSegment: i	2.9600	2.0030	1.4778
TargetSegment: o	3.3911	1.8434	1.8396
TargetSegment: ʊ	2.8364	2.1093	1.3447
TargetSegment: u	4.9362	1.8901	2.6116
log(VowelDurationms) x TargetSegment: æ	0.4091	0.5022	0.8146
log(VowelDurationms) x TargetSegment: ʌ	-0.3870	0.3743	-1.0340
log(VowelDurationms) x TargetSegment: ɔ	-0.7279	0.4178	-1.7421
log(VowelDurationms) x TargetSegment: ɛ	-0.5662	0.3701	-1.5298
log(VowelDurationms) x TargetSegment: ɪ	-0.4845	0.3696	-1.3110
log(VowelDurationms) x TargetSegment: i	-0.5912	0.4029	-1.4672
log(VowelDurationms) x TargetSegment: o	-0.6804	0.3702	-1.8379
log(VowelDurationms) x TargetSegment: ʊ	-0.5879	0.4296	-1.3683
log(VowelDurationms) x TargetSegment: u	-1.0055	0.3804	-2.6433

Model Call:

```
logRTWordOffset ~
  SynthLevel * TargetSegment
  + (1|Subject)
```

Predictor	Estimate	std.Error	t.value
(Intercept)	6.4761	0.0833	77.7180
SynthLevel: long	0.1138	0.0723	1.5734
SynthLevel: longest	0.4520	0.0883	5.1209
SynthLevel: short	0.0133	0.1193	0.1115
SynthLevel: shortest	-0.1512	0.1091	-1.3856
TargetSegment: æ	-0.0581	0.0922	-0.6303
TargetSegment: ʌ	-0.0611	0.0901	-0.6775
TargetSegment: ɔ	0.0743	0.0976	0.7618
TargetSegment: ɛ	-0.0886	0.0848	-1.0449
TargetSegment: ɪ	-0.1135	0.0858	-1.3234
TargetSegment: i	-0.0306	0.0995	-0.3074
TargetSegment: o	-0.0660	0.0873	-0.7555
TargetSegment: ʊ	0.0579	0.1093	0.5300
TargetSegment: u	-0.1348	0.0943	-1.4292
SynthLevel: long x TargetSegment: æ	-0.0483	0.1023	-0.4723
SynthLevel: longest x TargetSegment: æ	-0.5406	0.1287	-4.2003
SynthLevel: short x TargetSegment: æ	0.0679	0.1377	0.4931
SynthLevel: shortest x TargetSegment: æ	0.0025	0.1393	0.0180
SynthLevel: long x TargetSegment: ʌ	-0.0366	0.0951	-0.3844
SynthLevel: longest x TargetSegment: ʌ	-0.3789	0.1309	-2.8944
SynthLevel: short x TargetSegment: ʌ	-0.0249	0.1313	-0.1895
SynthLevel: shortest x TargetSegment: ʌ	0.0506	0.1490	0.3395
SynthLevel: long x TargetSegment: ɔ	-0.1515	0.1035	-1.4641
SynthLevel: short x TargetSegment: ɔ	0.0156	0.1464	0.1068
SynthLevel: long x TargetSegment: ɛ	-0.1603	0.0828	-1.9371
SynthLevel: longest x TargetSegment: ɛ	-0.4453	0.0990	-4.4990
SynthLevel: short x TargetSegment: ɛ	0.1083	0.1320	0.8200
SynthLevel: long x TargetSegment: ɪ	-0.1043	0.0941	-1.1077
SynthLevel: longest x TargetSegment: ɪ	-0.5834	0.1119	-5.2154
SynthLevel: short x TargetSegment: ɪ	-0.0250	0.1279	-0.1953
SynthLevel: shortest x TargetSegment: ɪ	0.0757	0.1214	0.6238
SynthLevel: long x TargetSegment: i	-0.1540	0.1031	-1.4936
SynthLevel: short x TargetSegment: i	-0.0008	0.1483	-0.0051
SynthLevel: long x TargetSegment: o	0.0041	0.0881	0.0461
SynthLevel: short x TargetSegment: o	-0.0685	0.1271	-0.5386
SynthLevel: shortest x TargetSegment: o	0.1865	0.1207	1.5448
SynthLevel: long x TargetSegment: ʊ	-0.4442	0.1391	-3.1937
SynthLevel: short x TargetSegment: ʊ	-0.2231	0.1590	-1.4037
SynthLevel: short x TargetSegment: u	0.1549	0.1388	1.1162
SynthLevel: shortest x TargetSegment: u	0.4648	0.1526	3.0463

Table A.22: LMER call and coefficients for the simple model of duration manipulation by vowel for the morphological decision data.

```
Model Call:

logRTWordOffset ~
  log(VowelDurationms) * TargetSegment
  + (1|Subject)
```

Predictor	Estimate	std.Error	t.value
(Intercept)	5.7441	3.7169	1.5454
log(VowelDurationms)	0.2391	0.7427	0.3219
TargetSegment: æ	-2.7057	4.8921	-0.5531
TargetSegment: ʌ	1.2981	3.8009	0.3415
TargetSegment: ɔ	3.7681	4.1277	0.9129
TargetSegment: ɛ	0.9242	3.7352	0.2474
TargetSegment: ɪ	1.0435	3.7302	0.2797
TargetSegment: i	3.4473	3.9706	0.8682
TargetSegment: o	2.2134	3.7375	0.5922
TargetSegment: ʊ	0.4468	5.0654	0.0882
TargetSegment: u	1.9982	3.8129	0.5241
log(VowelDurationms) x TargetSegment: æ	0.5407	0.9849	0.5490
log(VowelDurationms) x TargetSegment: ʌ	-0.2910	0.7637	-0.3811
log(VowelDurationms) x TargetSegment: ɔ	-0.8236	0.8411	-0.9792
log(VowelDurationms) x TargetSegment: ɛ	-0.2047	0.7467	-0.2741
log(VowelDurationms) x TargetSegment: ɪ	-0.2456	0.7461	-0.3291
log(VowelDurationms) x TargetSegment: i	-0.6916	0.7960	-0.8688
log(VowelDurationms) x TargetSegment: o	-0.4712	0.7472	-0.6306
log(VowelDurationms) x TargetSegment: ʊ	-0.0793	1.0362	-0.0765
log(VowelDurationms) x TargetSegment: u	-0.4203	0.7639	-0.5502

```
Model Call:

logRTWordOffset ~
  SynthLevel * TargetSegment
  + (1|Subject)
```

Predictor	Estimate	std.Error	t.value
(Intercept)	6.8767	0.1476	46.5910
SynthLevel: long	0.0568	0.1456	0.3902
SynthLevel: longest	0.0884	0.1842	0.4798
SynthLevel: short	0.2133	0.1995	1.0696
SynthLevel: shortest	-0.0571	0.2165	-0.2638
TargetSegment: æ	0.0260	0.1728	0.1505
TargetSegment: ʌ	-0.1089	0.1671	-0.6515
TargetSegment: ɔ	-0.0797	0.1859	-0.4285
TargetSegment: ɛ	-0.0345	0.1499	-0.2303
TargetSegment: ɪ	-0.0795	0.1525	-0.5213
TargetSegment: i	-0.0134	0.1656	-0.0807
TargetSegment: o	-0.0596	0.1544	-0.3860
TargetSegment: ʊ	-0.1663	0.2253	-0.7382
TargetSegment: u	-0.0273	0.1792	-0.1523
SynthLevel: long x TargetSegment: æ	0.0252	0.1955	0.1288
SynthLevel: longest x TargetSegment: æ	-0.0260	0.2634	-0.0988
SynthLevel: short x TargetSegment: æ	-0.2254	0.2379	-0.9477
SynthLevel: shortest x TargetSegment: æ	-0.2976	0.2701	-1.1018
SynthLevel: long x TargetSegment: ʌ	-0.0395	0.1841	-0.2145
SynthLevel: longest x TargetSegment: ʌ	0.1822	0.2492	0.7311
SynthLevel: short x TargetSegment: ʌ	-0.2571	0.2365	-1.0869
SynthLevel: shortest x TargetSegment: ʌ	0.2441	0.2709	0.9013
SynthLevel: long x TargetSegment: ɔ	-0.1443	0.2133	-0.6766
SynthLevel: short x TargetSegment: ɔ	0.1242	0.2676	0.4642
SynthLevel: long x TargetSegment: ɛ	-0.0822	0.1587	-0.5179
SynthLevel: longest x TargetSegment: ɛ	-0.1369	0.1977	-0.6923
SynthLevel: short x TargetSegment: ɛ	-0.1546	0.2178	-0.7100
SynthLevel: long x TargetSegment: ɪ	-0.0572	0.1692	-0.3383
SynthLevel: longest x TargetSegment: ɪ	-0.1951	0.2122	-0.9195
SynthLevel: short x TargetSegment: ɪ	-0.3063	0.2109	-1.4520
SynthLevel: shortest x TargetSegment: ɪ	0.0524	0.2350	0.2230
SynthLevel: long x TargetSegment: i	0.0236	0.1886	0.1251
SynthLevel: short x TargetSegment: i	0.1291	0.2366	0.5456
SynthLevel: long x TargetSegment: o	-0.0751	0.1723	-0.4360
SynthLevel: short x TargetSegment: o	-0.1690	0.2093	-0.8074
SynthLevel: shortest x TargetSegment: o	0.0978	0.2334	0.4189
SynthLevel: long x TargetSegment: ʊ	0.4233	0.3140	1.3478
SynthLevel: short x TargetSegment: ʊ	0.2110	0.3628	0.5815
SynthLevel: short x TargetSegment: u	-0.1360	0.2410	-0.5642
SynthLevel: shortest x TargetSegment: u	-0.0244	0.3523	-0.0692

Table A.23: LMER call and coefficients for the lexical decision data.

```
Model Call:

logRTWordOffset ~ SynthLevel
  + logPreviousRTWordOffset
  + Tense
  + scale(ObsVowelSupportTenseNP, center=TRUE)
  + scale(PhoneNeighbourhood, center=TRUE)
  + VowelQualitydichot
  + (1|Subject)
  + (1|Word)
```

High NDL			
Predictor	Estimate	std.Error	t.value
(Intercept)	4.9013	0.2322	21.1037
SynthLevel: short	0.0692	0.0366	1.8884
SynthLevel: shortest	0.1111	0.0366	3.0369
logPreviousRTWordOffset	0.2054	0.0334	6.1484
Tense: present	0.0226	0.0745	0.3034
scale(ObsVowelSupportTenseNP, center = TRUE)	-0.0047	0.0364	-0.1296
scale(PhoneNeighbourhood, center = TRUE)	0.0070	0.0373	0.1886
VowelQualitydichotTense:	0.0492	0.0737	0.6670
Mid NDL			
Predictor	Estimate	std.Error	t.value
(Intercept)	5.4712	0.1715	31.9079
SynthLevel: long	-0.0189	0.0238	-0.7926
SynthLevel: short	0.0266	0.0245	1.0859
logPreviousRTWordOffset	0.1566	0.0250	6.2500
Tense: present	-0.1469	0.0546	-2.6927
scale(ObsVowelSupportTenseNP, center = TRUE)	-0.0210	0.0377	-0.5561
scale(PhoneNeighbourhood, center = TRUE)	0.0325	0.0249	1.3044
VowelQualitydichotTense:	0.0846	0.0837	1.0108
Low NDL			
Predictor	Estimate	std.Error	t.value
(Intercept)	5.1370	0.2428	21.1607
SynthLevel: long	-0.0830	0.0387	-2.1437
SynthLevel: longest	0.0112	0.0382	0.2938
logPreviousRTWordOffset	0.1954	0.0351	5.5662
Tense: present	-0.0942	0.0685	-1.3762
scale(ObsVowelSupportTenseNP, center = TRUE)	-0.0001	0.0324	-0.0030
scale(PhoneNeighbourhood, center = TRUE)	0.0135	0.0415	0.3257
VowelQualitydichotTense:	0.3196	0.1411	2.2653
All NDL			
Predictor	Estimate	std.Error	t.value
(Intercept)	5.5510	0.1215	45.6981
SynthLevel: long	-0.0294	0.0190	-1.5473
SynthLevel: longest	0.0159	0.0305	0.5201
SynthLevel: short	0.0337	0.0193	1.7441
SynthLevel: shortest	0.0603	0.0302	1.9966
logPreviousRTWordOffset	0.1330	0.0175	7.5809
Tense: present	-0.1062	0.0346	-3.0684
scale(ObsVowelSupportTenseNP, center = TRUE)	-0.0405	0.0208	-1.9465
scale(PhoneNeighbourhood, center = TRUE)	0.0450	0.0172	2.6116
VowelQualitydichotTense:	0.0967	0.0426	2.2686

Table A.24: LMER call and coefficients for the morphological decision data.

Model Call:

```
logRTWordOffset ~ SynthLevel
  + logPreviousRTWordOffset
  + scale(PhoneNeighbourhood, center=TRUE)
  + (1|Subject)
  + (1|Word)
```

High NDL			
Predictor	Estimate	std.Error	t.value
(Intercept)	5.5566	0.3284	16.9192
SynthLevel: short	0.0278	0.0624	0.4456
SynthLevel: shortest	0.0270	0.0640	0.4215
logPreviousRTWordOffset	0.1734	0.0468	3.7060
scale(PhoneNeighbourhood, center = TRUE)	0.0270	0.0277	0.9745
Mid NDL			
Predictor	Estimate	std.Error	t.value
(Intercept)	5.4946	0.2469	22.2571
SynthLevel: long	0.0084	0.0434	0.1934
SynthLevel: short	0.0862	0.0424	2.0338
logPreviousRTWordOffset	0.1911	0.0344	5.5517
scale(PhoneNeighbourhood, center = TRUE)	0.0365	0.0204	1.7921
Low NDL			
Predictor	Estimate	std.Error	t.value
(Intercept)	4.8775	0.3308	14.7465
SynthLevel: long	-0.0906	0.0623	-1.4534
SynthLevel: longest	-0.0496	0.0645	-0.7686
logPreviousRTWordOffset	0.2794	0.0466	5.9951
scale(PhoneNeighbourhood, center = TRUE)	0.0308	0.0276	1.1152
All NDL			
Predictor	Estimate	std.Error	t.value
(Intercept)	5.5193	0.1760	31.3664
SynthLevel: long	-0.0194	0.0324	-0.5990
SynthLevel: longest	-0.0270	0.0483	-0.5591
SynthLevel: short	0.0501	0.0325	1.5401
SynthLevel: shortest	-0.0026	0.0515	-0.0512
logPreviousRTWordOffset	0.1863	0.0247	7.5507
scale(PhoneNeighbourhood, center = TRUE)	0.0433	0.0139	3.1074