Do choirs have accents?

A sociophonetic investigation of choral sound

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To Dr Katy Lavinia Cooper, Dr Kevin Corby Bowyer, and the University of Glasgow Chapel Choir family

Declaration

I declare that, except where explicit reference is made to the contribution of others, that this dissertation is the result of my own work and has not been submitted for any other degree at the University of Glasgow or any other institution.

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Abstract

Many UK cities, including Glasgow, have a long history of choral singing, with recordings dating back to the 1920s (for example, the Glasgow Orpheus Choir). Choirs have a 'sound' which is both musical and linguistic. Speakers from different localities can be said to have an accent. Is there such as thing as a regional choral 'accent'? Neither phoneticians, singers, nor choir directors have a clear understanding of how such choral sound–accents are achieved, how they arise, and are maintained. The main research questions for this thesis are:

1. Is there evidence of regional differences between Glasgow and Cambridge, in the phonology of vowels, rhoticity, and word-final /d/?

2. Is there evidence of a common choral accent uniting Glasgow and Cambridge in the phonology of vowels, rhoticity, and word-final /d/?

3. What changes have taken place in the phonology of choral singing over time?

    (a) Are the changes linked with changes in spoken phonology over the relevant time period?

    (b) Are the changes linked with changes in aesthetic conventions of choral singing?

    (c) Are the changes linked with individual properties of the choir directors?

To answer these research questions, two time-aligned electronic corpora were constructed in LaBB-CAT containing 26 hours of commercially-released recordings of British classical choral singing of choirs from two different regions, Glasgow and Cambridge. 1. Recordings of the Choir of King's College, Cambridge (1949–2019). 2. Recordings of the Glasgow Orpheus and Phoenix choirs (1925–2016).

This thesis presents the analysis of three different variables. Analysing the front vowels I found a shared front vowel phonology and realisation. The consonant variable rhoticity (e.g. *car*) was selected to investigate impact of spoken dialect. Word-final /d/ (e.g. *lord*) was selected to investigate aesthetic–stylistic differences between the two corpora.

In a Bayesian analysis of acoustic measures F1 and F2, I found that the vowels KIT, DRESS and TRAP (over 14,000 tokens) demonstrate a pattern of lowering over time consistent with a change in a spoken prestige accent e.g. from Received Pronunciation to Southern Standard British English. The analyses also support separate TRAP and BATH phonemes in both Glasgow and Cambridge, which we would not expect based on spoken vowel phonology. These findings suggest an emerging standard 'accent' of choral singing that has changed over time, following the pattern presented by Received Pronunciation. However, the realisation of the GOOSE vowel differs between Glasgow and King's, perhaps relating to the sociolinguistic salience of GOOSE in Scottish English.

Rhoticity (auditory coding of 8,407 tokens) differs between the Glasgow choirs and King's, as we might expect, based on regional accent phonology. The Glasgow choirs produce postvocalic /r/ in all contexts, though there is a reduction over time; they also produce alveolar trill realisations in initial position 50% of the time in the Orpheus Choir early recordings directed by Hugh S. Roberton (1925–1945), perhaps indicating that the variable was enregistered as part of a distinctly Scottish choral sound.

The realisation of word-final /d/ (auditory coding of 3,213 tokens) also differs between the two corpora, with King's producing more affricated variants and more shadow vowel (epenthetic schwa) variants in pre-pausal contexts. The /d/ findings confirm a change in style suggested by musicological literature (Day, 2000). Phonetic affrication at King's increases over time as the choir sings more frequently with orchestral accompaniment, likely to improve audibility, and this was carried over into the choir's unaccompanied singing (Day, 2018).

This thesis is the first to provide a quantitative acoustic analysis of choral sound and explore the sociolinguistics of classical choral singing in a UK context. I have found evidence that supports a non-regional standard British classical choral singing vowel phonology and regional differences based on the phonology of the spoken accent of the singers and their choir directors. Future research is needed to explore the perceptual salience of the findings reported in this thesis and whether recordings of other regional choirs support the pattern of non-regional standard vowel phonology.

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Chapter 1

Introduction

Previous sociolinguistic studies of singing have primarily focused on popular singing varieties, such as rock, pop, punk, and indie, investigating what factors affect the pronunciation of solo singers. The first study of this kind, Trudgill (1983), applied Le Page & Tabouret-Keller's (1985) theory of *acts of identity*, considering the way that the singers of the Beatles and the Rolling Stones shifted over time from an American model towards a more British-influenced model. This was initially thought of as the singers producing linguistic patterns resembling those of the groups with which they wish to identify (Le Page & Tabouret-Keller, 1985, p. 191) – in this case, the originators of pop, Americans.

Since Trudgill (1983), sociolinguistic studies of singing have incorporated Referee Design which is where speakers (or singers) 'shift to become more similar to some group with which the speaker wishes to identify' (Gibson & Bell, 2012, p. 140). Western classical choral singing may be a case of 'institutionalised referee design' – as Wilson writes, 'British English has become institutionalised with regard to choral singing – it is so consistently associated with choral singing that it has begun to function as the default style of this activity' (2014, p. 316).

It is unclear whether Wilson considers Southern Standard British English the default 'institutionalised' accent of Western classical choral singing – or, if there is, for choral singing in English, an international standard choral accent mainly informed by Western classical singing technique. Indeed, it is not known whether this accent is as accurately British as the 'American' accents of British pop or rock artists. This thesis complements (Wilson, 2014)'s research by investigating the accent of choral singing within the United Kingdom using quantitative acoustic methods. Choral singing as an activity is widespread across the British Isles. There is also a diversity of spoken accents within the UK (e.g. Wells, 1982a). Are there shared norms of Western classical choral singing that match those proposed by Wilson (2014)?

Early sociolinguistic studies of singing neglected the impact of the aesthetic requirements of singing (Morrissey, 2008; Gibson & Bell, 2012). How does the form of Western classical choral singing contribute to the sung accent? The 'correct' accent for choral singing has been discussed in choral literature since at least the 1890s, with George Martin writing in *The art of training choir boys* that 'a provincial rustic "burr" must be eliminated' (Martin, 1892, p. 12 in Day, 2018, p. 83). In 1951, American choral director Wynn York wrote:

> What type or standard of pronunciation should be chosen from the many existing varieties as the desirable basis for the singing of a given song, or for singing in general? There are those who recommend the use of the southern British, or stage diction; but admirable as this may be in some respects, it is not in accord with our fundamental postulate, for the American people have clung and continue to cling to their own ways of treating the mother tongue.
>
> If one performs consistently in his home town or state, it would seem desirable as well as most natural for him to develop the dialect of the local region. If he goes on national tours, makes national broadcasts, or records for one of the major companies, it might be of benefit for him to cultivate the general American. (Wynn York, 1951, 'Dialects and English Pronunciation in Singing' in De'Ath, 2019)

It is clear that there are elements of a shared standard choral practice, but also that the choral signal may incorporate regional accent features. The quote from York (1951) above suggests an Audience Design model (Bell, 1984) for selecting the choir accent – that we should tailor the pronunciation based on the context, audience, and type of choir.

This thesis investigates the accent of choirs in commercially-released recordings over time, comparing the pronunciation of choirs from a Southern Standard British English dialect area, Cambridge, and a non-SSBE dialect area, Glasgow. These two areas were selected not just because of their spoken accent differences but also based on the availability of recordings and existing musicological work on choirs. Thus, this thesis examines the recordings of the Choir of King's College, Cambridge (1945–present), and two Glasgow choirs, the Glasgow Orpheus Choir (1925–1951) and the Glasgow Phoenix Choir (1959–present).

1.1 What is an accent?

Wells (1982a, p. 1) defines an accent as ‘a pattern of pronunciation used by a speaker for whom English is the native language or, more generally, by the community or social grouping to which he or she belongs.’ Accents can vary by region, socioeconomic class, gender, age. What would it mean for a choir to have an accent?

1.1.1 Choir accent: Speech

One relevant sociological perspective is to consider choirs as Communities of Practice (COP) (Lave & Wenger, 1991; Wenger, 1999). Communities of practice are ‘groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly’ (Wenger-Trayner & Wenger-Trayner, 2015). COP often exhibit shared linguistic patterns and norms (Eckert, 1989). Choirs typically meet regularly, spend a considerable amount of time together, interact with one another and sing together, often with the aim of improvement (e.g. Bonshor, 2020). It would be unsurprising to find a shared repertoire of stylistic features in the spoken accent of the members of a particular choir. That is, we might expect choir members to have shared accent features, shared lexicon, and shared lore specific to a particular group. In addition to group-specific features, there are shared features common to the wider choir-singing community. If choirs can develop their own speaking styles, what about the accent used for singing?

1.1.2 Choir accent: Singing

Choirs in regional dialect areas may reproduce local vowel and consonant phonology in their singing. Do choirs from different dialect areas sound different? Can we distinguish recordings of one choir from another depending on the distributions of linguistic features? Anecdotally, we can answer in the affirmative. However, Western classical singing training has been reported to have a centralising effect on vowels (Dromey et al., 2011), which could reduce accent differences. In addition, Wilson (2014) posits a Western classical choral style independent of a particular accent or variety. Is there evidence of a shared Western classical choral phonology and/or are there regional differences in choir pronunciation?

1.1.3 Choir accent: Musical performance practice

Both musicology and sociolinguistics have their own conception of ‘style’, but central to both are patterns of shared musical or linguistic features. Coupland

(2007) defines sociolinguistic style as 'ways of speaking'. Meyer defines style as 'a replication of patterning, whether in human behaviour or in the artifacts produced by human behaviour, that results from a series of choices made within some set of constraints' (1996, p. 3). The relationship between style and genre in music is complicated as it is positioned differently in the domains of popular music, and musicology (Moore, 2001). Typically in popular music, genre is considered above style, whereas, in musicology, style is the larger category (Moore, 2001). Moore, however, views genre and style as orthogonal and outlines four ways of distinguishing them; the first of these is most pertinent to the present research:

> …style refers to the manner of articulation of musical gestures and is best considered as imposed on them, rather than intrinsic to them. Genre refers to the identity and the context of those gestures. This distinction may be characterized in terms of 'what' an art work is set out to do (genre) and 'how' it is actualized (style) (Moore, 2001).

These definitions of style and accent complement each other. To say that there are unifying patterns of features is to talk of musical and linguistic varieties. Consequently, it is possible to conceptualise certain types of musical performance practice as an 'accent'.

1.1.4 Choir accent: Change over time

Within musicology, there is work that has investigated tempo, rubato, ornamentation, vibrato, dynamics, and has shown that these variables have changed over time (e.g. Leech-Wilkinson, 2009b). Language varies and changes over time, including in the spoken form of the language. Do recordings of choirs exhibit change over time? If so, in what ways have they changed? What are the musical or stylistic constraints of choral singing? For example, in choral pedagogy, directors are taught to train their singers to avoid prolonging diphthongs at all costs, or rather, to delay movement until the last moment possible to maintain the 'purity' of the vowel colour (Marvin, 1991) which could lead to a reduction of diphthong trajectory.

1.2 The choirs

This thesis investigates (sociolinguistic and musicological) style change and variation in commercially released recordings of the Glasgow Orpheus Choir and the Glasgow Phoenix Choir, and the Choir of King's College, Cambridge. The Glasgow Orpheus Choir was an elite auditioned mixed-voice choral society in the Western classical mixed voices choir tradition (with soprano, alto, tenor, and bass sections), directed by Hugh S. Roberton from its founding as the Toynbee Musical Association in 1901. The choir was refounded as the Orpheus Choir in 1906 and continued operating till 1951. The Orpheus typically sang four-part arrangements of Scottish hymns, psalms, folk songs, and songs from around the world. Fifty-nine tracks were commercially released on a number of Extended Play records and later in compilation albums. Of these, forty-two were available and twenty-five met the criteria for analysis (Criteria for analysis are outlined in Chapter 4 Section 4.3.1).

The Glasgow Phoenix Choir was founded when Hugh S. Roberton retired in 1951, starting with Orpheus singers that wanted to continue singing. The Phoenix has continued singing to the present day. The repertoire of the Phoenix Choir reflected that of the Orpheus, with popular Scottish hymns, and folk-song arrangements. The Phoenix Choir was directed by Peter Mooney (1955–1983), John Cranston (1984–1986), Peter S. Shand (1986–1990), Marilyn J. Smith (1991–2019), and Cameron Murdoch (2019–present). The choir produced 33 albums, of which 28 were available and 129 tracks were selected for analysis.

The Choir of King's College, Cambridge is a collegiate chapel choir comprising boy trebles – who sing the top line instead of adult female soprano singers – and undergraduate male choral scholars who sing the parts of alto, tenor and bass. The choir was established when King's College was founded in 1441, as a liturgical choir, to sing for daily services. The choir's repertoire continues to reflect its primary purpose, with liturgical music at the fore, specialising in early music and contemporary church music. In the twentieth century, the choir was directed by Arthur Henry Mann (1876–1929), Boris Ord (1929–1957), Harold Darke (Boris Ord's substitute during the war 1940–1945), David Willcocks (1957–1974), Philip Ledger (1974–1982), Stephen Cleobury (1982–2019), and most recently, Daniel Hyde (2019–present). Here, I analyse 317 tracks from 50 albums.

1.3 Research questions: Do choirs have accents?

This thesis is primarily concerned with choir accents in singing. I decided to focus on to what extent commercially-released recordings of choirs reflect regional accent features. In this thesis, when I ask 'Do choirs have accents?', I refer specifically to whether choirs in different dialect areas sing differently based on regional dialect features.

1. Is there evidence of regional differences between Glasgow and Cambridge, in the phonology of vowels, rhoticity, and word-final /d/?

2. Is there evidence of a common choral accent uniting Glasgow and Cambridge

in the phonology of vowels, rhoticity, and word-final /d/?

3. What changes have taken place in the phonology of choral singing over time?

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   (b) Are the changes linked with changes in aesthetic coventions of choral singing?

   (c) Are the changes linked with individual properties of the choir directors?

In order to answer these questions, I adopt a Labovian quantitative sociolinguistic approach (Labov, 1978). Chapter 2 outlines similarities in the approaches and findings of sociolinguistics and musicology, outlining some key issues in the framing of pronunciation in singing and choral singing. Chapter 3 reviews existing literature, first outlining theoretical approaches in sociolinguistics relevant to the present research. I then summarise the existing sociolinguistic literature on singing. The final section explores musicological literature on change over time in choral singing. Chapters 5, 6, and 7 present quantitative acoustic analyses of vowel quality. Chapter 8 presents an auditory analysis of rhoticity. Chapter 9 presents an auditory analysis of word-final /d/. Chapter 10 draws these strands together.

Chapter 2

Background

This thesis is concerned with analysing variation and change in recordings of choral singing over time. As will become apparent, choirs are musical, social, and linguistic entities. Consequently, this research combines approaches and insights from sociolinguistics, musicology and singing pedagogy. In this short chapter, I will draw parallels between diachronic analysis from both fields. Sociolinguistics attempts to correlate linguistic practices with social factors such as region, socioeconomic class, gender, sexuality, and age (for an overview see Tagliamonte, 2012). Sociophonetics is a sub-discipline of sociolinguistics which focuses on analysing speech, particularly how social meanings are attached to different ways of speaking (e.g. Kimball et al., 2019). Musicology is the academic study of music, particularly associated with Western classical music history, or notated repertories. In asking, 'Do choirs have accents?', I consider recordings of choirs as musical expressions of identity operating at multiple levels, working within the constraints of vocal production. To approach the primary research question, 'Do choirs have accents?' with any degree of seriousness, we must concurrently consider perspectives from musicology, sociolinguistics, and singing pedagogy.

2.1 Sociolinguistics and musicology

Previous sociolinguistic work on singing tends to neglect singing aesthetic factors (Morrissey, 2008), such as the acoustics of singing, singing mechanisms, or musical factors, such as tempo (speed/sung-speech rate), dynamic (loudness), timbre (sound quality, for example, bright or dark), word-setting (whether a syllable is set to one note or spread over multiple notes), and the impact of artistic direction. On the other hand, musicological work on singing lacks the precise terminology that phonetic analysis can provide, for example, allowing the researcher to differentiate between different consonant and vowel realisations;

often, pronunciation is ignored altogether.

2.1.1 Defining accent and style

How do we define accents in sociolinguistics and musicology? As we have seen, Wells (1982a, p. 1) defines accents as ‘a pattern of pronunciation used by a speaker for whom English is the native language or, more generally, by the community or social grouping to which he or she belongs.’ Wells’s definition evokes synchronic regional variation in style/pronunciation. Another name for regional variants of the same language is dialect. There is a history of dialectology which, as a discipline, seeks to document regional dialects and compare across dialects (see Wells, 1982a). Recently, there have been large-scale mapping projects of regional dialect areas within the UK using quantitative methods. For example, the English Dialects App (EDA) uses crowd-sourced linguistic data to produce a large-scale corpus for mapping dialectal variation within the United Kingdom (Leemann et al., 2018). SPeech Across Dialects of English (SPADE) compares varieties of English across space and time using large-scale corpus phonetic methods (Stuart-Smith et al., 2020). Taking Coupland’s (2007) definition of style as ‘ways of speaking’, accents can also be considered styles. The reason for making this point is that musicological investigations of regional variation in performance practice are analyses of style.

Within ethnomusicology, there have also been cross-cultural comparisons of musical style. one notable, or perhaps notorious, investigation of singing styles is *Cantometrics* (Lomax, 1976). Lomax conducted a cross-cultural comparison of song styles, particularly focusing on the idea of music as a functional reinforcer of social structures. In *Cantometrics*, Lomax quantitatively compares features of songs across 148 cultures using a sample of 10 folk songs per culture. 37 factors were coded by researchers using Likert scales. These included factors relating to vocal performance (ornamentation, blend, tension, dynamics), structure (pitch, rhythm, text, texture, form), and instrumentation (Savage et al., 2012). These features clustered into ten larger regional song styles (Lomax, 1976, pp. 232–236). More controversially, *Cantometrics* also sought to correlate song features and features of the social structure of the culture to which it belongs. Savage (2018) review the main criticisms that were made of *Cantometrics*, which include: sample size (10 songs per culture), sampling method (lack of transparency about how songs were selected), classification scheme (how the factors analysed were coded), statistical analysis (corrections for multiple comparisons), interpretation, and ethnocentrism/reductionism. However, Savage remains sympathetic to Lomax’s vision of ‘a unified humanistic science of the arts’ (Savage, 2018). Most recently, the data from *Cantometrics* has been republished alongside new data as part of the

Global Jukebox as a ‘resource for comparative and cross-cultural study of the performing arts and culture’ (Wood et al., 2022).

This subsection has demonstrated similarities in approaches adopted in sociolinguistics and ethnomusicology for analysing variation in style and accent. In the next section, I will focus more on how both literatures have also explored how accents and styles have changed over time.

2.1.2 Variation and change over time

In both sociolinguistics and musicology, there is evidence that practices change over time. That is, the way people speak – their accent or linguistic style – and the way they perform – their performance practice or musical style – have been shown to evolve. We now have over a century of recorded sound data, and there has been some extensive work done separately in both disciplines (for example, in sociolinguistics Stuart-Smith et al., 2017; in musicology Cook, 2007; Leech-Wilkinson, 2009a). One critical development, therefore, is the possibility of long-term diachronic studies. For example, the Glasgow Sounds of the City project (Stuart-Smith et al., 2017) investigated how Glasgow vernacular English changed over the past century. Similarly, CHARM (Research Centre for the History and Analysis of Recorded Music) investigated changing performance practices in recordings of over a century of music, finding that the musical techniques that carry the function of expressivity have changed over the past century (Leech-Wilkinson, 2009a):

> What is characteristic of particular places and times is particular choices and combinations of elements (habits of timing, dynamics and pitch adjustment); it’s these combinations and interactions that change over time on a broad scale (period style) and from person to person on a smaller scale, from performance to performance on a still smaller scale, and from moment to moment at the musical surface (Leech-Wilkinson, 2009a, par11).

Leech-Wilkinson’s (2009a) description of variation in music has uncanny parallels with our understanding of language, variation and change. For example, Tagliamonte writes that ‘variation is inherent in the individual, the group, the community and beyond’ (2012, p. 21). Both sociolinguistics and musicology note that innovation tends to be introduced by younger people. It is generally accepted within sociolinguistics that speakers are linguistically innovative in their late teenage years, known as the adolescent peak, where ‘the frequency of the incoming form is highest among 15–17-year-olds’ (Tagliamonte, 2012, p. 48). An analogous period of innovation has been found in musical performance among emerging professionals in their early twenties (Leech-Wilkinson, 2009b). In both fields, the development of accent or style is more influenced by peers than by families or teachers.

2.1.3 Choirs as communities of practice (COP)

Speech communities and musical communities are groups of people that meet regularly and work towards a shared goal forming Communities of Practice (Lave & Wenger, 1991; Wenger, 1999). Lave & Wenger (1991) described how newcomers to a community transition from legitimate peripheral participation to full membership of a community through social learning within a COP. That is, they learn how to be a member of the COP through interacting with existing members. This process of situated learning has been explored in both sociolinguistics and musicology. COP often develop their own shared identities and linguistic practices (Eckert, 1989). As choirs are musical, social, and linguistic entities, and both the shared goal and the means of communication require expert use of the vocal tract, choirs are ideal for examining COP at work. Indeed, COP may also serve a function in musical variation and change. Bonshor (2020) finds that 'effective peer learning, in a supportive choral environment, can assist task mastery, improve performance and consequently develop higher levels of perceived self-efficacy'.

2.1.4 Impact of linguistic background on musical style

Crucially, there is evidence that the non-linguistic musical signal can be influenced by linguistic background; for example, the impact of first language on tongue position in trombonists investigated using ultra-sound tongue imaging (Heyne, 2016). If first language background can affect tongue position in trombonists, why not in singing? There is plenty of commentary in Western classical singing pedagogical literature on the impact of first language background; for example, English and German native speakers are cautioned when singing Italian monophthongs, not to use their native diphthongal qualities (Emmons & Chase, 2006; Adams, 2008; Johnston, 2016); English speakers are cautioned when producing the stop voicing distinction in French *chansons* (Néron, 2017). However, there is curiously little sociolinguistic literature about the impact of the first language background of a singer. Perhaps, this is due to sociolinguistic studies of singing focusing mostly on popular singing – an environment where singers are likely to sing in their first language, or the language deemed most appropriate for the genre. Beal (2009) investigates local features compared to the American popular norms in Arctic Monkeys. Krause & Smith (2017) investigate local variants of /r/ in the singing of two Glasgow indie artists. Yang (2018) investigates accent mixing in the singing of Lenka, and Westphal & Jansen (2021) investigates stylistic factors in the singing of Rhianna, which includes the Caribbean features of her own accent. However, these studies tend to consider the inclusion of local features in performance as a conscious aesthetic act. As sociolinguistic studies have largely focussed on popular singing in English, the impact of a singer's first language on the sung signal has largely gone unexplored.

2.1.5 Impact of recordings

As disciplines, musicology and linguistics took time to view performances and conversation, and later recordings of each, as objects worthy of study (Labov, 1978; Leech-Wilkinson, 2009a). The ability to make audio recordings revolutionised both fields; it allowed the ephemeral phenomena of speech and musical performance to be nailed down and inspected. The advent of recording led to the development of empirical acoustic methods.

While the ability to record has positively impacted methodologies of both sociophonetics and musicology, recording itself has also been reported to affect how we perform music and speak. The recording studio setting can elicit a more formal speech style from participants, which can be unhelpful for linguists trying to study the vernacular – how people typically speak (Labov, 1978, p. 190). Likewise, musicians recording for CD recordings have been observed adapting their style compared to live performances. For example, Day (2000) writes that:

> …some conductors have deliberately tried to 'restrain' the musicians they work with in the recording studio, not simply because accuracy is so important, but because 'wild risks' or 'a fantastic cadenza', which would come off and elicit cheers in a live performance, nearly always pall, in their opinion, on repeated hearings. And one record producer was sure that performers do make subtle changes to their performing styles which happen 'automatically' (Day, 2000, pp. 53–54).

Day (2000) also notes that expressivity has changed over time, inside and outside the recording studio: 'the music performed at the end of the century is a much more literal realisation of the notes on the page' Day (2000, p. 143). Change in the performance of expressivity in classical music was explored more fully in Leech-Wilkinson (2009a). Thus far, I have established similarities in the methods, data, and findings of variation and change in sociolinguistics and musicology. This research focuses on singing, specifically recordings of Western classical choral singing.

2.2 Singing and choral singing

This thesis adopts sociophonetic methods and applies them to choral singing data. Sociophonetics is the correlation of phonetic data and social categories. Phonetics is the systematic study of speech sounds (Catford, 2002; Ladefoged, 1967). *Speech sounds* are any sounds produced using the vocal tract. The vocal tract is typically conceptualised as the stretch from the larynx to the lips, but may also include the lungs (Catford, 2002).

2.2.1 What is singing?

Pinning down what singing is, or is not, is non-trivial (Potter & Sorrell, 2012). The *Oxford English Dictionary* defines the verb to sing as 'to articulate or utter words or sounds in succession with musical inflections or modulations of the voice, so as to produce an effect entirely different from that of ordinary speech; *spec.* to do this in a skilled manner, as the result of training and practice' (OED Online, 2023). This entry has not been revised in the last century or so, but the clunkiness of the entry gives an indication of the difficulty of defining exactly what singing is. I also take issue with 'so as to produce an effect entirely different to that of ordinary speech'. Where do *Sprechgesang* or rap fit into this definition? More technically, Laurence Picken defines singing as the systematic variation of the fundamental frequency produced by phonation of the larynx: 'song is nothing else' (Fletcher, 2001). This definition also seems somewhat reductive. Overtone singing keeps the fundamental frequency constant and varies the overtones; is this singing? Turning to the phonetic analysis of singing, Sundberg tells us that *sung sounds* can be 'regarded as more or less modified speech sounds' (Sundberg, 1987, p. 1).

2.2.2 What is choral singing?

> …music and language have a primary function of shared activity and means of reaching out to other human beings, expressing trust and support. Group music-making helps to create empathy: if everyone sings the same thing in a way they cease to be individuals, and momentarily losing the sense of self can be deeply therapeutic (or socially and politically problematic) (Potter & Sorrell, 2012, p. 19).

This research is not only interested in singing but specifically choral singing. Broad definitions of choral singing could include any form of collective singing, with multiple people singing together. Why is choral singing of interest to sociolinguists? Wilson writes that 'in choral music language use is at least as important as the music itself' (2014, p. 254). And, as seen in the quote from Potter & Sorrell (2012), in choral singing, people can enter flow states. Flow states are when people become fully immersed in a feeling of focus (Csikszentmihalyi, 2008). Flow states have been reported to improve experiences in music (Örjan de Manzano et al., 2010), and choral singing (Garnett, 2017; Slimings, 2022). This is one of the ways that choral singing has been found to be beneficial for the health and well-being of the singers. In a survey of choral singers from England, participation in choral singing was found to improve mental health (Clift et al., 2010). Boyd (2021) reports the benefits of communal singing for people living with respiratory illness and how a singing-for-breathing group allows participants to renegotiate their relationship with their voice and breath in a non-clinical setting.

Choral singing, in the broad sense outlined above, is not restricted to a particular genre of music. Recently, for example, there has been an explosion in the popularity of Rock Choir in the UK, which now boasts over 30,000 members and 80 Rock Choir leaders across the UK (Rock Choir, 2023). This thesis will focus on a specific branch of choral singing: the Western classical choral tradition. One of the reasons for focusing on classical choral singing is that there are recordings of pre-eminent choirs and choral societies singing from the 1920s to the present day. The genre of singing needs to be constrained, as far as possible, as it is thought to have an impact on pronunciation.

2.2.3 Definitions

For the purpose of this thesis, a choir is a group of singers that meet regularly and sing together. Note that this definition includes professional and amateur groups. The term 'choral' as a form refers to the singing of choirs, but 'choral' as a style also carries with it the connotations of the history of Western church music, classical repertoire, notions relating to blend, and ideologies about 'correct' ways of singing. Due to these connotations, I try to avoid using the term choral as much as possible. I typically use the term 'Western classical choral singing', which, for the purposes of this research, refers to the repertoire typically sung by classical choirs in the Western musical tradition. Classical refers to both a style of singing and a style of repertoire which typically co-occur. The repertoire of classical choirs often includes sacred music, such as church music (hymns, psalms, anthems, which each serve a liturgical purpose) and oratorio (biblical stories set to music, typically in epic form); secular music, such as folk song arrangements, part-songs (settings of secular texts e.g. poetry). The classical repertoire generally excludes popular music forms such as pop, rock, punk, rap, heavy metal and indie, however, this is not always the case, with more recent arrangements of popular songs in a classical style.

The choirs examined in this study would perhaps be better described as 'para-classical'. King's has a primary religious and liturgical function which is prioritised over a 'classical' aesthetic. The Glasgow choirs adopt a sort of classical ethos, but apply it to a repertory and identity that is self-consciously Scottish, bringing its own marks of excellence. A truly 'classical' choir might be one that regularly sings with orchestras in classical repertory, and in concert halls, or one which is so expert that it can cover several forms of prestigious music (e.g. the BBC Singers). Although Phoenix and King's are very different, they both rely on 'classical' prestige in a way, but can also serve quite 'non-classical' purposes. However, for the purposes of this thesis, I will use the term 'Western classical choral singing' to refer to the singing of the choirs investigated in this study.

2.2.4 Singing as we speak – or singing as somebody speaks

There is a tension between styles with the notion of 'singing as we speak', as in the idea of authenticity and speech variants used in indie music (Beal, 2009; Krause & Smith, 2017) and 'singing the sung (non-speech) accent' (Trudgill, 1983; Emmons & Chase, 2006; Wilson, 2014) appropriate for the 'reference style' (Morrissey, 2008). Exemplifying this debate in choral singing, there is debate in the choral literature about whether to articulate American /r/ in choral singing. For example, some authors argue that in order to sound like American choral singing (rather than British), a touch of American /r/ is required (Decker, 1977), while others say American /r/ should be reduced or avoided as much as possible apart from in specific repertoire (Emmons & Chase, 2006).

This is related to a wider debate within singing pedagogy itself extending to singing in your natural voice, for example, the Natural Voice Network (2023) and Estill Voice Training (2023) contrasting with Western classical training. Natural Voice Network (2023) argue that 'singing is everybody's birthright':

> For thousands of years all over the world people have sung – to express joy, celebration and grief, to aid healing, to accompany work, devotion and the rituals of life – without worrying about having a 'good' voice or 'getting it right'. Singing has been a part of life, a way of binding communities.
>
> Creating an accepting community is an essential element of our approach: a community where singing together is a natural experience that is open and accessible to all.

In contrast, Potter & Sorrell write that 'there is no such thing as a "natural voice" – or, rather, a natural voice is what is natural to the singer producing it and how that singer's culture perceives it' (2012, p. 26).

I have experienced both of these ideologies at work in the choral rehearsal. At the crux of it are two tensions – whether to prioritise the intelligibility of text or singability (for example, altering vowel quality to make a word easier to sing) –

and whether to prioritise individual vocal identity or group blend. Textual primacy became its own aesthetic at King's under Ord and Willcocks (Potter, 1998, p. 117). The point of this digression is the draw attention to this debate (whether we sing as we speak), as it is particularly relevant to vowel and consonant realisation, and central to this project as it rests on the idea that regional spoken variation can be audibly detected in the choral signal.

Sociolinguists have also entered this debate. The earliest sociolinguistic study of singing, Trudgill (1983), found that British singers of popular music avoided using features of their spoken accents in singing. Rather, they were approximating a set of features that are stereotypes of American accents. Morrissey writes that 'it is a truism that singing is not speaking and that singing style and speaking style are therefore subject to different parameters' (Morrissey, 2008, p. 213). Of popular singing, Gibson & Bell (2012) write:

> If successfully performed, 'own accent singing' may index sincerity and authenticity, but if the accent is perceived as contrived it will attract a negative response. Singers must therefore negotiate a path between imitation and innovation in order to be both accessible and distinctive. They do this through their music, their image, the way they move, and the pronunciation they use when they sing (Gibson & Bell, 2012).

Of classical choral singing, in *Prescriptions for Choral Excellence*, Emmons & Chase (2006) write:

> Many of the troubles that plague choral directors in the area of diction and intelligibility are caused by the honest conviction that their choristers should sing as they talk. Aside from the fact that this is anatomically impossible, there remain each singer's problems with regional accents and bad language habits in spoken English, which would probably yield a diction that is, in any case, neither uniform nor clear (Emmons & Chase, 2006, p. 60).

From Emmons & Chase's quote above, we can see that there are singing ideologies and prescriptive language ideologies at play. Wilson (2014) investigates language ideologies at work in choral rehearsals in Trinidad, finding that while singers and choir directors privilege 'British' accent features in singing, there is also evidence of a non-regional classical choral style. Wilson identifies some of the features of the neutral classical singing style, for example, the rounding of FLEECE and FACE vowels, and devoicing of word-final /d/ (Wilson, 2014, pp. 117–8).

2.2.5 'Standard' language ideology

In sociolinguistics, there is the concept of standard language ideology where at a simplistic level, vernacular forms contrast with standard forms (for example, *walkin'* versus *walking*). Standard language ideologies are generally held because standard varieties have been accepted and codified. Milroy defines language ideologies as 'thoroughly naturalised sets of beliefs about language intersubjectively held by members of speech communities' (Milroy, 2004, p. 162). However, 'since there is no neutral reference point and no neutral way of reacting to and analyzing language variation, scholars imbue their sociolinguistic analyses with unintended ideological significance when they focus on the characteristics of some variety by comparing it with a supposedly neutral standard' (Milroy, 2004, p. 165).

In singing, there is also a tension between standard and vernacular forms of language. However, we must also consider idealised 'singing forms'. Ophaug (2017) suggests a 'tug-of-war' hypothesis, such that: 'A good singer strives to maintain a vowel quality as true (natural) to the spoken quality as possible and will abandon this goal only when musical demands are in conflict with it.' Choral singers and conductors must be sensitive to these competing ideologies. For example, a particularly salient item produced every week as part of sung Choral Evensong in Anglican churches worldwide is the phrase 'deliver us from evil' in the preces and responses. The realisation of the word *evil* is particularly complex. The standard spoken form is [iːvɫ]. Singing aesthetic factors dictate that the final syllable cannot be realised as syllabic-l as in [iːvɫ], nor can it be realised with the central unstressed vowel [iːvəɫ], which is typical for both standard and vernacular speech. The accepted sung forms tend to adapt the vowel quality to [iːvil] or [iːvɪl], but these can be perceived as 'affected'.

The present research asks whether a Western classical choral style, perhaps based on Southern Standard British English, posited by Wilson (2014) coexists with local, regional variation. Indeed, I would expect the classical choral style to be different in the UK, US, or Trinidad, though there will be many shared features. For example, anecdotally, the distribution of the TRAP–BATH distinction (BATH = PALM) in US and UK classical choral singing is different (for example, *path*, is realised /pæθ/ by US choirs, but typically /pɑːθ/ by UK choirs). Also the lexical distribution of the LOT–BATH distinction differs between Received Pronunciation and General American English speech (e.g. Wells, 1982a), and also in singing (LaBouff, 2008, p. 57). This may indicate that if there is a Western classical choral standard accent, it may be locally influenced by national accents, and/or there are regional variations of a shared wider classical sung phonology. Future work is needed to unpick these possibilities, but it will come some way to exploring the regional variation of choral singing within the UK.

This thesis will adopt a descriptivist approach to analysing variation in pronunciation of choral singing. This means I will outline what is going on without attaching judgement. That being said, choral singing is an art form, and therefore it is prescriptive – that is, some sung sounds are considered inherently more aesthetically pleasing than others; for example, sung monophthongal qualities are preferred, with diphthongs temporally reduced in comparison, in classical choral singing (e.g. Marvin, 1991). This is one of the reasons Italian is often the preferred language for singing in Western classical singing due to the 'pure' vowel quality of Italian, compared to Germanic languages like English and German, which have more diphthongs and 'mixed vowels' (Emmons & Chase, 2006, p. 64). Much of the singing literature is based on an improvement narrative – choir directors want to know how to make their choir sound as good as possible (for example, Crowther, 2003; Emmons & Chase, 2006; Hollins & Vango, 2022) – or to make individual singers produce their best (for example, LaBouff, 2008; Adams, 2008; Johnston, 2016). The philosophical positions of descriptivism and prescriptivism are not entirely irreconcilable, and, as far as possible, I present an unbiased description of choral accents whilst also considering the aesthetic aspects of singing.

In this short background section, I have motivated the interdisciplinary study of choral sound, drawing on insights from sociolinguistics, musicology and singing pedagogy. I have briefly introduced singing and choral singing, and the notion of language attitudes relating to singing. In the following chapter (Chapter 3), I will review the relevant existing literature in sociolinguistics, musicology and singing pedagogy.

Chapter 3

Literature Review

An earlier version of some of the sections of this chapter will appear in Marshall et al. (2024).

In Chapter 1, I outlined why the present research questions require an interdisciplinary perspective incorporating aspects of sociolinguistics and musicology. I outlined how linguists define accents and the multiple ways choirs could be considered to have accents. I finished by saying that this study primarily concerns the 'sung accent'. That is, can the overall choir sound during singing be considered to have an accent? In Chapter 2, I brought together some of the themes that emerged from both literatures, comparing variationist approaches to spoken accent and musical style. I raised the issue of competing ideologies relating to 'singing as we speak' and the standard language ideology that tends to permeate singing pedagogical literature. In the present literature review chapter, I outline the variationist sociolinguistic approach to language. Then, I give an overview of sociolinguistic studies of singing and the sociolinguistic theories that have been applied to singing. Following this, I outline Western classical singing and choral literature and existing musicological studies of choral singing. I conclude by drawing together these strands.

3.1 Variationist sociolinguistics

Linguistics seeks to describe languages and relationships between languages, but until recently, it has not been concerned with language in use – or language in its social context. Sociolinguistics is a branch of linguistics that takes language and places it back in its social context rooted in the idea that 'one cannot understand the development of a language change apart from the social life of the community in which it occurs' (Labov, 1978, p. 3). Two main strands of sociolinguistics developed in the 1960s and 1970s: variationist sociolinguistics which focuses on language in its social context (e.g. Labov, 1966), and ethnography of communication which is a social interpretation of language (for example, Hymes, 1986). The two approaches differ in focus. That is, variationist sociolinguistics is more focused on language, whereas the interactional approach focuses on society. At a simplistic level, the variationist approach is quantitative, whereas the interactionist approach is qualitative and ethnographic in nature.

Variationist sociolinguistics is inherently statistical and correlational – a particular way of looking at language and society that assumes that we can chunk up language and society and that we can learn more about both by correlating these chunks and make inferences based on these correlations. In this study, I identify quantifiable aspects of choral singing, which are then correlated with other quantifiable aspects of the choir, for example, dialect area, choir director, and the year a recording was made.

In this section, I give an overview of the core concepts that underpin variationist sociolinguistic approaches. Variationist sociolinguistics, also known as Labovian sociolinguistics, is a quantitative approach to language variation. The first tenets of quantitative sociolinguistics were outlined in Labov (1966). In *The social stratification of English in New York City*, Labov defines the linguistic variable as a linguistic unit with two or more variants that covary with other linguistic and/or social variables. As in Labov (1966), in New York City, the (-ing) variable has two variants /ŋ/ and /n/, for example, *walking* versus *walkin'*. Labov finds that the variants are correlated with the socioeconomic class of the speakers and the amount of attention the speakers paid to their speech. /ŋ/ and /n/ are different in social and stylistic terms, but linguistically, they are essentially different ways of 'saying the same thing'. Linguistic variables can exist at any level of language, from high-level discourse, lexis, and syntax, to phonology and phonetic variation. This thesis is sociophonetic, meaning that I am investigating how the pronunciation of the choirs varies.

The principle of accountability states that we must report values for every context where the variable occurs. The researcher must 'specify where the variable occurs and where it does not' (Weiner & Labov, 1983, p. 36). In the case of (-ing), we must identify all sites where [in] could occur. For example, in the second half of the analysis of Chapter 8, I investigate the variable *postvocalic /r/*. Postvocalic /r/ means all instances of /r/ following a vowel, for example, *car*, *appear*, *father*. Limiting the focus to /r/ in these contexts allows us to hone in on variation. /r/ in prevocalic contexts (for example, *red*, *ridiculous*, *rafter*) in English is invariant, meaning that, while the phonetic realisation may differ, /r/ is almost always articulated in these contexts. In contrast, postvocalic /r/ may be articulated in some varieties, such as Standard Scottish English or General American English, or may be deleted altogether in some varieties, such as Southern Standard British English.

The researcher then needs to 'define as many phonetic variants as we can reasonably distinguish' (Labov, 1978, p. 71). Returning to the /r/ example, in the data reported in this thesis, postvocalic /r/ could be phonetically realised as an alveolar approximant [ɹ]; alveolar tap [ɾ]; alveolar trill [r]; or no audible /r/ [∅]. When we have defined the phonetic variants, we locate every instance where the variable occurs in the context we previously defined, for example, all tokens of postvocalic /r/. We then report what phonetic variant is produced for each instance of postvocalic /r/. Doing so allows us to investigate, in a principled way, how linguistic variation can be related to social factors. What we have discussed so far is restricted to linguistic variables. Labov (1978) defines the sociolinguistic variable as one that is 'correlated with some nonlinguistic variable of the social context: of the speaker, the addressee, the audience, the setting…' (Labov, 1978, p. 237).

Previous sociolinguistic research on language ideologies in choirs in Trinidad used a predominantly qualitative approach and gathered rich data from surveys, interviews and observation, and notes the difficulties of using an acoustic method with choir recordings (Wilson, 2014, p. 94). Wilson also noted that previous work on singing tended to work with the published artefact, commercially released recordings, rather than investigating meaning being made in situ (Wilson, 2014).

As this thesis was embarked upon just prior to the pandemic, at first, I decided to expand my planned pilot study of acoustic analysis of commercially released recordings. I continued to pursue analysing this pre-recorded data in more depth. As a consequence, one of the areas that this study lacks answers to is the relative salience of these variables: which variables are more important to singers, choir directors, and audience members. Existing work suggests audiences are more sensitive to consonant variables than vowel quality; Wilson (2014) quotes Bell (1992) writing:

> "the consonants do much more than their share of the work", perhaps due to the relative "difficulty of achieving native-like control of an alien vowel system" (Wilson, 2014).

Wilson (2014) also finds that audiences attend mostly to 'British-like' consonants:

> …singers targeting a British accent may be perceived as achieving their target, or at least of singing with standard pronunciations, without ever making use of an SBE vowel, so long as they use the consonants that are considered to be British (Wilson, 2014, p. 329).

However, I would caution against applying this directly to British perceptions of British choral singing. As we have seen, auditory analysis of musicologists has detected a salient change in vowel quality in the recordings of King's under David Willcocks, as Day writes: 'so alleluia became *e-lleluia*. I know thett my Redeemer liveth ent thett he shell stent…' (Day, 2018, p. 261).

3.1.1 Spoken varieties that may influence choral singing in this sample

In order to answer research questions (Section 1.3) 1 and 2 relating to dialectology, I lay out the varieties explored in this thesis. Here, I focus on four spoken varieties of English which may impact the sung choral signal: Received Pronunciation (RP), Standard Southern British English (SSBE), Morningside/Kelvinside accent (M/K), and Standard Scottish English (SSE).

England: Received Pronunciation and Southern Standard British English

Received Pronunciation (RP) is the speech of upper-class educated elites in the first half of the twentieth century, aligning with the speech of the aristocracy and the monarchy – the enduring spectres of the dowager duchess or public school boy. There are different shades of RP. Wells writes that 'drawing a line between RP and Near-RP is in many ways a subjective and contentious task' (Wells, 1982a, p. 297). For the purposes of this research, I treat RP as monolithic, and tend to base my predictions on mainstream–conservative RP norms.

Standard Southern British English (SSBE) is the more-recently established accent of middle-class speakers of English from the South of England which is similar to RP but omits some of the indentifying features of conservative RP. For example, both accents show evidence of BATH broadening and both have separate TRAP–BATH lexical sets. However, for conservative RP, we would expect TRAP /a/ to be more raised (closer to [æ] or [ɛæ] in realisation) than [a].

Scotland: Morningside/Kelvinside and Scottish Standard English

In Scotland, there existed earlier in the twentieth century the Morningside/Kelvinside (M/K) accent which was a upper-middle-class accent associated with those regions of Edinburgh and Glasgow respectively. Johnston compares M/K to conservative RP accents, writing

> It thus appears to be a compromise between elocuted Hyper-RP and Scots vernaculars, just as what one might call mainstream SSE is (at least historically) between middle-class RP and Scots. It is tempting to conclude that M/K, like all other types of SSE is also founded on a historical compromise with RP, the only difference being that the English input is, in fact, not RP at all, but Hyper-RP of some type (Johnston, 1985, p. 40).

Scottish Standard English (SSE) is the present accent of middle-class speakers of Scottish English.

3.1.2 Relationship between RP–SSBE and M/K–SSE

In *English After RP*, Lindsey describes how 'contemporary standard British speech differs from the British upper class accent of the last century, Received Pronunciation (RP)' (2019, p. vii). He goes on to say that '…the kinds of speaker who constitute today's pronunciation models are different in social terms from the typical speakers of RP, and the sound of their speech is different, too.' This suggests a model where the standard form of Southern British English has shifted from Received Pronunciation to a new standard over the past century as shown in Table 3.1.

Table 3.1: Change over time in spoken standard British accents A

Time	English model	Scottish model
1900–1959	Received Pronunciation	Morningside/Kelvinside accent
—	↓	↓
1960–present	Southern Standard British English	Scottish Standard English

However, it is also conceivable that RP and SSBE varieties co-existed earlier in the twentieth century, as Johnston suggests above for M/K and SSE. However, the 'target accent' in choral singing has shifted from conservative RP to SSBE in England, and from M/K to SSE in Scotland. This possible world is described in Table 3.2. That is, the English choral model has shifted from an RP speech target to an SSBE speech target, but allowing both accents to co-exist in the earlier time period. For the Scottish model the target accent has shifted from a Kelvinside/Morningside accent to SSE, but again acknowledging that SSE may have existed, in a different guise, earlier in the twentieth century. It might also be possible to consider a continuum to exist between these accents, RP–SSBE and M/K–SSE, where there are shared features between them.

I think it is likely that RP and SSBE, or its precursor, coexisted earlier in the twentieth century. In practice, however, it would be too difficult to distinguish

Table 3.2: Change over time in spoken standard British accents B

Time	English model		Scottish model	
1900–1959	**RP**	SSBE	**M/K**	SSE
—	↓		↓	
1960–present	RP?	**SSBE**	M/K	**SSE**

these models from one another in the data presented in this thesis. So, for the purposes of this thesis, I follow Lindsey (2019) and assume that Received Pronunciation is an earlier form of 'the standard accent' that later becomes SSBE (as in Table 3.1).

3.1.3 Vowel systems

Chapters 5–7 investigate the realisation of vowel quality in recordings of the Glasgow Orpheus and Phoenix choirs and the Choir of King's College, Cambridge. What would the choral vowel space look like if it was based on any of these spoken varieties?

Table 3.3: Phonology and realisations of Received Pronunciation, Southern Standard British English, Morningside/Kelvinside accent, and Standard Scottish English monophthongs, based on Wells (1982b), Cruttenden (2014), Abercrombie (1979) and Johnston (1985).

<table>
<tr><th></th><th colspan="2">English model</th><th colspan="2">Scottish model</th></tr>
<tr><th>Lexical set</th><th>RP</th><th>SSBE</th><th>M/K</th><th>SSE</th></tr>
<tr><td>FLEECE</td><td>i</td><td>i</td><td>i</td><td>i</td></tr>
<tr><td>KIT</td><td>ɪ</td><td>ɪ</td><td>ɪ̝</td><td>ɪ</td></tr>
<tr><td>DRESS</td><td>e</td><td>ɛ</td><td>e</td><td>ɛ</td></tr>
<tr><td>TRAP</td><td>æ or ɛæ</td><td>a</td><td>ɛ</td><td rowspan="2">a</td></tr>
<tr><td>BATH</td><td>ɑ̠</td><td>ɑ</td><td>ɛ or a</td></tr>
<tr><td>STRUT</td><td>ʌ̠</td><td>ʌ</td><td>ɛ̈ or ɛ</td><td>ʌ</td></tr>
<tr><td>LOT</td><td>ɒ or ɔ</td><td>ɒ</td><td>ʌ</td><td rowspan="2">ɔ</td></tr>
<tr><td>THOUGHT</td><td>ɔ</td><td>ɔ</td><td>ɒ</td></tr>
<tr><td>FOOT</td><td>ʊ</td><td>ʊ</td><td rowspan="2">u̟̝</td><td rowspan="2">ÿ</td></tr>
<tr><td>GOOSE</td><td>u</td><td>ʉ</td></tr>
</table>

As shown in Table 3.3, I do not predict many differences in vowel phonology for the lexical sets FLEECE or KIT, though KIT may be higher for the earlier time period in Scotland if the target accent is M/K. Wells writes that 'the height and degree of centralization of /ɪ/ and /e/ vary. Relatively close and peripheral qualities associated particularly, but not exclusively, with old-fashioned RP; relatively open and central qualities are common with younger speakers' (Wells, 1982a, p. 291).

For DRESS, conservative RP typically had a more raised realisation akin to [e]. RP TRAP may be realised as [æ] or [ɛæ], in contrast to SSBE and SSE which have [a]. However, Wells notes that 'the pharyngeal strictures associated with the traditional RP [æ] – something which many phoneticians have commented on – does impair voice projection. Teachers of singing, too, have taught [a] as the correct quality for sung /æ/; here there may be Italian influence reinforcing the other considerations' (Wells, 1982a, p. 292). Thus, if /a/ was to be found at an earlier time in Cambridge, this may be a possible explanation.

One of the phonological contrasts which will be made much of in this thesis is that most speakers of Scottish Englishes, M/K or SSE speakers typically do not distinguish between the lexical sets TRAP–BATH, although some do (Abercrombie, 1979), whereas all speakers of SSBE and RP will distinguish TRAP–BATH, albeit with different heights for TRAP.

Similarly for the phonological contrast LOT–THOUGHT, there is typically no contrast in SSE with both lexical sets taking [ɔː], whereas M/K, RP and SSBE usually differentiate the sets. Conservative RP may have [ɔː] as a variant of the LOT vowel, meaning that LOT is very high and back.

The change in vowel quality over time from RP to SSBE is visualised in Figure 3.1. The starting position of each arrow is the predicted vowel quality of RP; the end point of the arrow is the quality in SSBE.

3.1.4 Vowel duration

In terms of vowel quantity, or duration, for the purposes of this research, I assume that RP and SSBE are similar in distribution. Though, Wells (1982a, p. 299) describes a tendency for 'allophonic lengthening of short vowels when intonationally prominent' being a feature of SSBE.

M/K and SSE, however, behave differently. The Scottish Vowel Length Rule (SVLR) shows that a set of vowels phonologically lengthen when followed by /r/, voiced fricatives /v, z, ð, ʒ/, or morpheme boundaries (Aitken, 1984). Of the monophthongs explored in this research, FLEECE, DRESS, TRAP, THOUGHT, and GOOSE follow the SVLR. This means that we would expect the vowels to be short in other contexts, and long in the lengthening contexts mentioned above. For example, in FLEECE vowel in *fleas* /fliz/ [fliːz] would be long, but short for *fleece*

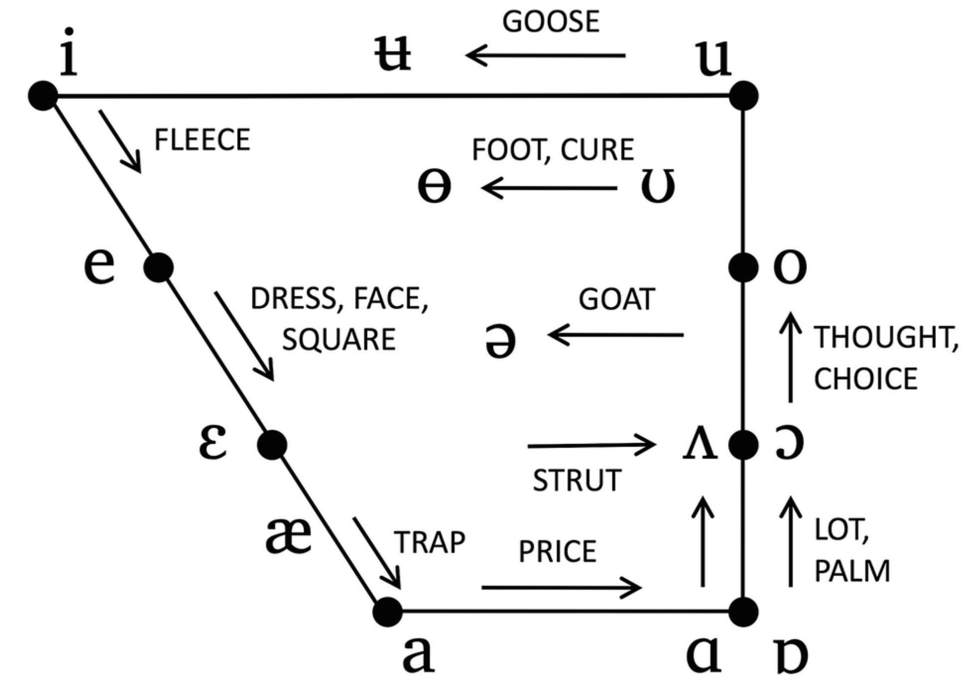


Figure 3.1: The anti-clockwise vowel shift of RP–SSBE over the twentieth century (Figure 4.1 from Lindsey, 2019)

/flis/ [flis]. However, as duration is at least partly specified by the music, do recordings of Scottish songs show evidence of the SVLR present in the sung signal?

3.1.5 Consonant systems

Chapter 8 investigates the realisation of orthographic ‘r’ in choral singing.

Table 3.4: Phonology and realisations of /r/ in Received Pronunciation, Southern Standard British English and Standard Scottish English

<table>
<tr><td>/r/ contexts</td><td>RP</td><td>SSBE</td><td>M/K & SSE</td></tr>
<tr><td>initial /r/ e.g., ring, three</td><td>/r/ = [ɹ, ɾ]</td><td>/r/ = [ɹ]</td><td rowspan="6">/r/ = [ɹ, ɻ, ɾ, r]</td></tr>
<tr><td>intervocalic /r/ e.g. very</td><td>/r/ = [ɹ, ɾ, ∅]</td><td>/r/ = [ɹ]</td></tr>
<tr><td>postvocalic pre-pausal /r/ e.g. car#</td><td colspan="2">/∅/</td></tr>
<tr><td>postvocalic linking /r/ e.g. car and</td><td>/r/</td><td>/r/ or /∅/</td></tr>
<tr><td>postvocalic pre-consonantal e.g. car could</td><td colspan="2">/∅/</td></tr>
<tr><td>postvocalic pre-consonantal e.g. card</td><td colspan="2">/∅/</td></tr>
</table>

As shown in Table 3.4, initial /r/ is categorically articulated across all speech varieties, however, the phonetic realisation of /r/ may vary in all contexts. Conservative RP may produce tapped variants of /r/ in intervocalic position e.g. *very* [vɛɾɪ], or initially when following a dental fricative, e.g. *three* [θɾiː] rather than [θɹiː]. /r/ can also be elided in intervocalic position e.g. [vɛ.ɪ] (Wells, 1982a).

In native-speaker RP it is usual to use sandhi /r/ in the appropriate

> places, in the environments where it is 'intrusive' (unhistorical, not corresponding to spelling) just as in those where it is not. But the speech-conscious tend to regard intrusive /r/ as incorrect, and hence attempt to avoid it…the typical outcome is the suppression of most sandhi /r/s. Thus we may expect to find sandhi /r/ used freely in mainstream (native) RP, but sparsely in speech-conscious adoptive RP (Wells, 1982a, pp. 284–285).

3.1.6 Phonology and realisation of final voiced stops

SSBE is more likely to have 'frequent voiced or glottal realisations of /t/, as [ˈbrɪrɪʃ] *British*, [geʔ ˈʌp] *get up*. Occasional T Voicing, and Glottalling in certain preconsonantal environments, are found in RP; extensive intervocalic T Voicing and prevocalic Glottaling are not' (Wells, 1982a, p. 299).

According to Wells, the degree of aspiration in SSBE is higher than that of RP for all voiceless plosives across place of articulation. Affrication can be found in all positions, and even in voiced plosives, particularly /d/ (Wells, 1982a, p. 323). In SSE, the place of articulation of /t, d/ may be alveolar or dental (Wells, 1982a, p. 409).

In sum, there are no predicted phonological differences based on accent (RP, SSBE, M/K, SSE). Phonetic differences might include greater aspiration for SSBE voiceless consonants compared to RP and SSE. Affrication of /d/ is possible in SSBE, but not RP.

3.2 Genre, register, style, accent

This section considers sociolinguistic notions of style and how they may apply to choral singing. Choral singing can be considered both a form and a genre subject to sociolinguistic stylistic constraints. Before I outline sociolinguistic treatments of stylistic variation in singing, I will outline first some key terms: genre, style, accent, and register – how these are defined in sociolinguistics – and what it means to apply these constructs to choral singing. Here, I borrow a set of terms from sociolinguistic approaches to text corpora:

> We regard genre, register, and style as different approaches or perspectives for analyzing text varieties, and not as different kinds of texts or different varieties. In fact, the same texts can be analyzed from register, genre, and style perspectives…As shown in Table 1.1, the three perspectives differ in four major ways, with respect to: (1) the "texts" considered for the analysis, (2) the linguistic characteristics considered for the analysis, (3) the distribution of those linguistic

characteristics, and (4) the interpretation of linguistic differences. (Biber & Conrad, 2019)

Table 3.5: Defining Characteristics of Registers, Genres, and Styles, from Biber & Conrad (2019)

Defining characteristic	Register	Genre	Style
textual focus	sample of text excerpts	complete texts	sample of text excerpts
linguistic characteristics	any lexico-grammatical feature	specialized expressions, rhetorical organization, formatting	any lexico-grammatical feature
distribution of linguistic characteristics	frequent and pervasive in texts from the variety	usually once-occurring in the text, in a particular place in the text	frequent and pervasive in texts from the variety
interpretation	features serve important communicative functions in the register	features are conventionally associated with the genre: the expected format, but often not functional	features are not directly functional; they are preferred because they are aesthetically valued

Biber & Conrad (2019) are writing about sociolinguistic analyses of text-based corpora. Typically in speech data we refer to registers and styles, however in the data analysed here, genre is more relevant as I am analysing recordings of choral singing. For the purposes of this thesis, *genre* operates at the level of the complete musical work, for example, whether a piece of music is Classical or Popular – and whether the piece co-opts the prestige associated with those 'reference styles' (Morrissey, 2008). Specific accents may be associated with a particular genre, but accent may also vary within a genre (see variationist sociolinguistic research in popular singing, e.g. Krause & Smith, 2017).

An *accent* is the spoken form of a dialect. The accent of singing is therefore tied to a spoken variety (e.g., here RP, SSBE, M/K, or SSE), if not in terms of phonetic realisation, then in the distribution of variants. However, *style* can refer to any characteristic that is used to convey some form of social meaning – in this thesis stylistic features are sung speech sounds. Therefore, features of choral singing can either be 'accent' or 'stylistic' features. For example, Chapter 8 explores rhoticity in choral singing from two dialect areas, and whether the sung realisation of /r/ differs based on the spoken dialects of those areas. In Chapter 9, however, I explore how phonetic realisation of word-final /d/ is used stylistically (i.e. not based on accent differences between the dialect areas).

I will now outline three main approaches to style within the sociophonetic literature (see Kendall et al., 2023 for an overview), including the Attention-to-speech model (Labov, 1966; Labov, 1972), Audience Design (Bell, 1984), and Speaker Design (Coupland, 2001; Coupland, 2007).

3.3 Sociolinguistics of style

3.3.1 Attention-to-speech model

The Attention-to-speech model describes variation in the speaker by how much focus the speaker is placing on their own speech. For example, in formal settings or tasks, speakers will monitor their speech more closely, whereas in informal contexts, they will monitor it less. In *Sociolinguistic patterns*, Labov finds that five phonological variables vary across speech styles, supporting contrasting formal–informal contexts and casual–careful speech styles. Labov suggests that the different styles of speech form part of a continuum based on the amount of attention paid to speech, with a casual speech style at one end and more careful formal speech at the other (1972, p. 99). The Attention-to-speech model has been largely ignored in other sociolinguistic studies of singing; however, in choral singing, where singers are often sightreading, sightreading or singing from a score (or a memory of a score), orthography may play more of a role. Choral performances are often formal situations or in liturgical settings which may also increase the attention to speech, or in this case, singing.

3.3.2 Audience Design model

Bell's (1984) Audience Design framework (as shown in Figure 3.2) suggests that variation in speech may be explained by speakers accommodating to the audience. Bell's Audience Design 'argues that speakers modify their language primarily in response to their audience, orientating to *people* rather than to functions or mechanisms' (Gibson & Bell, 2012, p. 140). Rather than accommodating to the audience – which suggests converging or diverging from the audience's spoken accent – Audience Design suggests that a performer tailors their accent for the audience, but in a way that does not falsely assume the audience is an interlocutor.

3.3.3 Speaker Design model

The third sociolinguist model of style is that of Speaker Design or speaker agency Coupland (2007), which describes how speakers are able to use linguistic variation to create specific meanings at a local level.

High performance

Coupland (2007) notes that, for many years, performed language was avoided by sociolinguists in search of the vernacular, or natural speech. However, more recent research has started to investigate speech in performance. Coupland (2007) writes of *mundane* versus *high performance*. Bell & Gibson (2011) talk of *everyday* versus *staged* performance. Thus, a distinction is drawn between the performance of

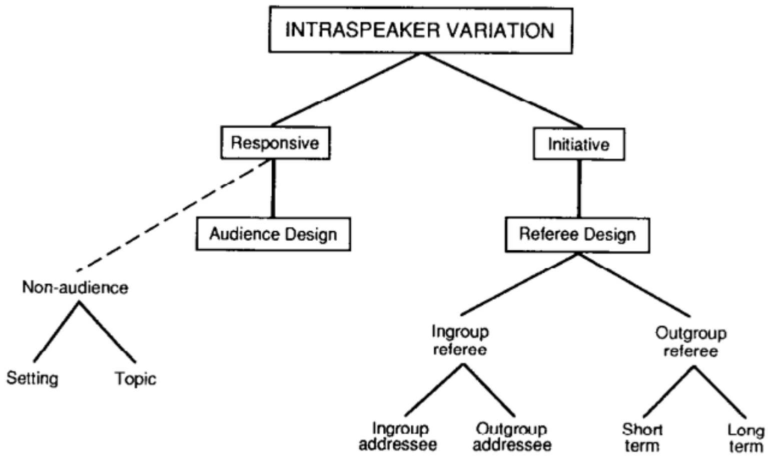


Figure 3.2: Categories and characteristics of Audience and Referee Design (Bell, 1992, p. 327), a revised version of Bell (1984)

ordinary conversation and a 'programmed' performance. Bell & Gibson (2011) write:

> Performed language provides a window on the world of the creative and the self-conscious, the kind of language excluded from sociolinguistic work which targets 'natural, unselfconscious speech'. The focus here shifts to the non-everyday and the non-vernacular – or to the vernacular which is intentionally reproduced. This opens up to sociolinguistic enquiry a much broader and richer range of styles, genres and media. Exaggerated linguistic forms are part of the stock-in-trade of performers, with specific forms often associated with particular genres (Bell & Gibson, 2011, p. 558).

Based on Baumann 1992's linguistic anthropology of performance, Coupland tells us that high performance events are:

> …scheduled, pre-announced and planned, and therefore programmed … They are temporally and spatially bounded events, marked off from the routine flow of communicative practice. They are coordinated, in the sense that they rely on specific sorts of collaborative activity, not least in that performance and audience members will establish themselves in these participant roles for the enactment of the performance … Baumann also identifies the heightened *intensity* of performance events as a key characteristic. (Coupland, 2007, p. 147)

Coupland (2007, pp. 147–148) outlines seven dimensions of high performance:

- *form focusing* The poetic and metalinguistic functions of language comes to the fore and considerations of ‘style’ in its most commonplace sense become particularly salient.

- *meaning focusing* There is an intensity, a density, and a depth to utterances or actions, or at least this is assumed to be the case by audiences.
- *situation focusing* Performers and audiences are not merely co-present but are ‘gathered’, according to their particular dispositional norms. People know their roles.
- *performer focusing* Performers hold a ‘floor’ or a ‘stage’, literally or at least in participants’ normative understandings of speaker rights and sequencing options.
- *relational focusing* Performances are *for* audiences not just *to* audiences [...] Although audiences are often public, performers will often have designed their performances for specific groups.
- *achievement focusing* Performances are enacted in relation to more or less specific demands: ‘stakes’ (gains, losses, and risks) are involved, with potential for praise or censure for good or bad performance.
- *repertoire focusing* Performers and audiences are generally sensitive to what is given and what is new in a performance. Performances may be versions of known pieces, or at least known genres. Innovative interpretation can be commended. Rehearsal is relevant.

Choral performances meet the criteria for *high performance*. Undoubtedly, the poetic and metalinguistic functions of language come to the fore; there is an intensity and depth in audience perceptions of choral performances; performers and audiences are usually ‘gathered’; choral singers and directors hold the floor during performances; choral singing is *for* audiences, not just *to* audiences – and often with different audiences in mind; there are notions surrounding a ‘good’ or ‘bad’ choral performance; there are well-known pieces and genres and both conservatism and innovation in repertoire and performance practices.

Solo singing events tend to be in unidirectional focus with the performer at the centre, performing *to* and *for* the audience. However, in Coupland’s (2007) definition, multi-performer events are absent. What about in theatre, for example, where there is not only ‘the performer’ and ‘the audience’ but also other performers – often we are trying to perform *to* or *for* other members of the cast (or choir) – and also the director is an audience too. In choral singing, there may be singer–singer corrections and corrections from choir directors. Choir directors can make corrections relating to pitch mid-performance using gestures and facial expressions – there is often direct feedback in that sense. Therefore, the question of whom choral singers are performing *to* or *for* is non-trivial. As we have seen, sociolinguistic analysis of high performance has the potential to shed new light on linguistic practices more widely.

Quantitative variationist approaches to style have been critiqued for their reductive view of style. For example, Hymes (1986) writes 'statistics and deviations matter, but do not suffice. Styles also depend upon qualitative judgements of appropriateness' (Hymes, 1986, p. 57). Coupland (2007) notes that speakers are not consistent in their use of accent features, either within an individual's usage or within the usage of the wider social group. This means that the results we gather in variationist research are inevitably generalisations based on 'probabilistic' truths. Even if we carefully interpret such data, 'we should not expect linguistic features to have unique social meanings, even in the same socio-cultural context' (Coupland, 2007, p. 23). We also need to be wary of inferring about the social salience of a particular variant from the distribution of variants alone.

Coupland also notes that 'stylistic analysis is the analysis of how style resources are put to work creatively. Analysing linguistic style again needs to include an aesthetic dimension. It is to do with designs in talk and the fashioning and understanding of social meanings' (2007, p. 3). Addressing the aesthetic component of style is essential to the current work. Investigating Western classical choral singing necessitates considering style-specific aesthetic dimensions. I will address relevant aesthetic features of Western classical singing and choral singing pedagogy in Section 3.7.

While these are potential drawbacks of the variationist approach (Coupland, 2007), this is the framework I will work within. Following Wilson (2014), this study will adopt Coupland's definition of style as 'ways of speaking'. This encourages us to consider the possibility of Western classical choral style as a 'way of singing' and ask what features are inherent to the style.

Linguistic Register and Genre

The form *choral singing* could be considered a register of singing. Coupland defines genres as 'culturally recognised, patterned ways of speaking, or structured cognitive frameworks for engaging in discourse' (2007, p. 15). Another way of reframing the primary research question of this thesis (do choirs have accents?) is to ask whether there are 'culturally recognised, patterned ways of [singing]' which constitute a genre of Western classical choral singing. Choral singing as a form is, in the broadest sense, a group of people singing together. However, the phrase also carries connotations of genre – a sense of the repertoire sung, perhaps the way it is sung, evoking Western classical choral singing or even church singing in that tradition. In this thesis, the terms choral singing and Western classical choral singing are used interchangeably.

This thesis is concerned with the sociolinguistic analysis of choral singing. The context of choral performance constrains the sociolinguistic notion of genre. In linguistic terms, choral singing can be conceptualised as read speech, with the connotations of formality and increased attention-to-speech that it brings. In addition to the sociolinguistic level of genre, there is also an effect of musical genre at play which will be discussed more fully in section 3.7. I will now review existing sociolinguistic studies of singing.

3.4 Sociolinguistics of singing

In the following section, I outline existing sociolinguistic research on singing. Following Trudgill's (1983) influential study, sociolinguistic research on singing has continued to focus on popular styles of solo singing. For example, Simpson (1999); Beal (2009) on Arctic Monkeys (a rock band from Sheffield); Morrissey (2008); Krause & Smith (2017) on the Twilight Sad and the Unwinding Hours (indie bands from Glasgow); Yang (2018), Lenka (a pop singer from Australia); Caillol & Ferragne (2019), British heavy metal bands Def Leppard and Iron Maiden. These studies use a combination of a variationist Labovian approach correlating pronunciation variability with artists over time (for example, Labov, 1978) and qualitative information. Data in this work is usually the result of auditory coding. However, Yang (2018) provides qualitative acoustic analysis in the form of spectrographic analysis of some vowel qualities to illustrate the variation in the Australian pop singer Lenka. Regardless, nearly all existing sociolinguistic studies have focused on popular singing styles such as rock, pop, punk and indie (Morrissey, 2008).

3.4.1 Acts of conflicting identity (Speaker Design or speaker agency)

Trudgill (1983) presented the first sociolinguistic study of popular singing and, in fact, singing of any kind. Trudgill recognised that singers modify their pronunciation in singing and tried to explain why they do, using the sociolinguistic theory available at the time. He first investigates the possibility of speech accommodation theory (Giles & Smith, 1979), where speakers have been shown to converge or diverge over the course of conversation. However, as Trudgill (1983) noted, as there is no interlocutor to accommodate with, there is limited application of the theory in popular solo singing. Trudgill (1983) turns to

Le Page & Tabouret-Keller's *acts of identity* framework where 'the individual creates for himself the patterns of his linguistic behaviour so as to resemble those of the group or groups with which from time to time he wishes to be identified or so as to be unlike those from whom he wishes to be distinguished' (Le Page & Tabouret-Keller, 1985, p. 191). Le Page & Tabouret-Keller's approach falls within the speaker agency model later proposed by Coupland (2007). Trudgill found this approach to be more applicable. Trudgill writes that 'it is appropriate to sound like an American when performing in what is predominantly an American activity; and one attempts to model one's singing style on that of those who do it best and who one admires most' (1983, p. 144).

Trudgill (1983) showed that British pop singers performing in the 1960s–70s used different accent features when singing compared to their spoken pronunciation. He argued that this phenomenon of 'modified pronunciation' had existed in popular music 'probably since the 1920s'. He analysed a set of consonantal and vocalic variables, including: intervocalic taps, for example, in *better*; non-prevocalic /r/ (now known as postvocalic /r/); realisation of the TRAP vowel as [æ] or [a]. He presented theories that could explain why singers select the linguistic variants they do, focusing on the 'domination' of one culture to explain popular singing practices, including the early adoption of rhoticity by groups such as the Beatles. For example, in his analysis of non-prevocalic /r/, or rhoticity (Wells, 1982a) – that is, the production of /r/ in words such as *car, card* – found that rhoticity decreases over time in The Beatles and The Rolling Stones albums 1963–1969. Trudgill suggested that 'British pop music acquired a validity of its own, and this has been reflected in linguistic behaviour' (Trudgill, 1997, p. 161).

Simpson's (1999) critique of Trudgill's study problematised what he calls the 'USA-5 model' – the popular singing model with 5 different linguistic variables that are based on features perceived as prototypically 'American' features set out by Trudgill (1983). The USA-5 model includes:

- intervocalic flaps
- non-prevocalic /r/
- SSBE BATH phoneme /ɑː/ realised as TRAP [a]
- PRICE monophthongisation /aɪ/ realised as [a]
- SSBE LOT /ɒ/ phoneme realised as [ɑ]

Simpson argued that, in sociolinguistic terms, 'the ideology of the punk movement brought with it a new set of linguistic motivations which made substantial inroads into the USA-5 model. The vernacular working speech of urban London became the new paradigm…' (Simpson, 1999, p. 349). Simpson suggested that accounting for phonological shifts in singing can be informed by sociolinguistic theories devised to explain style and register shifts in speech, as well as code-switching. For example, topic-based style-shifting in speech, in response to the genre, situation, topic and field, may also exist in singing (Simpson, 1999).

> the notional linguistic code which is mediated through a singer's vocal style does not necessarily coincide with the accent of the intended audience. Rather than seeking to match or accommodate to the speech style of the addressee, the type of style shifting embodied by pop and rock is more the result of a change in what Coupland calls the 'projected social role and persona' of the speaker (Simpson, 1999, p. 351)

More recently, Beal (2009) explored the use of local, Northern English variants, including the BATH and STRUT vowels, H-dropping and TH-fronting, and their enregisterment in the singing of the Sheffield-based band, Arctic Monkeys, in comparison to spoken interviews. Rather than an orientation towards an American 'reference style', Beal found considerable phonological similarities between Arctic Monkeys' sung style and their spoken variation, providing 'some justification for the perception that Arctic Monkeys are singing in their 'own' accents…constituting a 'divergence' from the pop mainstream' (Beal, 2009, p. 236). She rejects the accommodation theory explanation, posited by Trudgill (1983) and Simpson (1999) since this would entail regarding local features as a 'default'. In contrast, she suspects the band is making a 'positive choice' in selecting the Sheffield variants for singing. She writes that:

> The language-ideological approach provides the best explanation for the use or avoidance of 'American' features by British pop singers at various times and in various genres. Features such as rhoticity and /t/-flapping have become enregistered, not just as 'American' but as appropriate for the performance of pop music, so avoidance of these by British popular singers reflects a rejection of this style and model. (Beal, 2009, p. 238)

Beal also notes that genre is a salient issue, suggesting that for indie groups like Arctic Monkeys, being perceived as singing in their own accents is considered stylistically appropriate for the performance of the genre, in the same way that an 'American' accent is recognised as the most suitable variety for the performance of pop music (Beal, 2009).

3.4.2 Indexicality

More recent sociolinguistic theory focuses on how individual speech sounds can take on specific meanings in specific contexts. Indexicality theory describes how sounds can come to index particular meanings. Some sounds have higher orders of indexicality and thus are more socially salient than others (Silverstein, 2003). Indexicality was originally conceived of in interactional communication – that is, how speech sounds take on specific meanings in conversations between two people. However, indexicality has also been discussed in performance. For example, Bell & Gibson (2011) write:

> Performance encourages reflexivity for both performer and audience, and therefore also leads to the formation of what Silverstein (2003) has called 'higher order indexicalities' – awareness that a certain stylistic variant operates as an index for a certain social meaning (Bell & Gibson, 2011, p. 559).

Black (2014) notes that '[the] linkage between musical patterns and social meanings is a form of indexicality'. This is particularly interesting from a choral perspective. Not only can certain speech forms take on new meanings in choral contexts, but it is also possible that certain musical forms may also index specific social meanings. As part of her research Wilson (2014) interviews choir members and choir conductors, finding that: 'The language of choral singing, like that of wine drinking, may be viewed as a 'fashion of speaking' with its use similarly signalling the anxiety for distinction among its users' (Wilson, 2014, p. 78). The esoteric terminology associated with choral singing can be conceived of as metalanguage – language about language.

Krause & Smith (2017) investigate the enregisterment (Agha, 2003) of local features in the Scottish indie music scene, focusing on the realisation of postvocalic /r/ by the lead singers of the Twilight Sad and the Unwinding Hours in spoken and sung contexts. They find that 'overall, there is a high rate of the variants at the weakly, rather than the strongly rhotic end of our continuum. This is despite postvocalic /r/ being a classic stereotype of Scots' (Krause & Smith, 2017, p. 228). The authors attribute this surprising finding to the reduction of postvocalic /r/ in working-class speech in the Central Belt (Stuart-Smith & Lawson, 2017).

Subsequently, there was more focus on solo pop singers' ability to blend features from multiple accent sources. For example, Jansen & Westphal (2017) investigate the use of a blend of vernacular varieties in the singing of Rihanna, who incorporates Caribbean features alongside General American. Similarly, Yang (2018) finds that Australian pop singer Lenka does not follow the trend of eschewing the 'mid-Atlantic' model of singing for her own local variety but instead blends features from multiple different accents, including General Australian English, General American English, and Southern Standard British English.

Most recently, Caillol & Ferragne (2019) investigate T-voicing and FOOT–STRUT split, produced by the lead singers of the heavy metal bands Iron Maiden and Def Leppard in albums released 1980–2015. The authors showed that even in a genre with distinctly British origins, there was evidence of the Americanised features that Trudgill found in the pop and rock recordings of the 1960s. Flanagan (2019) investigates the pronunciation of Alex Turner – the lead singer of Arctic Monkeys – over a thirteen-year period. Flanagan adapts the USA-5 model suggested by Simpson (1999) to include features relevant to the singer's Northern heritage. Flanagan (2019) finds a reduction in non-standard forms produced by the singer over this time period, writing that: 'over time, Turner's singing style has notably shifted away from a delivery that is more in keeping with his local accent and identity, and more towards the institutional norms of the music industry' (Flanagan, 2019).

3.4.3 Audience Design theory

Thus far, we have seen that sociolinguistic studies of popular music have recognised that singers tend to adapt their spoken accents in singing. Reasons for adapting the spoken accent, it has been suggested, include phonetic convergence toward the audience (Accommodation theory – Giles & Smith, 1979) or projecting the persona of the singer (Speaker Design – Coupland, 2007). Bell's (1984) Audience Design 'argues that speakers modify their language primarily in response to their audience, orientating to *people* rather than to functions or mechanisms' (Gibson & Bell, 2012, p. 140). Rather than accommodating to the audience – which suggests converging with or diverging from the audience's spoken accent – audience design suggests that a performer tailors their accent for the audience, but in a way that does not falsely assume the audience is an interlocutor. Gibson & Bell (2012) summarise Morrissey's (2008) contribution to applying audience design in popular singing:

> Morrissey (2008) theorises singing style in terms of the Audience Design framework, classing the use of AmE in pop singing as a case of outgroup referee design, where Americans are esteemed by both singers and their audiences as an agreed referee for singing pop music. Morrissey uses the term *reference style* to refer to the collection of (usually AmE) variants which are used by singers for the purposes of referee design in pop singing. (Gibson & Bell, 2012, p. 142)

Morrissey (2008) discussed the approaches to sung style by Trudgill and Simpson, particularly their tendency to apply sociolinguistic theories of speech directly to singing without consideration for singing-related factors. He advocates incorporating the recognition that singing per se may influence phonological variability. Morrissey draws attention to the fact that, in singing, there is a hierarchy of speech sounds based on sonority. The more sonorous the sounds, the better they 'carry' the tune. At a simplistic level, this hierarchy is as follows:

vowel/glide > voiced consonants > voiceless consonants

For example, the sound sequence [wʌɹiːɪŋ] is highly sonorous, whereas the sequence [fɑstə] is less sonorous. Another contribution that Morrissey makes that is particularly relevant to this study is the theoretical construct for considering singing style, specifically the notion of the 'reference style'. He regards the 'mid-Atlantic' American-like accent and SSBE (formerly RP) as 'dominant reference style[s]'. He notes how deviating from these reference styles can be marked, such that popular singers can use deviation from the reference style as an effect in their performances.

3.4.4 Referee Design

Audience Design proposes that speakers, or in this case, performers, tailor their linguistic style in response to their audience, whereas in Referee Design, speakers orient their linguistic practice towards 'a third party, a reference group, or a model. Referees are third persons not physically present at an interaction but possessing such salience that they influence language choice even in their absence' (Bell, 1992, p. 328). Bell (1992) outlines how outgroup referee design can be 'long term, even institutionalised' (p. 330), giving the example of diglossia. In diglossia, the 'High' form is the 'dialect of an external referee, distanced by space or time'. He gives the example of Switzerland from Burger (1964, p. 215), where High German is the selected variant for formal media which contrasts less formal media, which uses Swiss German (Bell, 1992, p. 330).

Sociolinguists have applied Referee Design to explain variation in popular singing (Bell, 1992; Bell & Gibson, 2011; Gibson & Bell, 2012). In a study of male New Zealand pop singers, Gibson & Bell (2012) find that for most of the singers, the vowel phonology is consistent with that reported by Trudgill (1983) – that is a mid-Atlantic accent. However, rather than considering the behaviour of the singers as an *act of identity* in Le Page & Tabouret-Keller's (1985) terms, this is conceptualised as an orientation towards an outgroup referee – in this case General American English. Gibson & Bell (2012) argue that this is a case of institutionalised referee design, which refers to cases of referee design where the referee 'becomes so associated with a certain situation that it becomes responsive and functions as the default style' (2012, p. 161). They find that the use of American English features by popular singers from New Zealand helps the singers to 'fit in', and it is consistent with the Audience Design model in that using American English features helps the singers to meet the expectations of the listener (Gibson & Bell, 2012).

As we have seen, Audience Design, and Speaker Agency have been used extensively to explain variation in linguistic style within popular styles of singing. What sociolinguistic model of style is most applicable to choral singing? Or, which models – as Kendall et al. (2023) note, these three perspectives may often work together. There is some evidence from choral and singing literature that southern British prestige varieties may function as the default 'institutionalised' referee for classical choral singing – that is Audience Design or Referee Design. This relates to RQ2 and whether there are shared accent features between the two corpora. However, as I mentioned at the start of the literature review, the Attention-to-speech model may play more of a role in Western classical choral singing than has been attributed to solo popular singing. With recordings from over a century, choral singing is an untapped resource for researching variation and change over time from both musical and linguistic perspectives. Western classical choral singing, within the overarching classical 'reference style' (Morrissey, 2008), has received little attention within sociophonetics. In the next section, I summarise the work of Wilson (2014) that investigates the sociolinguistics of choirs in Trinidad.

3.5 Sociolinguistics of choirs

One particularly insightful work is Wilson's (2014) doctoral research, published in Wilson (2017). Wilson investigates the language ideologies at play in choral rehearsals in Trinidad. Wilson (2014) is the first sociolinguistic study to engage with a classical singing style. Secondly, it is one of the first works that investigates *high performance* in individuals whose variety of English is attributed lower prestige, adopting a higher prestige variety (Wilson, 2014, p. 75).

Wilson's (2014) participants include both adults and young people. Adult participants included 20 choral directors from across Trinidad and Tobago that worked with school, church and community choirs. There were interviews with five choral adjudicators, two from Trinidad and Tobago and three from abroad (US and Venezuela). The third group of adult participants included fourteen audience members that self-identified as regularly attending choral performances in Trinidad and Tobago. Youth participants were 11–18 years old and members of school and/or community choirs. Participants were from four girls' choirs and two boys' choirs from Trinidad.

Wilson (2014) interviews the choral directors, fourteen choristers, and twelve audience members. She also gathers ethnographic observations from corrections made during the rehearsals of the six youth choirs, which have, on average, forty members each. Participants were initially selected 'based largely on their involvement in choral singing as choristers, conductors, audience members, or competition adjudicators' (Wilson, 2014, p. 82). Wilson elicited responses from informants via a questionnaire, interviews, and observation of choir rehearsals. Auditory coding of variants produced by singers in rehearsals and corrections given by conductors.

Wilson (2014) acknowledges the benefits and difficulties of adopting an acoustic-phonetic methodology, writing that it is 'due in part to the complications arising when one tries to analyse several voices at once and also to the fact that measuring the formant frequencies in soprano voices is notoriously impossible (cf. Wray 1999)' (Wilson, 2014, p. 94) Wilson codes transcripts of the interviews regarding the opinion of the informants about accents in singing into three categories: Trinidadian, British, and Neither. Corrections relating to language were divided into two categories: Accent and Style (Wilson, 2014, p. 96).

3.5.1 Preferred accents for choral singing

Wilson's questionnaire results demonstrated a preference for 'British' accents in choral singing in Trinidad, with Trinidadian accents restricted to local forms of music, with the author writing that:

> …the former colonial language still enjoys relative prestige, at least in this genre, even half a century after colonialism. Furthermore, this orienting towards an external norm, with which singers and conductors have very limited contact, suggests that referee design may be an important element of style in singing. However, that four of the conductors opted for a neutral accent reinforces the belief of the conductor in the pilot study, who maintained that classical choral singing had its own system of pronunciation that operated independently of national varieties (Wilson, 2014, p. 102).

These findings were further substantiated in interviews: British accents are generally preferred, particularly in the Western classical choral repertoire. Explanations from informants suggest that this preference is tied to language attitudes, with British English 'felt to be more accurate, more pleasant, and more dignified' (Wilson, 2014, p. 109). In contrast, some informants expressed reservations with the 'British' target, and there were also some instances when

Trinidadian English or Creole variants were deemed acceptable in performances of Western classical choral music (Wilson, 2014, p. 109).

3.5.2 Genre – a 'neutral' classical choral sung accent?

Wilson (2014) finds that pronunciation in choral singing is constrained by genre, with 'Standard British English' deemed suitable for Western classical choral singing. At the same time, local musical forms from Trinidad[1] were felt to be best sung using vernacular features. Genre and style were strongly implicated by informants when deciding which accent to use, and Wilson comments that 'there may be occasions when neither a British nor a Trinidadian accent is desirable since the origin of the song, or the cultural context in which the piece was composed, is neither British nor Trinidadian' (Wilson, 2014, p. 115). Wilson (2014) observes features of a neutral classical singing style containing features that are not attributed to any of the languages relevant to Trinidad, including Standard British English, Standard Trinidadian English, or Creole. She writes that 'choral singing has specific stylistic demands that young singers must learn, just as they must learn musical terms and notes, as part of the enculturation process of being and becoming singers' (Wilson, 2014, p. 255).

> Singers seemed able to identify at least two features of this neutral pronunciation, namely the rounding of the close front vowel [i] to produce [y], and the devoicing of word final [d]. These sounds were reported by four of the seven pairs of teenagers interviewed (Wilson, 2014, pp. 117–118).

While the rounding of FLEECE to [y] is perhaps uncontroversial and supported by classical singing technique (for example, Sundberg, 1987, pp. 117–118; Emmons & Chase, 2006; LaBouff, 2008; Ophaug, 2017), the devoicing of word-final [d] is not universal. As we shall see, the choral literature states that special attention must be paid to word-final [d] (LaBouff, 2008). Wilson (2014) also provides evidence that word-final devoicing of voiced consonants is remedied with epenthetic vowels, with informants giving the examples *land* [landᵊ] and *sing* [sɪŋᵊ].

Wilson finds that many participants associate ideal forms of choral pronunciation with British English features, arguing that 'British English has become institutionalised with regard to choral singing – it is so consistently associated with choral singing that it has begun to function as the default style of this activity' (Wilson, 2014, p. 316). However, at times, it is unclear whether Wilson believes that the singers are aiming for a Standard British English target or a non-national

[1] choral music that is 'decidedly Trinidadian' tends to be choral arrangements of local calypsos (Wilson, 2014, p. 45)

'neutral' way of singing that is driven by singing technique rather than a spoken accent. While I share her view that there are non-regional phonological features common to Western classical choral singing, it is unclear what features form part of this phonology. The 'neutral' choral accent is also not integrated into the existing literature on choral pedagogy.

While I agree that the 'classical choral singing style … affords less flexibility' than popular styles of singing (Wilson, 2014, p. 321), there seems to be little recognition that this is due to the necessity of or desire for homogeneity in choral performance – or to do with the choral form – that there are multiple people singing at the same time. There may be more room for innovation in solo singing (not solely due to the popular genre), and choral soloists may exhibit more flexibility and variation in their performance than when singing in the choir. Indeed, future research needs to investigate within-choir or within-choir-section accommodation that goes on to achieve this notional homogeneity or blend.

Wilson (2014) finds that the language ideologies of the performers and audiences differ, leading to a mismatch between audience expectations and the performance given. She writes that 'players are loyal first to their craft, and second to their public. Genre trumps audience' (Wilson, 2014, p. 325). In summary, Wilson supports an initiative outgroup referee design which many informants call 'British', but Wilson argues it may be evidence of a non-national standard of Western classical choral singing. In this section, we have seen how Wilson suggests that Western classical choral singing may be tied to a standard British accent, and this accent may have become 'institutionalised' (following Gibson & Bell, 2012) as part of the stylistic requirements of the Western classical choral genre. In the next section, I turn to existing musicological studies of choral singing.

3.6 Musicological studies of Western classical choral singing

There is a large body of musicological literature which provides cross-cultural examinations of song and singing styles, for example, the previously mentioned Cantometrics and Global Jukebox projects (Lomax, 1976; Wood et al., 2022). There have also been attempts to combine musicology and anthropology and trace singing back to the evolution of communication (Mithen, 2006). CHARM explored how expressivity has evolved over time in recordings of singing (Leech-Wilkinson, 2009a).

In this section, I will summarise the contributions of four musicological works investigating the sound of singing and choral singing. Through careful auditory analysis, these studies provide insight into variation and change in choral sound at a more holistic level, incorporating more aesthetic dimensions than are examined in this thesis. These studies may provide hypotheses for testing for this study and help to situate the results of the present work within the culture of British classical choral singing and the 'English cathedral tradition' (Day, 2014).

In his book *Vocal authority: Singing style and ideology*, Potter (1998) traced back the evolution of Western classical singing technique. This is a discursive work adapted from his PhD thesis, where he gives a history of singing styles. Potter wrote of Western Classical music that 'a great deal of early recitative is very close to heightened speech' (Potter, 1998, p. 37). Potter conducted experimental work which shows that participants naturally produced recitative with intonation patterns similar to that of speech. Prioritising text or aesthetic has shifted over time:

> The declamatory style of the early seventeenth century was vertical and chordal with a minimum of counterpoint so that the text would always be clear. The words were, as Giulio Cesare Monteverdi put it, 'the mistress of the harmony and not its servant' (Strunk, 1981, in Potter, 1998, p. 49).

Potter (1998) described how the lowered larynx technique of bel canto (Western classical operatic technique) became ubiquitous in all forms of Western classical singing, connecting lowered larynx technique and Received Pronunciation. From a singing perspective, Potter argued that lowering the larynx darkens the sound; it lowers the formants allowing male classical singers to make use of an additional 'Singer's formant', allowing them to project over a large orchestra (see Sundberg, 1974; Sundberg, 1987, pp. 117–118). Potter wrote 'RP also involves the lowering of the larynx, which gives it its distinctive colour. Modern performers have no option but to sing in RP if they wish to maintain a technique appropriate for modern concert halls and acceptable to modern audiences' (Potter, 1998, p. 119).

Potter associated lowered-larynx vocal technique with the articulatory configuration of conservative-RP or Wells's upper-class RP that 'demands a "plumminess" achieved by lowering the larynx and widening the oro-pharynx' (Wells, 1982b, p. 283). Potter suggested that the primacy of lowered larynx singing technique in English is tied to the standard form of the language. However, in Wells's terms, U-RP is not the 'standard form' of the language, as speakers of U-RP are 'conspicuous in a way that makes it impossible to regard them as part of mainstream RP' (Wells, 1982b, p. 280). Nonetheless, Potter wrote that 'no research appears to have been done on the relationship between RP and singing and it is not yet possible to establish a specific link between them' (1998, p. 65).

It is entirely plausible that there is a connection between RP and classical singing technique regarding English phonology. However, the connection between the lowered-larynx technique and upper-class Received Pronunciation voice quality is surprising. Lowered-larynx technique is also associated with bel canto or traditional Italian operatic technique. Furthermore, we often conceptualise choirs, for example, the Choir of King's College, Cambridge, as singing in RP. However, I do not believe that singers in these choirs typically utilise this lowered larynx technique as they do not necessarily sing as if to project over a large orchestra in the same way an operatic soloist does. Choral scholars are most likely not capitalising on this fourth formant as it would be considered inappropriate in choral contexts. Sundberg & Ternström (1986) found that professional soloists singing in choirs still used the singer's formant, but Ternström & Sundberg (1989) found that amateur choir singers did not. It is unknown whether choral scholars, such as those at King's, use this lowered larynx technique. Welch & Sundberg write that 'choral singers show less evidence of the singers' formant. This probably reflects the need to ensure that individual voices do not stand out in the creation of a choral blend' (2002, p. 264). Returning to the present research, if lowered-larynx technique is found in the singing of the choirs explored in this thesis, I would expect to find the first and second formant decrease in frequency as the vocal tract is effectively lengthened.

3.6.1 Evolution of choral sound in professional choirs

Rugen (2013) investigates the evolution of choral sound in professional choirs from 1970–2013. Rugen's study includes 'choral institutions from the 1950s to the early twenty-first century that pay their singers' (2013, p. 17) with a few exceptions, including the Mormon Tabernacle Choir. Rugen seeks to establish whether professional choir sound has changed over a thirty-year period. She also investigates what factors may have driven the shift in professional choral tone in the late twentieth century: including imitative behaviour of choral singers and directors, modern compositional techniques, audience preferences, and technological innovations.

To investigate these questions, Rugen (2013) reports 22 interviews with conductors of professional choral ensembles from the US, UK, Canada, Ireland and many well-known contemporary composers of choral music. Subjects were asked, based on their experience, whether they believed choral sound had changed over time. Conductors interviewed by Rugen revealed that they had noticed a change in professional choral sound since the 1970s. These included:

- Singers are more precise in the application of vibrato
- Ensembles are more precise in rhythm and articulation
- Singers are more qualified and experienced than in the past
- Singers are more willing to adapt their vocal technique to suit the repertoire
- Conductors show a preference for a rich low bass sonority

Rugen reports that:

> While these changes forged a shift in the sound, some conductors voiced concerns about the disappearing warmth and spin in choral tone. They denied the fact that contemporary choirs exhibit finer intonation than previously, but instead sound distant and sterile (Rugen, 2013, p. 69).

Reasons given for these changes ranged from: a desire for better tuning, cleaner sound, smaller ensembles and a 'pervasive bias for extremely low sonority' (Rugen, 2013, p. 71). Rugen also investigated reviews of recordings released prior to 1980, finding that descriptions of earlier vocal production include: full, rich, throaty, less refined and harsh. However, of recordings of the Choir of King's College, Cambridge, produced under the direction of David Willcocks, Rugen writes:

> Of all the recordings, only those of Willcocks collected descriptions similar to twenty-first-century albums such as excellent intonation, haunting and angelic. That English sound became a model for choirs that sought a higher level of precision and accurate intonation (Rugen, 2013, p. 39).

Rugen reports general agreement among participants that the advent of digital recording had a great impact on choral sound in terms of professionalisation, leading choirs and conductors to strive for the literal 'perfection' found in CD recordings. Some participants reported that recording also had the unintended consequence of making the sound less warm and characterful, emphasising the dispassionate quality of the early music revival. Rugen also discusses differences between English and American choral sounds but does not discuss accent features directly, focusing on timbre (e.g. light/dark), pitch relationships (bass-heavy sound versus top-line heavy sound), and vibrato quality.

3.6.2 Early Music and the Choir of King's College, Cambridge

In his thesis, Sagrans (2016) investigates the connections between the Choir of King's College, Cambridge and the early music revival in Britain. Sagrans suggest that the recording output of King's helped popularize the 'King's sound'. Sagrans (2016) focuses on the Choir of King's College, Cambridge recordings of Renaissance and Baroque music 1958–2016. Sagrans provides a list of elements comprising choral sound including: acoustics, age(s) of singers, articulation, balance, breath, blend, clarity of text, dynamics, gender of singers, instrumentation, intonation, nasality, performance pitch, phrasing, pronunciation, rhythmic coordination, size of the ensemble, technical mediation, temperament, tempo, and vibrato. Sagrans uses the term 'sound' to refer to all audible characteristics of musical performances. In the present study, I will use the term 'accent' to refer to demonstrably structured linguistic variation, whereas choir 'sound' also encapsulates musical non-linguistic variation. Sagrans (2016) adopts multiple analytical approaches, including auditory comparison of recordings, comparing reviews of commercially released recordings, and acoustic analysis involving measuring the spectral centroid of recordings to compare overall brightness.

Sounds that have a higher spectral centroid tend to be perceived as brighter, and sounds with lower spectral centroid are perceived as darker (e.g. Grey, 1977). Sagrans compares the spectral centroid of eight recordings of the same excerpt, a section of *Tu es Petrus* by Giovanni Pierluigi da Palestrina, produced by different choirs in order to compare how bright or dark the realisations are. There are some issues with Sagrans's acoustic methodology. The sounds used were encoded in MPEG-1 Layer 3 compression schema, commonly known as *mp3*; or they were converted to mp3 from CD quality. The compression will have an effect on the spectral characteristics – and depending on the bit-rate used, the spectral characteristics of the sound may not be preserved (Gonzalez et al., 2003; Vogel & Morgan, 2009). Sagrans sensibly restricted the impacts of genre and text by selecting a particular piece of music (*Tu es Petrus*). However, as the choirs investigated were singing the excerpt in different keys (at different fundamental frequencies), the recordings had to be transposed to have the same fundamental. The effect of shifting the fundamental on the acoustic profile of choral recordings is unknown – anecdotally, after a certain point, it can severely affect the perception of vowel quality, but it is not known what spectral impacts such action has at lower levels. For example, Sagrans reports that transposing the fundamental of the King's recording shifted the centre of gravity (spectral centroid). When transposed to match recordings sung at different fundamental frequencies the centre of gravity of the same King's excerpt was reported as variously 1,506 Hz, 1,441 Hz, 1,413 Hz, and 1,318 Hz – showing variation of almost 200 Hz (2016, p.

45). It is not known whether Sagrans adjusted other spectral features, such as vowel formants when the fundamental was corrected.

Based on his in-depth auditory analysis, Sagrans suggests that there are separate but similar 'King's' and 'English' choral sounds (2016, p. 24), writing that 'the King's sound is a particularly high-profile example of a broader "English sound" for choral performance' (Sagrans, 2016, p. 29). He suggests that the King's sound is kept relatively constant regardless of the genre of the work being sung, and this is what enables us to talk of such a sound: 'If King's or other vocal ensembles approached each piece they sing in an entirely different way, it would not be feasible to make general characterizations of the ensembles' sounds' (Sagrans, 2016, p. 38). I do not dispute that the sound of King's is largely preserved across varying repertoire – however, the vast majority of music King's sings is Anglican Church Music – which could be said to be functionally of the same genre. Perhaps the 'unvarying sound' is due to the unified genre of music for liturgical purposes, as Sagrans writes:

> King's is almost exclusively a liturgical choir. In addition to singing in Evensong, Matins, and Eucharist services, the choir's radio broadcasts and webcasts are typically entire services, either broadcast live from the chapel at King's College, or broadcast at a later date, and the choir's albums often present music as if it were being sung in a service (Sagrans, 2016, p. 77).

Sagrans describes the sound of King's as 'light, bright, breathy, evenly balanced, and that there is a high level of blend within sections, minimal variation in dynamics and tempo, minimal vibrato, and mostly legato articulation for melismas' (2016, p. 38).[2] It is not clear if the 'King's sound' is distinct from the wider 'English sound' which Sagrans describes as 'being characterised by a high level of blend, precise intonation, light, bright, and not particularly nasal timbres, limited vibrato, clarity of text, and limited changes in expressive elements such as tempo and dynamics' (Sagrans, 2016, p. 48). Sagrans cites Day (2014) who suggests that the English choral sound reflects British values, including 'understatement', 'self-control', 'reserve' and 'reticence' (Day, 2014, in Sagrans, 2016, p. 55). Sagrans concludes that:

> While King's cannot be said to have created the English sound, the choir is one of the best-known ensembles to sing with a variant of this sound and has played an important role in bringing the English sound to both mainstream classical music audiences and to early music

[2]Legato refers to smooth articulation with minimal gap between notes; melismas are where the vowel of a syllable is allocated multiple pitches. Melismas or melismatic text setting contrasts with syllabic text setting where each vowel is allocated only one pitch.

> specialist and HIP [historically informed performance] ensembles (Sagrans, 2016, p. 197).

Sagrans suggests that the prolific recording output and broadcasts of the Choir of King's College, Cambridge was likely responsible for the 'widespread nature of the King's and English sounds and for the predominantly unchanging character of these sounds since the early twentieth century' (2016, pp. 59–60). Sagrans does not believe that the acoustic of King's College Chapel had a particularly large effect on the development of the King's sound, as it is similar to so many other choirs of the English sound model (2016, p. 62).

3.6.3 *I Saw Eternity the Other Night*

Day (2018) documents the development of an English collegiate choral style, drawing upon a diversity of sources to show how the composition of the Choir of King's College, Cambridge changed – for example, with the removal of the lay clerks in the 1920s and their replacement with undergraduate choral scholars which greatly professionalised the King's sound. He also draws on the beliefs of the directors of the choir, reviews of the choir's recorded output, and his own auditory analysis of choir recordings. Day suggests that the sound of King's evolved over time, writing that, under David Willcocks:

> The singing gradually began to develop a more incisive edge. When [Willcocks] was pressed to examine the tradition, to listen to the recordings – which he would not normally do – he had to admit that over a decade the singing style had indeed changed, though certainly that had not been his intention. It was likely to have happened, he suggested, through the frequent recording sessions with orchestras that the choir began to have from about 1960. His sensitive musicians had instinctively reacted to balance and rival the volume and attack of a full orchestra (Day, 2018, p. 173).

Later, Day writes of Stephen Cleobury:

> …if the sound of the choir had changed – and he had not set out to change the style deliberately – it might be because he had encouraged the choir to sing 'with a bright forward tone' and that even when they were singing in English he had encouraged them to try to use Italian vowel sounds wherever possible (Day, 2018, p. 261).

Day (2018) concludes that 'given the constant turnover of singers the sonic image of the choir had a remarkable constancy' (Day, 2018, pp. 263–4), the view also supported by Sagrans (2016).

3.6.4 Summary

This section has demonstrated how musicologists have investigated choral sound, using auditory analysis of choir recordings, surveys and interviews with singers and choir directors, and limited acoustic analysis. Potter (1998) suggests a relationship between RP and classical singing technique in English (motivating RQ2 – whether there are shared features between the choirs). Rugen (2013) supports change over time in the world of professional choral singing, and specifically cites recordings of King's made under David Willcocks as standing out from others made before the 1980s (motivating RQ3b–c). Sagrans (2016) gives a holistic auditory analysis of King's sound. Day (2018) provides specific descriptions of the sounds that different directors curated at King's specifically. Both Sagrans and Day seem to support a King's sound that has mostly stayed constant, with Day suggesting some changes under particular choir directors (relating to RQ3c).

As we have seen, both sociolinguists and musicologists have analysed recordings of singing with a mixture of acoustic and auditory methods – mostly the latter – using quantitative and qualitative approaches. However, there have been no large-scale acoustic analyses of singing and no acoustic analysis of choral singing. The analyses of popular singing that have taken place tend to feature auditory coded data analysed with quantitative methods or qualitative acoustic studies with small samples of spectrograms to support arguments. In this thesis, I analyse a large-scale corpus of recordings of choirs using acoustic and auditory methods combined with Bayesian statistical analysis. In the next section, I outline the potential impacts of Western classical singing pedagogy and choral pedagogy on the choral signal.

3.7 Western classical singing pedagogy

> To view a song or aria text purely in linguistic terms, without reference to its appropriation in sung performance, would be as one-sided as treating text merely as a necessary but inconvenient scaffold for making beautiful sounds (De'Ath, 2019).

Thus far, I have reviewed existing sociolinguistic literature on popular singing and choral singing and musicological studies of choral singing. Much of the sociolinguistic literature neglects the fact that they are analysing singing – and that singing itself has stylistic constraints (Morrissey, 2008; Gibson & Bell, 2012), which may impact the sung accent. In this section, I will illuminate some of these possible constraints from Western classical singing and choral literature which relate to research questions 3b–c.

Vowel quality

Western classical singing technique requires vowel modification for higher voices. As the fundamental frequency increases above 700 Hz, all vowels have similar formants, and intelligibility relies on consonants (Welch & Sundberg, 2002). Emmons & Chase (2006) write that:

> Generally speaking, at any given moment when the score asks for all sections to sing the same word, one or more sections will be vocally uncomfortable with the vowel. The section that is not uncomfortable is doubtless singing a vowel naturally or accidentally compatible with the pitch. Sopranos suffer more than the other singers. Modifying their vowels as necessary will give them vocal relief and, at the same time, improve the diction (Emmons & Chase, 2006, p. 64).

In moments of high volume and pitch, vocal production may be prioritised over intelligibility (Emmons & Chase, 2006, p. 65). As we saw in the summary of Wilson's (2014) findings, the front high vowels are often rounded (covered), so FLEECE is often realised as [y]. This is supported in Ophaug (2017), which found that the sung vowel space of four classically trained male singers is reduced in singing, partially due to the acoustic ramifications of rounding the front vowels.

As previously mentioned, in Western classical singing, Italian is preferred over English or German, which have more consonant clusters (consonant clusters disrupt the sung line), as well as 'comparatively impure or combined vowels which produce less beautiful tone quality' (Emmons & Chase, 2006, p. 64). When singing diphthongs in English (Western classical), there are specific durational distributions which typically involve elongating the first vowel quality and then moving to the second quality just before the end of the note (for example, Decker, 1977; Emmons & Chase, 2006; LaBouff, 2008, Wikan, 2017; Neuen, 2020).

Vowel quantity

The ratio of consonant-to-vowel duration of speech is not preserved in singing, with consonants typically double the length of speech – but vowels may be many times longer as they carry the tune (Emmons & Chase, 2006).

Regional accent features

Choral directors often call for the removal of regional accent features (Martin, 1892, p. 12 in Day, 2018, p. 83; Coward, 1914, pp. 86–87; Emmons & Chase, 2006). Moore writes:

> Our groups, always composed of a patchwork of students with

> dissimilar vocal backgrounds, will be a conglomerate of regional dialects, bad speech habits, and perhaps even incorrect vocal training. We must seek, through group instruction in the choral rehearsal, not only the textural sounds which are most appropriate for the music being sung as well as for the particular singers singing them, but also the fastest most efficient way of obtaining uniform pronunciation and enunciation (Moore, 1972, p. 22).

'Bad speech habits' is an example of prescriptivist standard language ideology at work in the choral literature and further supports the suggestion of a standard accent of choral singing based on a non-regional standard speech accent. Western classical choral pedagogy may aim to remove traces of regional accent from the sung signal in favour of a non-regional standard sung accent. Or, as suggested by Moore (1972) above, choir directors may tailor the overall sound to the 'particular singers singing', perhaps incorporating local accent features of the singers into the sung signal.

3.8 Summary

This literature review has covered four areas. I first outlined sociolinguistic approaches to language, sociolinguistic studies of singing, and the first sociolinguistic study of choirs. I then gave a summary of musicological research on choirs, with a particular focus on the sound of the Choir of King's College, Cambridge and its relationship to a wider 'English' choral sound. I then turned to the possible impacts of singing and choral pedagogy. This review has established that there is a lack of large-scale acoustic analyses of singing and none of choral singing. One of the major contributions of this work will be to remedy this situation by analysing recordings of choirs with a long and prolific history of recording.

We have seen how singers' phonetic choices regarding the accent of popular singing have been explained using referee design (Morrissey, 2008; Gibson & Bell, 2012). Also, musicologists have suggested that there is a particularly 'English' sound (Potter, 1998; Sagrans, 2016; Day, 2018). Is there evidence supporting a Referee Design model of Western classical choral singing as suggested by Wilson (2014), i.e. are there shared accent features between the choral singing from Glasgow and Cambridge? In Chapter 5, I analyse the recordings of two choirs from Glasgow: the Glasgow Orpheus Choir (1925–1951) and the Glasgow Phoenix Choir (1959–2016). The analysis seeks to establish whether there is evidence of change over time in choral singing from Glasgow over nearly a century of recordings (RQ 3a). In Chapter 6, I analyse the recordings of the Choir of King's College, Cambridge. In Chapter 7, I conduct a joint analysis of vowel quality produced in these two corpora to explore if there is evidence of a shared British choral phonology (RQ 1 & 2). In the following chapter (Chapter 4), I outline the methodology adopted in this thesis.

Chapter 4

Methodology

This chapter gives an overview of the methodological approaches used in this thesis. It uses a quantitative variationist sociolinguistic method to investigate whether choral singing differs by regional dialect area and whether there is evidence of change driven by time or choir director. A quantitative approach allows us to statistically correlate elements of the choral singing and other elements of the choirs such as the location, choir director and the year a recording was made. Such an approach cannot enlighten the salience of particular variables or the meanings attached by singers, directors, or audiences to particular variables.

This chapter is structured as follows. First, in Section 4.1, I detail the sample selected for analysis. In Section 4.2, I give background on the acoustics of vowels in speech. In Section 4.3, I outline the method for the acoustic analysis of choral singing vowel quality, including forced alignment, automatic formant extraction, manual formant extraction and data trimming. This acoustic method is applied in Chapters 5, 6 and 7, presenting the results of each choir separately and together. Section 4.4 of the present chapter outlines the methodology for auditory coding, which features in Chapter 8: rhoticity in the Glasgow and King's data, and Chapter 9: realisation of word-final /d/. Section 4.5 gives background to the general Bayesian statistical approach I use to analyse data in all chapters.

4.1 Sample

At this point, I will outline the sample analysed in this thesis. However, there will be additional background information for each corpus at the start of Chapters 5 and 6 respectively.

4.1.1 Glasgow Corpus

Chapter 5 reports variation and change in choral singing from Glasgow. The Glasgow Corpus features commercially released recordings of the Glasgow Orpheus Choir (1925–1951) and the Glasgow Phoenix Choir (1959–2016). The corpus includes extracts from 178 tracks (songs) from 28 albums. The Glasgow choirs were selected due to the Glasgow Orpheus Choir's prestige and broadcast history and the consistent recording of repertoire. Note that I will occasionally refer to the Glasgow Orpheus Choir and the Glasgow Phoenix Choir as the Orpheus, and Phoenix, respectively.

About the Glasgow Orpheus Choir

The Glasgow Orpheus Choir began life as the Toynbee Musical Association in 1901. Hugh S. Roberton set up the choir with the primary purpose being 'recreation. No test. Come one, come all. Rough and ready singing. Enthusiasm.' (Roberton, 1963, p. 4); 'They threw it at me in slabs' (Roberton, 1963, p. 8). In 1906, the choir broke away from the Toynbee Social Club and was refounded as the Glasgow Orpheus Choir. The Glasgow Orpheus choir went on to achieve international renown, touring the world (before tours like this became commonplace), visiting Australia, New Zealand, Canada and the United States and performing for royalty and politicians (Roberton, 1963). The Orpheus made a name for itself on broadcast radio 'from the Butt of Lewis to Land's End and far beyond' (Roberton, 1963, p. 5) with regular listeners around the Commonwealth. The Orpheus also played an important role in popularising Scottish tunes and repertoire worldwide, with Roberton arranging countless songs.

On the Choir's personnel, Roberton comments that the Orpheus was a 'classless society. Every member tested each year. Completely harmonious. The Choir's the thing. A camaraderie that transcends everything. In the ranks are, and from the ranks have come many of our best Scottish choral conductors, both men and women.' (Roberton, 1963, p. 6). We cannot take this at face value, as Glasgow's wider society is not a classless one. But it is interesting that they mention class explicitly. The Orpheus ceased to exist in 1951 when Roberton stood down as director due to ill health, and the Choir unanimously agreed to disband (Roberton, 1963).

About the Glasgow Phoenix Choir

The Glasgow Phoenix Choir was initially set up by members of the Glasgow Orpheus Choir that wanted to continue singing when the Orpheus Choir disbanded. The choir is still going to this day as a 'mixed voice SATB choir of approximately 120 singing members, ranging in age from teenagers to octogenarians' (Glasgow

Phoenix Choir, 2021). The Phoenix Choir continues to perform arrangements of Scottish traditional songs, many of them by Hugh S. Roberton, as well as classical and sacred music to popular music and music from around the world (Glasgow Phoenix Choir, 2021). There are recordings of the Glasgow Phoenix Choir almost every other year from 1959 to the present. The result is a long and, for the most part, continuous history of Choir recordings in Glasgow.

All available recordings of the Glasgow Orpheus Choir (1925–1951) and the Glasgow Phoenix Choir (1959–2016) were collected by the researcher. Detailed information about the discography of these choirs can be found in Appendix B. The basis for selecting recordings suitable for analysis is outlined in Section 4.3.1 of this chapter. Due to the cult status that the Orpheus achieved, the Glasgow Phoenix Choir recorded its most loved repertoire many times over the last 60 years. For example, there are nine different recordings of 'All in the April evening' composed by Hugh S. Roberton, ranging from being conducted by himself to a recording celebrating the centenary of the founding of the choir in 2001. This iterative recording history is excellent from an analytical point of view as it helps to constrain variation introduced by the text and the musical arrangement.

Glasgow Corpus Choir Directors

Table 4.1 shows the various choir directors of each choir and when they were active. Note, there were no recordings produced under John Cranston, and very few under Peter S. Shand, so these were collapsed into other factor levels, as shown in the table.

Table 4.1: Directors of the Glasgow choirs

<table>
<tr><th>Corpus</th><th>Dates active</th><th>Director</th><th>Coding</th></tr>
<tr><td>Glasgow Orpheus Choir</td><td>1901–1951</td><td>Hugh S. Roberton</td><td>HSR 1925–1951</td></tr>
<tr><td rowspan="5">Glasgow Phoenix Choir</td><td>1955–1983</td><td>Peter Mooney</td><td rowspan="2">PM 1959–1975</td></tr>
<tr><td>1984–1986</td><td>John Cranston</td></tr>
<tr><td>1986–1991</td><td>Peter S. Shand</td><td rowspan="3">MJS 1987–2016</td></tr>
<tr><td>1991–2016</td><td>Marilyn J. Smith</td></tr>
<tr><td>2018–Present</td><td>Cameron Murdoch</td></tr>
</table>

Glasgow Corpus discography

The Glasgow Corpus contains commercially-released recordings of the Glasgow Orpheus and Glasgow Phoenix choirs. These choirs were selected as they have a continuous history of recording from the 1920s to the present day. The recordings of these choirs were released in multiple formats, including Shellac, Long-play records (LPs) and extended-play records (EPs), compact cassettes, compact discs, and, more recently, digital downloads. I acquired all possible recordings via eBay, Discogs, Amazon, ScotDisc and Moidart publishing. For earlier recordings, of which there is less available discographic information, I made extensive use of the excellent publication, *Scottish vernacular discography, 1888–1960* (Dean-Myatt, 2013). Using Dean-Myatt's discography as a starting point (for recordings 1925–1960), I provide a discography of the recordings of the Glasgow Orpheus Choir in Appendix Table B.1, and the Glasgow Phoenix Choir in Appendix Table B.4. Later discography data is gleaned from LPs, CDs and the internet.

While I collected the original Extended Play records of the Orpheus Choir, I analysed the Moidart remastered recordings released on CD including *Glasgow Orpheus Choir: 20 Classic Recordings* and *Crimond*, as well as the Starline Long Play records. While the Starline LPs had to be digitised, and they themselves were compilations of the Orpheus Choir's earlier recordings, I opted to use them as they were better preserved than the Extended Play records.

Availability of recordings

Of the early recordings under Hugh S. Roberton, some are unavailable due to not being released. It is unclear whether these unreleased recordings are extant or where they are located. Appendix Table B.3 lists commercially-released recordings I was not able to access. Appendix Table B.2 lists all recordings of the Glasgow Orpheus Choir that were excluded. I have not provided exclusions for the Glasgow Phoenix Choir as there are many tracks that were excluded, and there are complete tracklists of the Glasgow Phoenix albums available online. As shown in Appendix Table B.5, two albums of the Glasgow Phoenix Choir were unavailable, as they were recorded while on tour in Australia under Peter Mooney. This Time/Director pair was already well represented in the Glasgow corpus, so I decided not to acquire the records from Australia as it was prohibitively expensive.

Some albums are compilations of previously released recordings – these have been excluded from analysis where each master recording is already represented in the corpus. The long play records and compact disc releases of the Glasgow Orpheus Choir are necessarily compilations, as the Orpheus recordings were originally released before these technologies had developed. The Orpheus recordings were initially released as extended play records made of Shellac, with typically two to four tracks each. While I have analysed recordings from compilations, care has been taken to ensure that each master (each recording that was made) features in the corpus only once. For example, in Appendix Table B.2, you can see that the Orpheus recordings of 'The faery song' and 'Sea Sorrow' were released over five times on extended play and long play records alone – and this does not account for more recent compact disc compilations. Recordings that were released multiple times, for example, 'All in the April Evening' (1945), are included in the corpus only once.

Glasgow Phoenix Choir has released three further albums: *St Andrew's Cathedral postcard CD* (2016), *Govan Old postcard CD* (2019), both conducted by Marilyn J. Smith, and *All in the April Evening* (2023) under their current director Cameron Murdoch. These most recent recordings were not included in this study as I was not aware of them at the time I collected the other recordings due to an incomplete discography of the choir.

4.1.2 King's Corpus

The King's Corpus includes commercially-released recordings of the Choir of King's College, Cambridge. King's was selected due to its prolific recording history and the perceived social salience of the King's sound in the British choral context (Day, 2018). The corpus includes extracts from 317 tracks from 50 albums.

There are several reasons for selecting the Choir of King's College, Cambridge, as part of the sample for this thesis. Day writes that 'the singing at King's had entered the consciousness of the English as no other choir had ever done' (Day, 2018, p. 4). Due to the choir's prolific broadcast and recording history, the rhythmical nature of the liturgical year, and the repertoire required for the office of choral evensong, King's is an excellent sample of the English cathedral or collegiate style for analysis. Because of the high-profile nature of the choir, there is also previous research on King's sound from musicology (for example, Sagrans, 2016; Day, 2018). The choir is also interesting for this research due to its perceived role in shaping this wider 'English' choral sound (Potter, 1998; Sagrans, 2016; Day, 2018).

About the Choir of King's College, Cambridge

The structure of the Choir of King's College, Cambridge, has remained the same since 1930, with 16 boy choristers, 12 undergraduate choral scholars, and typically two undergraduate volunteers. The composition of the Choir differs from the Glasgow choirs. The Glasgow Orpheus and Glasgow Phoenix choirs are both mixed voice choirs with soprano, alto, tenor, and bass sections. In contrast, the Choir of King's College is male only, with boy trebles and male alto, tenor, and bass choral scholars. The age of the singers too is also different; the Orpheus and Phoenix choirs generally had an older membership – and the Phoenix today includes teenagers to octogenarians (Glasgow Phoenix Choir, 2021). In contrast, the Choir of King's College is staffed by boys and young men. In addition, the membership of collegiate choirs such as King's has a fairly regular turnover, with the choir reconstituted around every three years, whereas the Glasgow Orpheus and Glasgow Phoenix Choirs both had long-term members.

While the Choir of King's College, Cambridge, sang frequently for radio broadcasts from the 1920s, it was not an early adopter of recording technology. There are only two recordings of the Choir pre-1945, produced under the direction of Arthur H. Mann in 1928. Boris Ord, while initially sceptical, later turned into a recording enthusiast, and there were a number of recordings made towards the end of his tenure. However, it was during David Willcocks' time as Organist and Director of Music that recording really took off:

> In the sixteen years that Willcocks was director of music there were five dozen twelve-inch long-playing discs released. In those years most cathedral choirs recorded very few twelve-inch discs, many none at all: the choirs at Westminster Abbey and New College and Magdalen at Oxford recorded fewer than half a dozen each. Canterbury recorded four LPs, Salisbury two. (Day, 2018, p. 6)

King's Choir Directors

Table 4.2 gives a summary of the directors of the Choir of King's College, Cambridge, of the recorded period investigated in this study.[1] 'Coding' year spans detail when there are recordings made (not director tenure).

Table 4.2: Recorded directors of the Choir of King's College, Cambridge

<table>
<tr><th>Corpus</th><th>Dates active</th><th>Director</th><th>Coding</th></tr>
<tr><td rowspan="7">King's</td><td>1929–1940</td><td>Boris Ord</td><td rowspan="3">BO 1945–1958</td></tr>
<tr><td>1940–1945</td><td>Harold Darke</td></tr>
<tr><td>1945–1958</td><td>Boris Ord</td></tr>
<tr><td>1957–1974</td><td>David Willcocks</td><td>DW 1959–1974</td></tr>
<tr><td>1974–1982</td><td>Philip Ledger</td><td>PL 1976–1982</td></tr>
<tr><td>1982–2019</td><td>Stephen Cleobury</td><td rowspan="2">SC 1984–2019</td></tr>
<tr><td>2019–present</td><td>Daniel Hyde</td></tr>
</table>

There is one record made under Arthur H. Mann from 1929, which is unaccompanied. However, this recording was excluded as there were few recordings from the time, and the recording is quite noisy.[2] There is one recording made under Harold Darke during Boris Ord's service in the RAF from 1941–1945,

[1] Note there is information relating to the college fellow that directed the choir going back to the early seventeenth century.

[2] You can listen to a digitisation of the recording on YouTube here: (`https://www.youtube.com/watch?v=iue8jGxlqVM`.

which is included under Ord. As there was only one album recorded by the Choir of King's College under the direction of Daniel Hyde at the time of analysis, the record was collapsed into the factor level SC = Stephen Cleobury.

King's Discography

While the Choir of King's College, Cambridge has broadcast and recorded prolifically, as well as being of academic interest (for example, Rugen, 2013; Day, 2014; Sagrans, 2016; Day, 2018), there is no published complete discography of the choir. The closest thing is the Recording and Broadcast Catalogue of the Archive of Recorded Church Music (Brownlee, 2023), which I used as a starting point. The full discography of the recordings of the Choir of King's College, Cambridge analysed in this research, can be found in Appendix Table B.6.

4.2 Vowels

The sociolinguistic variables analysed in Chapters 5, 6, and 7, are vowels. Vowels are voiced sounds produced with pulmonic airflow and typically no obstruction of the vocal tract (Ladefoged, 2006). Vowels are typically produced with a convex tongue shape and minimal friction (Ogden, 2009, p. 56).

In sociophonetic or dialectal studies of vowel quality, lexical sets (Wells, 1982a) are often used to group together all words that will predictably select comparable phonemes. For example, Wells (1982a) uses lexical sets to facilitate the comparison of Received Pronunciation and General American (and many other varieties of English). In this study, I will examine the monophthongs FLEECE, KIT, DRESS, TRAP, BATH, STRUT, LOT, THOUGHT, FOOT, and GOOSE, as well as `commA`. Taking FLEECE as an example, this lexical set refers to any words with the same vowel as the word FLEECE in Received Pronunciation or Southern Standard British English. For example, *keep*, *beat*, *sneak*, *wheel*, *alleviate*, *seamless*, and all words that contain a similar vowel (in RP or SSBE).

These lexical sets allow us to systematically compare the phonetic quality of vowels with a known lexical distribution across accents. This study investigates the accent of choral singing from Glasgow (Chapter 5), Cambridge (Chapter 6), and compares the accent of choral singing from Glasgow and Cambridge (Chapter 7). While singing at Cambridge is assumed to be produced with an RP or SSBE phonology, this is unlikely in Glasgow, where the speakers, even middle-class choral singers, would have a different phonology for their speech. For example, speakers of Standard Scottish English would usually not have separate lexical sets for TRAP–BATH, LOT–THOUGHT, and FOOT–GOOSE, instead having three lexical sets CAT, CAUGHT, and BOOT which select /a and ɑ/, /ɒ and ɔ/ and /ʉ/ (Abercrombie, 1979). Analysing the Glasgow choral singing using the common lexical sets will allow us to directly compare the phonology and realisation with the singing from Cambridge. That is, does Anglo-English phonology appear in choral singing in a Scottish-English dialect area?

4.2.1 Acoustics of vowels

At a simplistic level, different vowels are produced by altering the highest point of the tongue, and the backest point of the tongue, and whether the lips are rounded or spread (Catford, 2002). Acoustically, vowels are conceptualised using the source–filter model of speech production (Fant, 1960). In the source-filter model, the vibrations produced by the vocal folds in the larynx are considered the *source*. The voice source is a spectrum of frequencies (as seen in Figure 4.1). The supra-laryngeal vocal tract (everything above the larynx) acts as a *filter*.

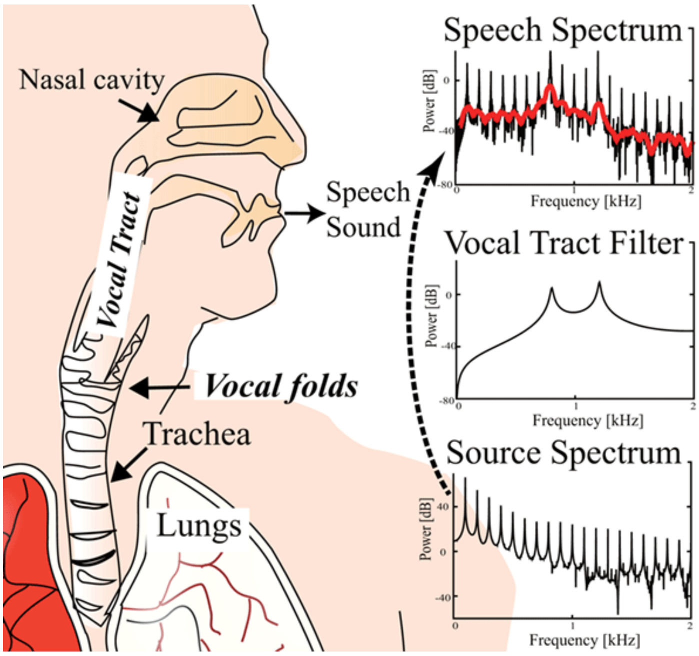


Figure 4.1: Diagram of the source-filter model of speech production from (Tokuda, 2021)

As can be seen in Figure 4.1, the vocal tract 'filters' the voice source because it amplifies some frequencies while damping others (Ladefoged & Johnson, 2015). Formants are the resonances (peaks) created by the filter. By changing the position and shape of the tongue, we alter what frequencies of the source are boosted or suppressed, and this, in turn, changes what vowel sound is perceived by the listener. The right side of Figure 4.1 shows three idealised spectrums. Spectrums are typically created by applying a smoothed Fast Fourier Transformation to the acoustic waveform.

Often phoneticians work with spectrograms. As shown in Figure 4.2, spectrograms

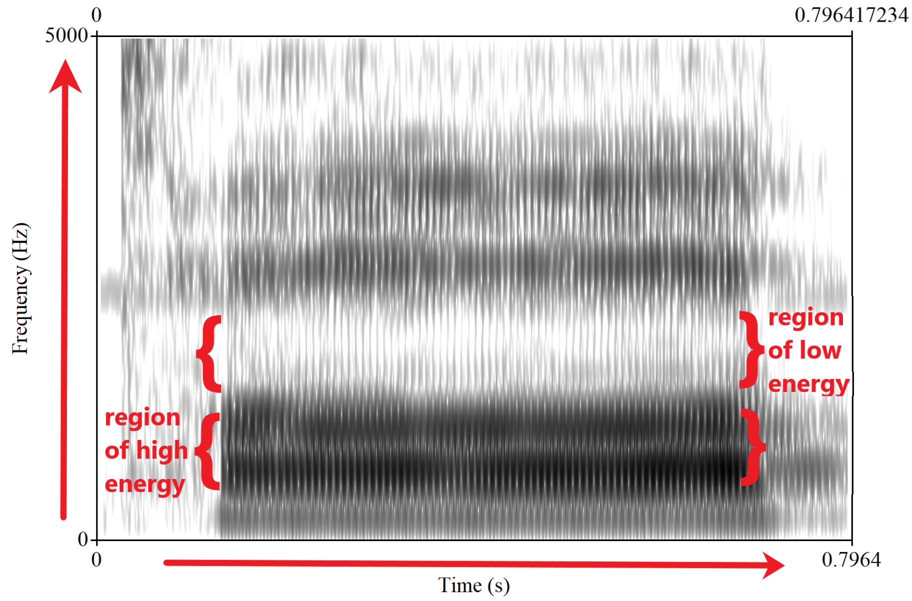


Figure 4.2: Annotated spectrogram of the researcher speaking the syllable ‘ta’ /tɑː/

show frequency over time, with higher amplitude regions of energy represented by a darker colour. The lowest amplitude regions (silence) are white, whereas the strength of the amplitude of frequencies represented is indicated in greyscale. The spectrogram is essentially many, many spectrums rotated and aligned.

Different acoustic vowel qualities are associated with different patterns of spectral frequency and intensity (Johnson, 2012). These acoustic qualities can be extracted from spectrograms. While intelligibility has been reported to decrease in Western classical operatic singing, particularly at high fundamentals (Gregg & Scherer, 2005), the fact that we are able to distinguish sung words at all tells us that acoustic speech patterns are, to some extent, preserved in choral singing. Figure 4.3 shows a waveform and spectrogram of Hugh S. Roberton, director of the Glasgow Orpheus Choir, reading the title of one of his compositions, *All in the April evening*. For comparison, Figure 4.4 shows the same phrase sung by the Glasgow Orpheus Choir. All figures containing waveforms and spectrograms with Praat TextGrids were produced using a Praat script (Pearce, 2023). Annotations to plots were manually added in Microsoft Paint or Microsoft Paint 3D.

Roberton’s reading lasts just over two seconds, whereas the sung version is over five seconds long. If you focus on the pattern of the first two words *All in* in both figures, they reveal a higher region of energy around 2–3 kHz that lowers and a region of energy around the 1,000 Hz region that rises. There is a loss of distinction in the formants that is characteristic of spectrograms of choral singing. However, it is also clear that there are regions of greater amplitude and regions of lower amplitude. For example, the increase in F2 is noticeable for FLEECE in the first vowel of the word *evening*, with the increasing white space showing the

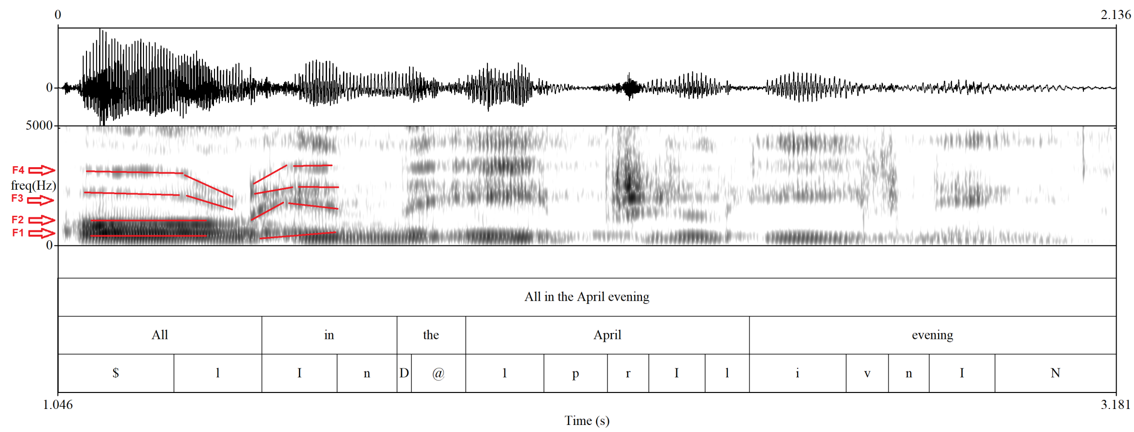


Figure 4.3: 'All in the April evening', spoken by Hugh S. Roberton

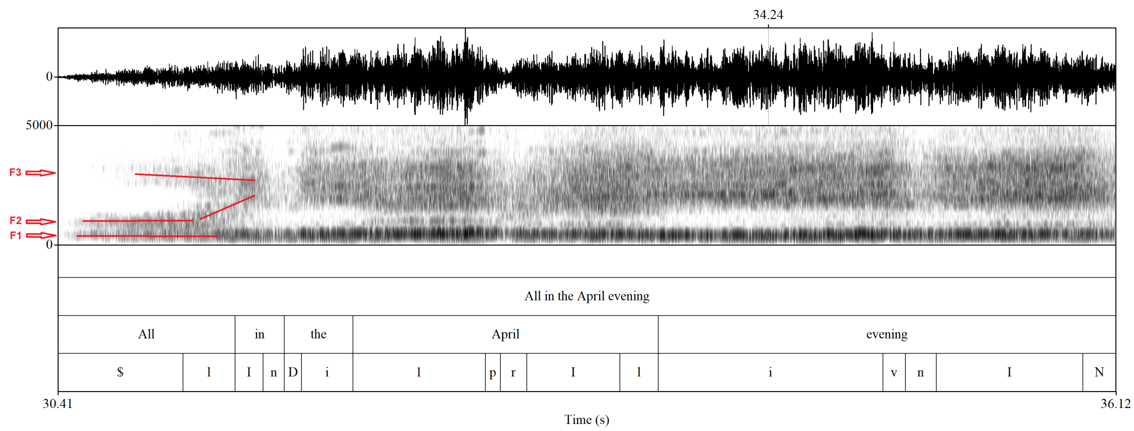
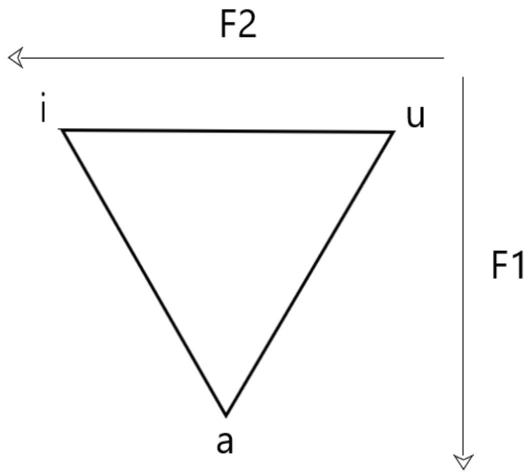


Figure 4.4: 'All in the April evening', sung by the Glasgow Orpheus Choir

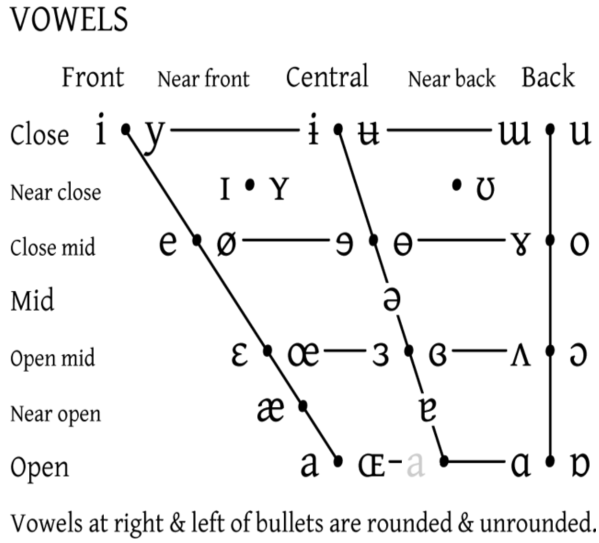
separation of F1 and F2, which is characteristic of the high front vowel, FLEECE.

Formant values can be extracted from spectrums and/or spectrograms. The highest point of the tongue acoustically correlates to F1, the first formant. The backest point of the tongue correlates with F2, the second formant. Thus the acoustic vowel space can be conceived as a two-dimensional cartesian plane with F1 relating to height and F2 relating to backness. Figure 4.5a shows a triangular vowel space containing the point vowels /i/ (FLEECE), /a/ (TRAP), and /u/ (GOOSE).[3] As seen in Figure 4.5a, /i/ is acoustically the highest (low F1) and frontest (high F2). /u/ is the highest (low F1) and most back (low F2). /a/ is the lowest (highest F1) and front–central (average F2). The International Phonetic Alphabet (IPA) is a system of phonetic notation that allows users to transcribe speech in a standardised way across languages and varieties (International Phonetic Association, 1999). Figure 4.5b shows the IPA vowel chart; The vowels are arranged in a quadrilateral based on three variables: Height, Backness, and (lip-)Rounding.

[3]In UPSID, a corpus of 317 languages, these are the three most frequently occurring vowels (Maddieson & Disner, 1984, p. 125).



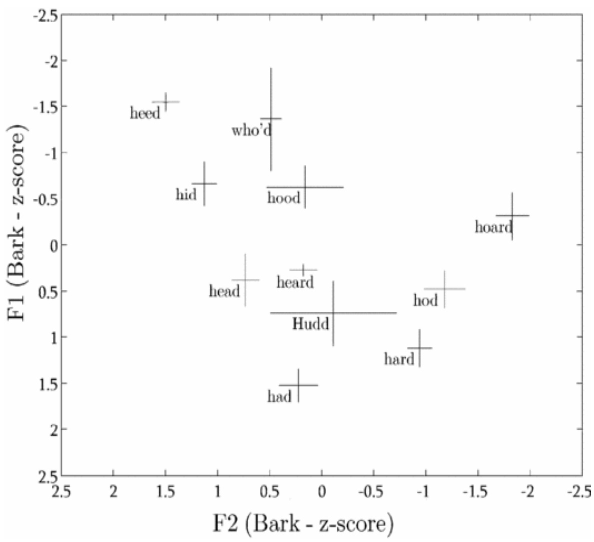
(a) Idealised triangular vowel space



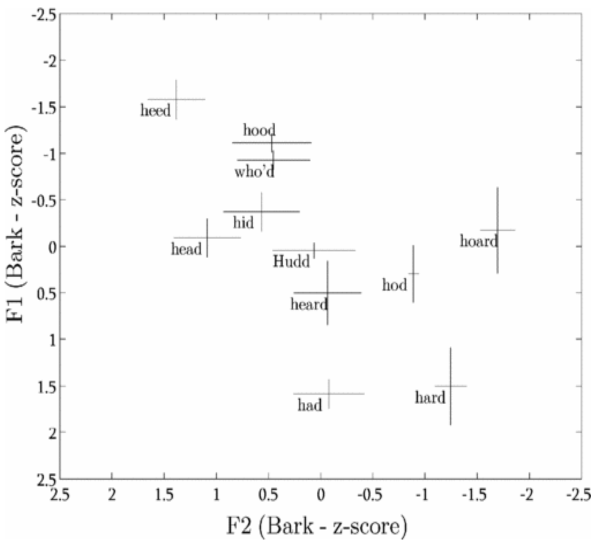
(b) IPA Vowel Chart (2005)

Figure 4.5: Idealised triangular vowel space showing point vowels FLEECE /i/, TRAP /a/, and GOOSE /u/ and the vowel space as represented by the International Phonetic Association Vowel Chart (International Phonetic Association, 2015)

Figures 4.6a and 4.6b show acoustic vowel plots of male speakers of Southern Standard British English and Glasgow English, respectively. Both vowel plots show that the GOOSE vowel (*who'd*) is acoustically quite front in realisation. In the SSBE plot, there is a clear separation between *who'd* and *hood*, whereas there is no difference between them for the Glasgow speakers. If the acoustic qualities of sung vowels are based directly on the spoken vowel qualities of the singers, I would expect the vowels to be distributed similarly in the vowel space.



(a) SSE – Figure 3. from Ferragne & Pellegrino (2010)



(b) Glasgow – Figure 21. from Ferragne & Pellegrino (2010)

Figure 4.6: Example vowel spoken vowel spaces of six male speakers of Southern Standard English and seven male speakers of Glasgow English from Ferragne & Pellegrino (2010)

4.2.2 Previous analyses of vowel quality in singing

In this section, I will briefly touch on the kinds of methodologies sociolinguists have used to investigate vowel quality in singing. Multiple studies have investigated vowel quality using auditory coding (see Section 4.4) combined with a mixture of qualitative and quantitative approaches. For example, Trudgill (1983) describes how English rock and pop singers typically realise the PRICE vowel as the monophthong [a] (instead of the typical diphthong [aɪ]), or LOT may be realised as the American [ɑ] rather than the British [ɒ] in words such as *body*, or *top*. Similarly, Wilson (2014) provides auditory analysis of corrections relating to vowels in choir rehearsals. Krause & Smith (2017) and Flanagan (2019) provide quantitative analyses of auditory coded data. Yang (2018) interprets spectrograms qualitatively in combination with auditory methods to show how diphthong trajectories differ between Lenka's singing and speech.

There are a number of studies that have compared the spoken and sung vowel space of singers quantitatively using acoustic methods. Ophaug (2017) compares the spoken and sung vowel space of four operatically trained baritone singers. However, it is unclear how the formants were measured or the resulting number of tokens for each participant in each condition. Caillol & Ferragne (2019) investigate the FOOT–STRUT split in the singing and speech of the lead singers of the bands Def Leppard and Iron Maiden. They use formant data extracted from singing and speech manually in Praat. However, the authors found that:

> While formant estimation was quite challenging in the interviews due to speech type (spontaneous) and the poor quality of some recordings, most vowels from the isolated sung tracks had to be discarded because no formant contours were visible in the spectrograms. Formant data from sung vowels was available for 24 /ʌ/ and 6 /ʊ/ for Iron Maiden, and 25 /ʌ/ and 6 /ʊ/ for Def Leppard (Caillol & Ferragne, 2019).

Gibson & Bell (2012) analysed the vowel quality of three New Zealand singers in singing and speech. Vowel formants were extracted automatically using Praat. The authors selected the vowels DRESS, TRAP, THOUGHT, LOT, START (BATH), GOOSE, GOAT, and PRICE. For monophthongs, measurements were taken from the vowel's target point and determined using F1 and F2 minima and maxima. For diphthongs, measurements were taken, as far as possible, from steady-state points. Gibson & Bell (2012) is the most complete in the data provided; however, GOOSE, START, LOT, and DRESS each had less than 10 tokens for each speaker in the sung or spoken condition.

Acoustic studies of singing from pedagogical perspectives have shown that, in Western classical operatic singing, singers balance corresponding front and back vowels, which allows for greater timbral uniformity or *chiaroscuro*. In acoustic phonetic terms, the singers aim to produce the different vowel phonemes with a similar amplitude or intensity, in each part of the voice (i.e. at low, middle and high pitches), by adapting the vowel qualities, in order to 'balance' them. In an experiment investigating this phenomenon, Dromey et al. (2011) found that 'for the sustained vowels, all formant changes suggested a more neutral tongue position after the training' (Dromey et al., 2011, p. 678), suggesting that some types of vocal training may have a centralising effect on vowel quality. Ophaug (2017) compares the spoken and sung vowel spaces of four (Western) classically-trained baritone singers (mid-low male voices). She finds that the sung vowel space is reduced in size and more central than the spoken vowel spaces of the singers. Ophaug attributes this to rounding the front vowels, which causes F2 to decrease, and jaw lowering, which causes F1 to increase. Gibson & Bell (2012) also find that the sung vowel space of their participants (male pop singers from New Zealand) is more open (lower jaw and/or tongue) than the spoken vowel space, so it is possible that this is a uniform effect of singing, regardless of genre. However, future work is required to investigate the general impact of singing across genres.

As we have seen, a handful of studies have attempted acoustic analysis of solo singing from a sociolinguistic perspective. However, on the whole, they have tended to be based on small datasets with few participants and a small number of tokens. In addition to answering whether there is a shared non-regional phonology in British classical choral singing, this research provides a large-scale analysis of acoustic vowel quality in choral singing.

4.3 Acoustic analysis of choral signal

4.3.1 Designing the choral corpus

The recordings selected for analysis were restricted to those sung in *English*. English was motivated by the research questions, that is, whether there are differences in choral singing across dialect areas in the United Kingdom. Selecting one language allowed me to control for the effect that language will inevitably have on the variables selected, for example, vowel quality. In addition, the recordings available were predominantly in English. We would expect choirs to sing differently when singing in other languages. Today elite Western classical choirs are expected to sing in many languages from the more 'traditional' romance languages (such as Italian, French, German and Latin), Slavonic languages (Russian, Old Church Slavonic), Nordic languages (Danish, Swedish, Norwegian, Icelandic, Finnish), and increasingly Asian languages such as Mandarin Chinese, Japanese, Korean, and Malay. In addition to choral arrangements of music in the local language(s) of where the choir is based, for example, choral arrangements of calypso in Trinidad (Wilson, 2014).

For the Glasgow choir data presented in Chapter 5, Scottish vernacular items (Scots) were included in the analysis and coded as 'Scottish Vernacular' in the factor Genre (as opposed to Church Music and Other Popular). The Choir of King's College, Cambridge, has recorded a large amount of music in ecclesiastical Latin, for example, renaissance motets like Gregorio Allegri's *Miserere mei, Deus* (Psalm 51, Have mercy upon me, O God). However, recordings not explicitly in English or Scottish English (and occasionally, Scots) were excluded from this study.

The recordings analysed in this research were *unaccompanied*, that is, not including any musical instruments. Musical accompaniments used by these choirs included: organ, piano, string quartet and solo violin. Recordings with accompaniment were excluded, as they have additional acoustic information, which may affect the formant data extracted. For example, with piano accompaniment, there is a percussive onset which the forced aligner may associate with plosive consonants. In addition, the acoustic data relating to vowel quality could be influenced by different kinds of instruments, like wind or brass instruments, or organ, the timbres of which are also identified by features of the spectral envelope, like formants (Hall & Beauchamp, 2009). As far as possible, all tracks analysed were unaccompanied; however, for some tracks, this had to be evaluated by ear where reliable metadata was unavailable. Consequently, some accompanied excerpts might have slipped through, though if inaudible, they should have little impact on the overall acoustic profile. In addition, the structure of the statistical model should be able to control for this kind of recording-specific variation (see Section 4.5).

Finally, the recordings had to be *homophonic*. That is, there is a simple texture with only one word being sung at a time, such as with hymn or psalm singing. In polyphonic music, there can be more than one word or syllable sung at a time, meaning it would be impossible to align and extract the formant data without it being a mixture of different vowel qualities and/or consonants.

The combined corpora include data from 511 tracks, which have been automatically aligned with their associated texts yielding 42,607 word tokens of 3,126 word types. The total duration of recordings is just under 26 hours, from 78 different albums.

In order to align the texts and recordings, I first located the text of the track (song), either from Compact Disc liner notes, online, or, as a last resort, transcribed by ear. I created single interval tiers in Praat (Boersma & Weeninck, 2018), which I pasted the text into. These interval tiers were manually divided into chunks of approximately ten seconds or less, with a gap of silence between each chunk of combined sound and transcript. These Praat TextGrids and the recordings were uploaded to the electronic speech corpus management software LaBB-CAT (Fromont & Hay, 2012). In LaBB-CAT, phonemes were annotated automatically from the CELEX dictionary (Baayen et al., 1995). Word and phoneme boundaries were aligned in LaBB-CAT using the Hidden Markov Model Toolkit (Young et al., 2009).

The example used in Figure 4.7 is taken from the opening line of 'Once in Royal David's City', sung by a solo treble from King's at the start of the annual broadcast of the Service of Nine Lessons and Carols (2010). When the TextGrids are initially uploaded, they looked as shown in Figure 4.7.

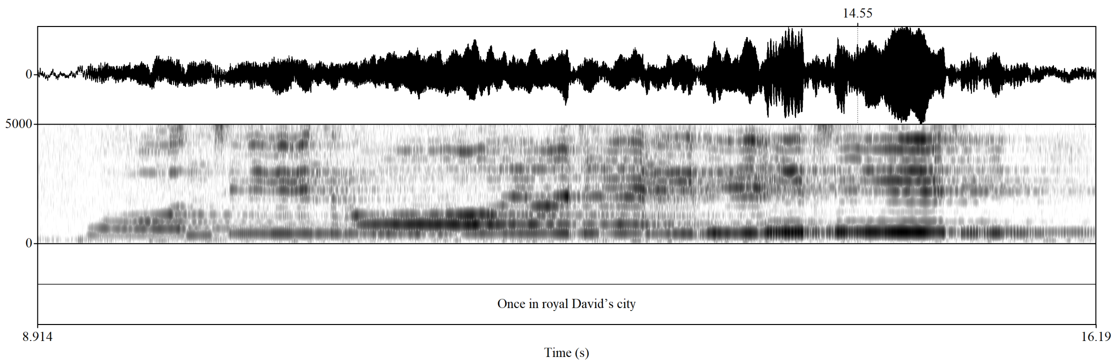


Figure 4.7: TextGrid prior to CELEX dictionary phonemes and HTK alignment

4.3.2 Forced alignment

LaBB-CAT is phonetic software designed to store corpora of sound data built by Fromont & Hay (2012). It allows the researcher to query the corpus and process the data. In LaBB-CAT, the text phonemes were labelled using the CELEX English dictionary (Baayen et al., 1995). This means that for each word in the text, the associated dictionary pronunciation was found and added to a new tier. Thus far, there is a word tier where the words have been separated (not aligned), and a new tier with the phonemes (dictionary pronunciation) has been added. When the text phoneme annotations have been added, an aligner attempts to match every speech sound with a portion of the acoustic signal. The phoneme layer and sound files were aligned using the Hidden Markov Model Toolkit (HTK) (Young et al., 2009) in LaBB-CAT.

To prepare the sound files for forced alignment, they were converted to mono in Praat. The sound files were automatically downsampled to 11,025 Hz as part of the HTK alignment procedure in LaBB-CAT. This has been found to improve aligner accuracy.

It is important to note that, as far as the author is aware, no forced aligner has been trained to work with choral singing. As anticipated, applying the HTK model to choral singing data had mixed results. Some chunks were surprisingly accurate, and some quite the opposite! There was no simple way of quantifying how accurate the aligner was. I estimate that the aligner was about 50% accurate; it provided a much better start for hand correction than annotating and hand aligning the whole corpus from scratch. Figure 4.8 is an example of the same chunk from Figure 4.7 after forced-alignment has been applied, prior to hand correction:

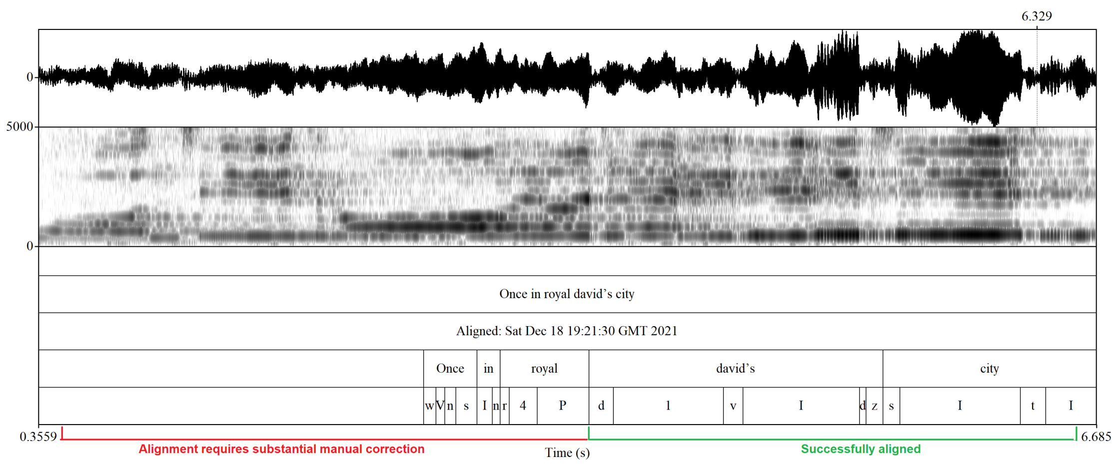


Figure 4.8: TextGrid after CELEX phonemes added and HTK aligned

As seen in Figure 4.8, the HTK automatic alignment sometimes works surprisingly well with sung data; the aligner has aligned 'David's city' nearly perfectly. However, the 'Once in royal' part needs substantial hand-correction.

I proceeded to manually correct the alignments at the word level and segment level for all sounds. The aligner performed better for certain sounds than others. For example, in the figure above, 'David's city' is better aligned because of the obstruent consonants (plosives and fricatives). Fricatives have high-frequency energy that is easier for the aligner to separate from the surrounding vowels. Plosives have a period of closure followed by a puff of air that appears also easier for the aligner to detect. The aligner is less successful for sonorant consonants (nasals, laterals, approximants and glides) like /n/ as in 'news', /l/ as in 'lose', /r/ 'ruse', /j/ 'use' and /w/ 'woos'. A hand-corrected TextGrid of the same chunk is shown in Figure 4.9.

4.3.3 Hand correction of forced alignment

Each TextGrid was hand-corrected by listening to the sound file and visually inspecting the alignment of the waveform and spectrogram. Hand correction was primarily auditory, meaning that it is somewhat impressionistic. However, for the

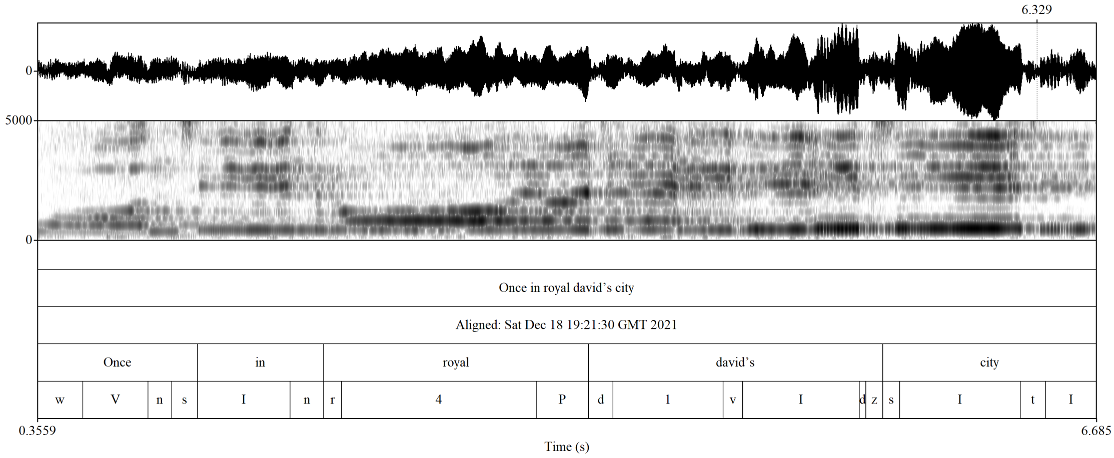


Figure 4.9: TextGrid after HTK alignment and hand correction

acoustic analysis, the impact of the alignment is minimised by various factors. I am investigating monophthongs (single target, simple vowel qualities). Acoustic measurements are averaged over seven time points equally distributed between 20%–80% of the vowel portion (0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8). I also apply statistical trimming methods to remove unlikely tokens. For these reasons, it does not matter if the alignment is not extremely accurate at a very fine-grained level – though, of course, I have attempted to make the alignment as accurate as possible.

4.3.4 Hand correction of phone labels

Phones were automatically labelled using the CELEX-English phoneme dictionary (Baayen et al., 1995). CELEX-English represents conservative Received Pronunciation canonical pronunciation. This means it is not an accurate representation of the vowel space for Scottish speakers; it is also not always correct for contemporary Southern Standard British English speakers either, for example, characterising the HAPP-Y vowel as [ɪ] as in KIT, where it is now categorically [i] as in FLEECE. However, labelling both of the corpora with the same 'incorrect' system allows me to directly compare variation in the realisation of underlying phonemes.

Occasionally, the phone label from the phoneme dictionary was incorrect. For example, orthographic $< a >$ in English is variably produced as the diphthong /ei/ as in FACE, or as /ə/ (schwa). However, $< a >$ was categorically transcribed as /ei/ even when it is frequently the short, unstressed, mid-central vowel /ə/ (schwa). I manually corrected these instances as and when I came across them. This confusion is also often the case with the TRAP phoneme, which is often a mislabelled /ə/ vowel. Likewise, $< the >$, which is variably realised as FLEECE /ði:/ or schwa /ðə/, is often mislabelled. Other less frequent words can have multiple pronunciations, for example, $< aye >$ can be produced using either the FACE /ei/ or PRICE /ai/. I have tried to correct these instances as systematically as possible throughout.

There are also instances where, in singing, a vowel is stressed where it is not in speech, and consequently, the vowel phonology differs. CELEX-English is based on Received Pronunciation. However, even in the earliest recordings I have of the choir of King's College, Cambridge, the word-final HAPP-Y vowel is almost categorically produced as /i/ as in FLEECE, rather than /ɪ/ as in KIT. For example, $< lady >$ is produced /leidi/ rather than /leidɪ/, $< heavenly >$ is produced /hɛvənli/ rather than /hɛvənlɪ/. I have corrected as much as possible as I have gone through.

Occasionally, words were not produced at exactly the same time – with consonants moving at different times as specified by the composer or arranger, or instances where the choir was less synchronised. In these cases, I stretched out the consonant segment, reducing the surrounding vowel segments slightly in order to make sure the vowels were as clean as possible for the acoustic measurements, as they are the primary area of interest for the acoustic analysis presented in this thesis.

CELEX-English does not take into account coarticulatory speech processes. Each word is labelled in isolation. For example, there are a few examples of sibilant assimilation, for example, where the phrase $< those\ ships >$ is produced with only one fricative sound in the middle [ðəʊʃɪps]. In this case, there are two separate fricatives annotated by CELEX /z/ and /ʃ/. As I am not currently investigating fricatives, in these cases, I have placed the word boundary approximately halfway through the long /ʃ/. If we want to investigate fricatives in future, they will have to be coded and hand-corrected in a new tier or excluded.

In addition, some words are systematically produced without rhoticity which in the dictionary are rhotic, and some words are produced with rhoticity due to following vowel-initial words (for an overview of rhoticity see Section 8). This means that the word *fear* in standard dictionary pronunciations of SSBE would be pronounced [fɪə], but in contexts where a vowel follows (for example, *fear of*), it would typically be realised as [fɪəɹ]. This is known as linking /r/ (Wells, 1982a) and will be discussed in Chapter 8. The methods used to automatically assign phonemes from dictionaries are not usually sensitive to the following context. For words where orthographic /r/ is not articulated in the choral signal, I have left the /r/ phoneme in the transcript but made the segment annotated as /r/ very short. Where there is rhoticity present in the recordings that is not transcribed by the automatic phonemic transcription, I have manually inserted /r/ as much as possible to account for the effect of Following Segment in the vowel formant analyses.

As I initially mainly focused on acoustic vowel quality, I expanded adjacent consonant segments slightly to take up a small part of the vowel portion. I did this with the aim of reducing the impact of coarticulation on vowel quality. Vowel–vowel coarticulation is comparatively much less common, but in these cases, I have placed the boundaries by listening and visually inspecting formant transitions. I also control for the impact of the following segment in all statistical models reported.

4.3.5 Automatic formant extraction

Formant data were extracted for F1, F2 and F3 from seven time points equally distributed from 20–80% of the way through the vowel interval for all monophthong vowels: FLEECE, KIT, DRESS, TRAP, BATH, STRUT, LOT, THOUGHT, FOOT, GOOSE, and SCHWA (yielding over 27,000 tokens). Using this method should reduce unwanted variation, such as the impact of coarticulation (the impact of an adjacent vowel or consonant). I then averaged over these time points to create the values I used for the following visualisation and analysis.

Vowel formants were extracted in LaBB-CAT (Fromont, 2019; Fromont & Hay, 2012; Fromont & Watson, 2016), using the Praat function 'Sound: To Formant (burg)'. This 'performs a short-term spectral analysis, approximating the spectrum of each analysis frame by a number of formants.' (Boersma & Weeninck, 2018)

4.3.6 Praat settings

The Praat settings were kept at default settings: time step 0.0; Window length 0.025 (s); Pre-emphasis 50 Hz.

Max number of formants

The max number of formants was set to 5. The maximum number of formants is quite important. Setting too high or too low a number means that the Linear Predictive Coding algorithm attempts to find formants that are not there, or it can combine multiple formants into one. It is unknown what the most appropriate number of formants to set for choral singing or singing more generally. I have assumed for this research that the appropriate number is the same as in speech. However, it is possible this may not always be optimal. For example, if choral tenors use the singers' formant in the 4–5 kHz range, this could affect the number of formants (see Section 4.3). However, this is less likely to occur in choral singing.

Formant ceiling (Hz)

The formant ceiling was set to 5,000 Hz. The formant ceiling is the maximum frequency of the formant search range in Hz. Boersma & Weeninck (2018) write that ‘it is crucial that you set this to a value suitable for your speaker’. Formant ceiling is usually altered for speakers with high or low voices, as it is affected by the fundamental frequency. However, it is unknown what value is most suitable for choral singing (and joint speech), as we are trying to approximate formant values from various vocal tract lengths. As I am mostly interested in F1 and F2 I opted for 5,000 Hz in the hope it would be more accurate when F1 and F2 are lower…‘if you choose a too high ceiling, you may end up with too few formants in the lower frequency area’ (Boersma & Weeninck, 2018).

Examples of the results of Praat automatic formant extraction can be found in Figures 4.10 and 4.11.

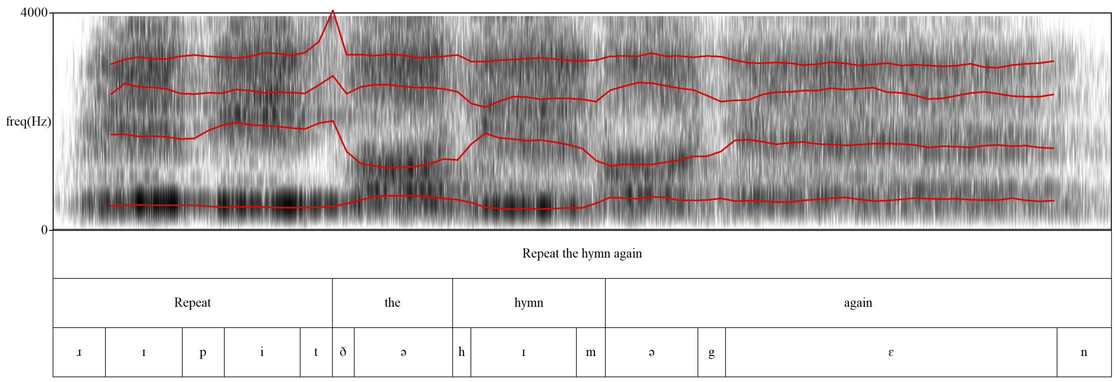


Figure 4.10: Example spectrogram with formant tracks of ‘Repeat the hymn again’ from ‘A Great and Mighty Wonder’ (King’s, A Festival of Lessons and Carols, 1964, directed by David Willcocks), showing good estimation of first and second formants in Praat. Measures were taken for the underlined instances of the FLEECE, KIT, DRESS, and SCHWA vowels.

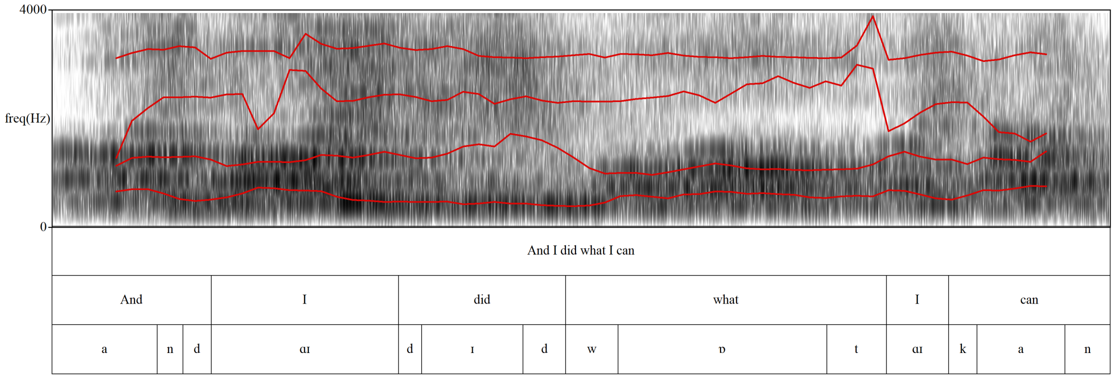


Figure 4.11: Example spectrogram with formant tracks of 'And I did what I can' from 'Remember, O Thou Man' (King's, A Festival of Lessons and Carols, 2008, directed by Stephen Cleobury), from a poorer-quality recording. Measures were taken for the underlined instances of the KIT, TRAP, and LOT vowels.

4.3.7 FOOT–GOOSE

Upon inspection, the high back rounded vowel (/u/ as in GOOSE) formant frequencies were quite poorly estimated compared to the others. This is a well-documented problem which can occur with the high back vowels, when GOOSE is indeed a high back rounded vowel (unlike contemporary /u/ across many varieties of English), as F1 and F2 are very close together (Ladefoged, 1967). This is often mistaken by the algorithm in Praat for one peak, leading to F2 being put in the F3 region. This is problematic from an analysis point of view, as the statistical trimming methods discarded many more tokens than necessary. Consequently, I took hand measurements using Linear Predictive Coding (LPC) spectra in Praat for GOOSE and FOOT.

4.3.8 Manual formant extraction

I used a Praat script adapted from Jane Stuart-Smith, which selected the full vowel interval, created a Fast Fourier Transform (FFT) and Linear Predictive Coding (LPC) spectra, and opened the LPC and the FFT spectra side by side to visually compare them. The script then took point values from the cursor location, and I used this method to extract measurements of up to the first 5 (typically 3) peaks. An example of FFT and LPC spectra can be seen in Figure 4.12, which shows the GOOSE vowel from the word *to*, as sung by the Glasgow Orpheus Choir. This LPC was made with 8 peaks. In this example, F1 = 401 Hz, F2 = 892 Hz, F3 = 2,987 Hz.

LPC spectra were automatically generated with 12 poles (in more recent versions of Praat, this is equivalent to 6 peaks), which overall seemed to fit most of my data. However, there was a large portion of the data that this did not work for.

Rather than discard these data points, I flagged the tokens that this was unsuitable for and returned to them later. For each flagged example, I found the best number of poles ranging from 8–24.

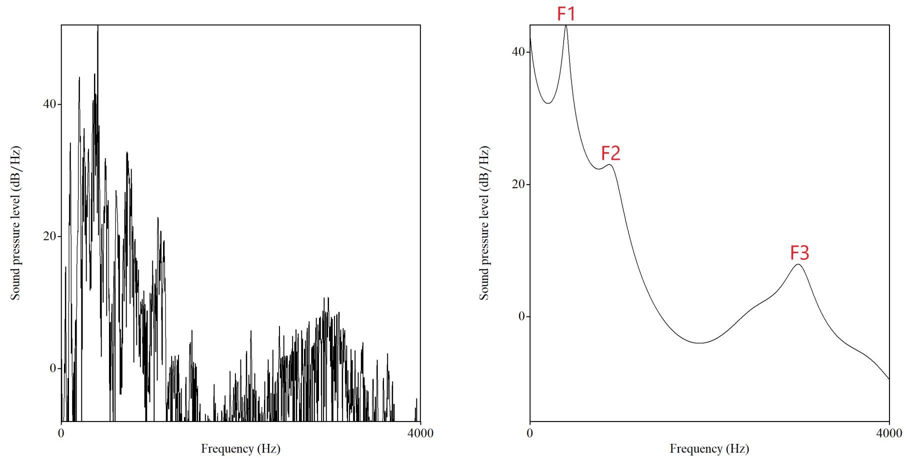
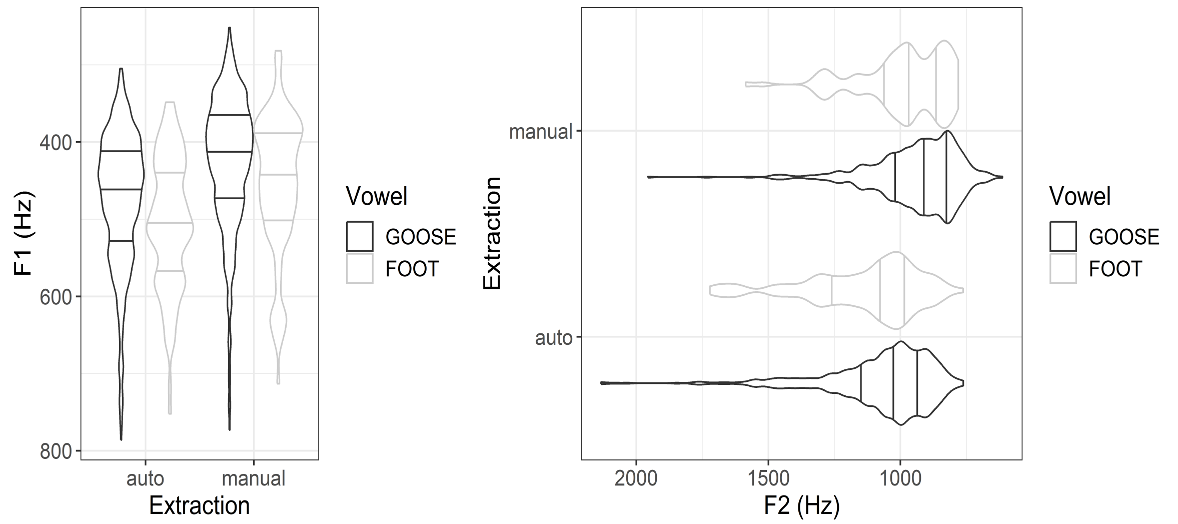
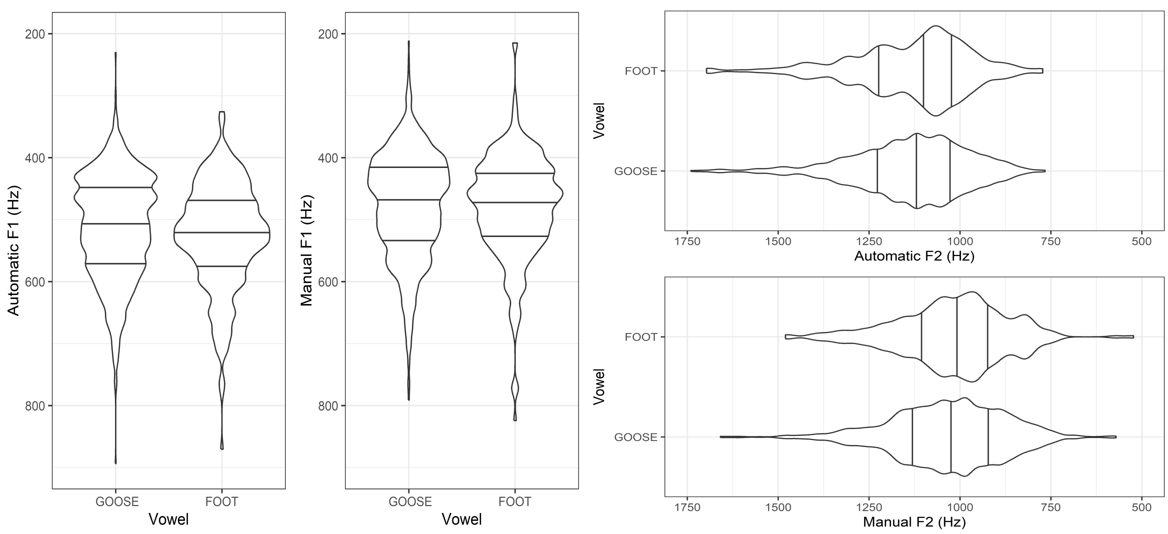


Figure 4.12: Example FFT (left) and LPC (right) spectra of the GOOSE vowel from the word *to*, sung by the Glasgow Orpheus Choir.



(a) Violin plot of F1 (Hz) (b) Violin plot of F2 (Hz)

Figure 4.13: Violin plot of vowel formants for GOOSE and FOOT, by method of extraction for Glasgow Corpus.



(a) Violin plot of F1 (Hz) (b) Violin plot of F2 (Hz)

Figure 4.14: Violin plot of vowel formants for GOOSE and FOOT, by method of extraction for King's Corpus.

As can be seen in Tables 4.3 and 4.4, and Figures 4.13 and 4.14, overall manually extracted formant values for GOOSE–FOOT were lower in F1 and F2 for both Glasgow and King's data, meaning that GOOSE–FOOT are acoustically higher and backer in the vowel space acoustically – closer to cardinal vowel 8 /u/ (and not like contemporary spoken SSBE /u/, and certainly not like SSE barred /ʉ/. The standard deviation is lower for all manually corrected formants in both corpora, but particularly noticeably for FOOT F2. In the models reported in Chapters 5, 6, and 7, the data used for GOOSE–FOOT are the manually extracted data.

The trade-off for using these methods (forced alignment and automatic formant extraction) is time versus discarding a significant portion of the data (for example,

Table 4.3: Comparison of automatic and manual formant extraction for Glasgow Corpus GOOSE–FOOT. (Values in Hz. N = 585)

Extraction	Vowel	F1 Mean	F1 SD	F2 Mean	F2 SD
Automatic	GOOSE	475	87	1073	206
	FOOT	505	85	1136	218
Manual	GOOSE	424	84	939	163
	FOOT	454	90	987	167

Table 4.4: Comparison of automatic and manual formant extraction for King's Corpus GOOSE–FOOT. (Values in Hz. N = 1,334)

Extraction	Vowel	F1 Mean	F1 SD	F2 Mean	F2 SD
Automatic	GOOSE	513	83	1142	177
	FOOT	527	85	1138	180
Manual	GOOSE	476	83	1030	166
	FOOT	480	95	1019	151

Reddy & Stanford, 2015). In this case, it would have been impossible to investigate recordings of multiple choirs or over time if I had hand-corrected each individual formant value. This is widely accepted within corpus phonetics research, and it is not unheard of to discard up to one-third of the data. This is why I had to be pragmatic and only hand correct as essential (as in the case of GOOSE–FOOT above).

Thankfully, as seen in Chapters 5, 6, and 7, formants in the choral signal are robust to Sound-to-Noise ratio (SNR) in line with Rathcke et al. (2017). This means that despite the additional noise in the signal created by multiple people singing together, any cues that we usually use to evaluate vowel quality in speech are robust enough to be used to differentiate acoustic vowel qualities in choral singing.

4.3.9 Duration

Following Dodsworth (2013), vowel tokens of less than 50 ms were removed prior to vowel normalisation and statistical trimming to remove any qualities that are reduced to schwa that were not corrected. In addition, vowel duration was log-transformed in R and centred around zero for all the models reported.

As vowel quality is cued by vowel quality (vowel formants) and vowel quantity (duration), and duration as a cue to vowel identity works differently in different varieties of English, I will also investigate vowel duration as a dependent variable.

In addition to vowel quality (formants), vowel phonological contrasts in English can also be cued by vowel quantity – the duration of a given vowel. In singing, we have an additional constraint, that texts are set to music – and this include durational properties. There are different possibilities. For example, the contrast FOOT–GOOSE may be mapped onto the metrical properties of the music, that is, shorter vowels are mapped onto shorter notes. Alternatively, there may be no such relationship. The questions that we seek to answer, therefore, are can vowel identity influence duration in choral singing? I have two predictions, 1) that duration varies with regard to phonological duration of vowels, 2) there may be a change in absolute durations over time. Analysing vowel duration is of interest linguistically and stylistically. Durations may also vary across dialects – if there are differences between the corpora there is a possibility that these may reflect differences in a spoken model. From a stylistic perspective, absolute vowel duration may vary by genre, choir director, or over time. As vowel quantity plays a role in characterising spoken accents, so it may form part of the unique character of a particular choir's sound. As noted in Chapter 2, musicologists have also noted an increase in tempo, and a more literal interpretation of musical scores as texts (Day, 2000; Leech-Wilkinson, 2009a). In linguistic terms, this resulted in a decrease and standardisation of vowel duration over time.

4.3.10 Normalisation

F1 and F2 values were normalised by corpus using the Lobanov method (Lobanov, 1971) in R. Lobanov normalisation is a z-score transformation where each data point is divided by the standard deviation of the mean, which centres the data points around zero (the mean). Z-score transformation is a linear transformation that does not alter the shape of the distribution. Z-score vowel normalisation reduces speaker-specific information in the signal, or in this case, recording specific information we want to keep to a minimum. That is, artefacts of a particular recording set-up which we cannot control due to lack of information, for example, type of microphone, acoustic of the recording venue, sound engineer and more. There are many different vowel normalisation methods. The Lobanov method was selected as it has been found to minimize speaker-specific information while maximizing sociolinguistic variation in the signal (Rathcke et al., 2017).

All vowels analysed were normalised together, meaning all Glasgow Corpus monophthongs were normalised together for the analysis presented in Chapter 5. All King's Corpus monophthongs were normalised together for the analysis presented in Chapter 6. The within-corpus normalised data were combined for analysis in Chapter 7.

4.3.11 Statistical data trimming

The normalised F1 and F2 values were trimmed using statistical methods to remove outliers. Following Sóskuthy & Stuart-Smith (2020), I excluded vowel tokens with F1 or F2 values that fall outside the 1st and 99th percentiles for each choir. I also excluded vowel tokens with F1 or F2 values more than 1.5 IQR (Inter-Quartile Range) away from the lower or upper quartiles for a given vowel for each choir. Trimming was conducted within each vowel category for F1 and F2.

For example, the vowel /a/ as in TRAP, an upper bound was created, which was the 75th percentile plus (1.5 × Inter-Quartile Range) and a lower bound, which was the 25th percentile minus (1.5 × Inter-Quartile Range). All values beyond the upper or lower bound were discarded. The same process was followed for each vowel for both F1 and F2 separately. Manually extracted data for GOOSE and FOOT were trimmed using the same statistical method.

After trimming, there were 21,530 monophthong vowel tokens for the vowels FLEECE, KIT, DRESS, TRAP, BATH, STRUT, LOT, THOUGHT, FOOT, and GOOSE (Glasgow, 7,213; King's 14,317). Figure 4.15 is a plot of the vowel space that results from applying the method as described. The plot shows normalised F1 and F2 data for the point vowels FLEECE, TRAP–BATH and GOOSE. We can see that the plot looks surprisingly similar to the idealised vowel triangle shown in Figure 4.5a and the IPA chart in Figure 4.5b.

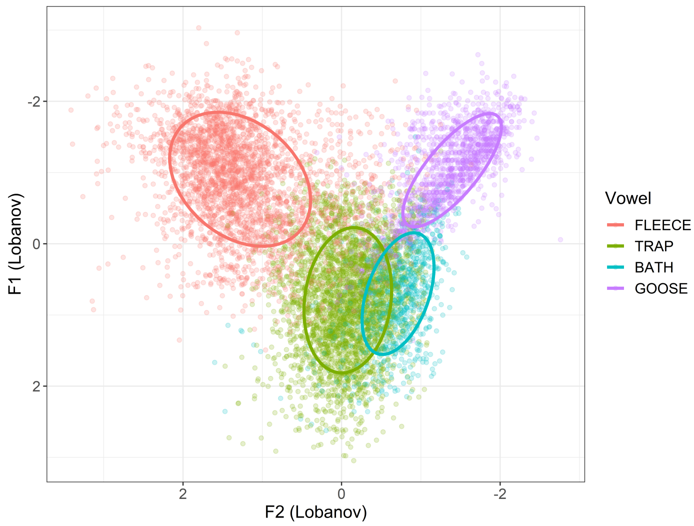


Figure 4.15: Combined corpora normalised F1 and F2 for point vowels FLEECE, GOOSE, and TRAP–BATH. Ellipses show 1 standard deviation. N = 8,265.

We can see from examining Figure 4.15 that it does not look identical to either the vowel space of SSBE speakers or Glasgow English speakers (Figures 4.6a and 4.6b).[4] FLEECE and GOOSE appear acoustically more peripheral than in typical

[4]Note, however, that the formant values from Ferragne & Pellegrino (2010) are Bark normalised,

spoken English. Note that in Figure 4.15 TRAP–BATH are distinct in the combined corpora as reported in Chapter 7. However, FLEECE (*heed*), TRAP (*had*), and BATH (*hard*) appear to be approximately distributed as we could expect based on either variety.

I was satisfied that the acoustic analysis led to results that are consistent with our understanding of the acoustic vowel system with regard to the location and distribution of vowels in spoken English – as well as other studies of acoustic vowel quality in singing – I decided to proceed with the analysis as reported in Chapter 5, Chapter 6, and Chapter 7.

4.3.12 Influence of F0 on acoustic vowel quality

Subsequent to the analysis reported in Chapter 5, I became concerned about the effect of fundamental frequency (F0) on vowel quality, as in Western classical solo singing, vowel quality tends towards /a/ as F0 increases (Hollien et al., 2000). However, there is no easy or accurate way of extracting F0 from a signal comprising multiple fundamentals other than taking a mean value. It is unknown how accurate pitch trackers are when presented with signals with multiple voices or instruments. Recent developments in Machine Learning have allowed researchers to extract fundamentals from sources comprising multiple sung signals (Cuesta et al., 2020) and separating sources using Neural Networks (Petermann et al., 2020). While these approaches would allow us to come some way to analysing the impacts of fundamental frequency on vowel quality produced by different Western classical voice types (for example, soprano or treble, alto, tenor, or bass), it was outwith the scope of the present research to adopt these approaches.

As vowels tend towards /a/ as F0 increases, I expected to find concentrations of data on violin plots where a-like realisations of a particular vowel would be found. That is, in the F1 dimension (vowel height) for the high vowels (FLEECE, DRESS, FOOT and GOOSE), I would expect to see a mass of data pooling at the bottom of the violin. For front vowels F2 dimension (Backness), I would expect a mass of data towards the right of the plot (closer to /a/). In Figure 4.16, there is no evidence of masses of data closer to /a/-like vowel quality. Consequently, I proceeded with the analysis without including F0. It is possible that the predicted F0 effect is absent due to the statistical trimming procedure, which may have removed tokens that are biased towards /a/.

An increase in loudness is associated with increased articulatory effort,

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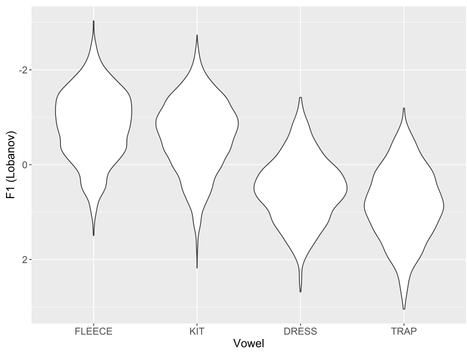
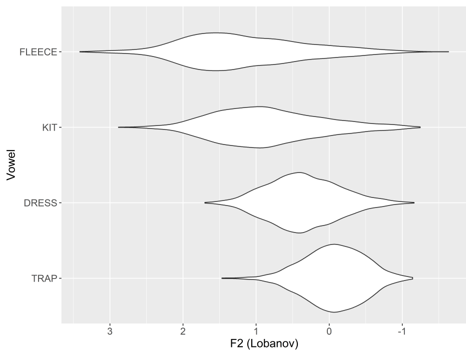
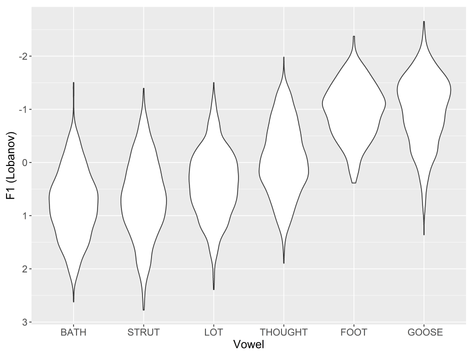
which is a different type of normalisation from the values reported in this study.



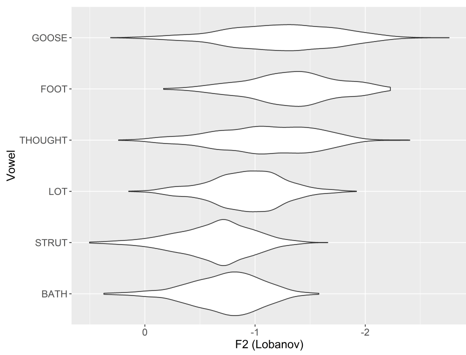
(a) Front vowel F1



(b) Front vowel F2



(c) Back vowel F1

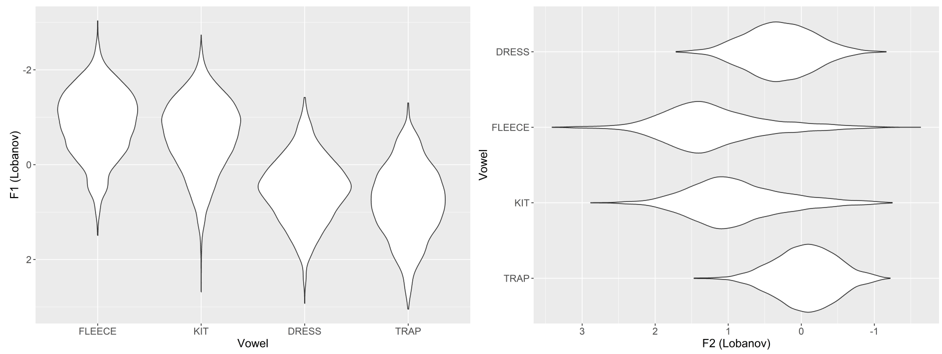


(d) Back vowel F2

Figure 4.16: King's: Front and back vowel F1 and F2 violin plots

particularly jaw lowering (Schulman, 1989). This is consistent with classical solo singing pedagogy, which recommends lowering the jaw and increasing the size of the aperture in order to increase volume, for example, Callaghan et al. (2018). Crucially, loudness-related jaw lowering will also strongly affect F1 (Lindblom & Sundberg, 1971). Given that formants and amplitude are correlated, I did not fully control for the effect of loudness in the models. Also, as I was working with commercially-released historical recordings, there are many unknowns regarding the recording set-up and mastering process. While it might be possible to extract numerical amplitude from these recordings, this would not allow me to compare how loudly the singers are singing on different albums due to gain, compression, and equalisation, which are often added in professional recordings. I also do not know the proximity of the microphones to the singers, which would also affect the signal. While loudness has an effect that we are not able to quantify, the effect is at least partially controlled by the hierarchical varying effects structure outlined in Chapter 5 Section 5.3.6. Rathcke et al. (2017) also recommended Lobanov normalisation specifically as it reduces speaker-specific variation in F1, which could be due to individual speaker variation in loudness and habitual jaw position.

Figures 4.17 and 4.18 show violin plots for the Combined corpora formant data, and again, there is no evidence of masses of data closer to /a/-like vowel quality.



(a) Front vowel F1 (b) Front vowel F2

Figure 4.17: Combined: Front vowel formant violin plots

(a) Back vowel F1 (b) Back vowel F2

Figure 4.18: Combined: Back vowel formant violin plots

4.4 Auditory coding

Two consonant variables were auditory coded with a combination of listening to the recordings with visual aids of waveforms and spectrograms. Chapter 8 investigates rhoticity in the Glasgow and King's choir corpora. Chapter 9 investigates the realisation of word-final /d/. As with the vowels acoustic analysis, all consonant phonemes were annotated using the CELEX-English dictionary and automatically segmented and aligned using the HTK forced aligner. This allowed me to search the corpus for all tokens of /r/ and word-final tokens of the voiced alveolar plosive /d/. I queried the orthography layer in LaBB-CAT using the regular expressions '.*r.*' (any character + $< r >$ followed by any character) and '.*d' (any character + $< d >$), respectively. As I listened to the tokens, I conducted further hand-correction at the phone level; however, for /d/, it was impossible to accurately segment the phases of the stop.

Auditory coding involves systematically listening to the audio files, in conjunction with a visual inspection of the spectrogram and waveform where helpful, categorising each token of /r/ and /d/ into known phonetic categories. In this coding, I listened to each token of etymological /r/ and asked whether I perceived

/r/ to be articulated, and if so, what phonetic variant it was predominantly realised as. Similarly, for /d/, I asked whether I perceived it as phonetically Voiced or Voiceless. Then I split these categories into their various realisations. All tokens of /r/ in the Glasgow and King's Cambridge corpora (8,407 tokens) were extracted and auditorily coded for /r/ realisation. All tokens of word-final /d/ in both corpora (3,213 tokens) were extracted and auditorily coded for phonetic realisation.

One of the key methodological issues of auditory coding consonant realisations for choral singing is the first concern mentioned at the start of the methodology, the joint speech or joint singing issue. That is, in choirs, there are multiple people singing at the same time. There is, presumably, a desire of both singers and conductors to produce final consonants together and with a similar type of realisation. However, the issue of coordination is nonetheless present. When choirs are not singing together effectively, for /d/, it was possible to have more than five identifiable stop bursts spread over a 200 ms window. Even when people are singing in time together, in reality, there are still forty different vocal tracts aiming at producing the same consonant phoneme and not always hitting the same articulatory target.

The way that I have dealt with this issue in the coding process is to 1) exclude any passages where multiple different words are being sung at once. 2) exclude any tokens where there is noise in the vicinity of the consonant coded. Where there was *any* auditory percept of /r/ or /d/, these were coded as having been articulated. Where a token was articulated, but there were multiple different realisations, which is quite common, I endeavoured to code the majority percept, that is, the variant that was most prominent and/or most people were producing. Sometimes I would also code a secondary percept as needed. For the statistical analyses, tokens were grouped under the primary percept. In the next section, I will outline the Bayesian statistical approach adopted in this thesis.

4.5 Statistical modelling

In this thesis, I model formant data extracted from recordings of choral singing using Bayesian methods. There are broadly three types of modelling approaches that I adopt for this thesis. In the analyses of vowel quality presented in Chapters 5, 6, and 7, vowel formants F1 and F2 are modelled separately using Bayesian linear mixed regression models. In Chapter 8, statistical analysis of rhoticity investigates the binary presence or absence of post-vocalic /r/ using Bayesian binomial logistic regression. In Chapter 9, I apply binomial logistic regression to the presence or absence of Affrication and Voicing for the realisation of word-final

/d/. I also present a Bayesian multinomial regression of a subset of the phonetic variants of word-final /d/. All analyses were carried out using `brms` (Bürkener, 2018) in R (R Core Team, 2021), using the integrated development environment R Studio (RStudio Team, 2020). In the following section, I motivate the use of Bayesian statistical methods.

4.5.1 Why statistical analysis?

Regression allows us to model the effect of one or more predictor (independent) variables on our outcome (dependent) variable. For vowel formant models, our outcome variables are F1 (how high the tongue is in the mouth) and F2 (how forward or back the tongue is in the mouth). We want to know, for example, what effect the predictor variable Time has on both F1 and F2; does vowel height or backness change over time? Regression cannot tell us if there is a causal relationship, but it can tell us about the strength of a relationship between two variables.

I originally hoped to conduct a multivariate mixed model approach, modelling F1 and F2 together in the same model, which is now possible. For an example of this kind of analysis with vowel formants, see Alexander (2019). This proved too unwieldy for the present research and is outwith the scope of this study.

4.5.2 Theoretical motivation for Bayesian statistical analysis

Bayesian statistics have become more well-known and are increasingly applied in the fields of quantitative phonetics and sociolinguistics. Bayesian analyses allow researchers to incorporate prior knowledge into our analyses, whereas Classical (frequentist) models start from a position of zero knowledge. This sometimes gives a false sense of objectivity and, as we will see, can lead to unlikely assumptions.

In everyday situations, we use Bayesian reasoning, which incorporates prior knowledge. For example, we know, based on prior experience, that the hypothesis the sun will not rise tomorrow is extremely unlikely. Suppose we used a classical model to predict whether the sun will rise tomorrow. In that case, it starts from a position of considering all possibilities equally (that is, the sun will or will not rise are equally probable in a frequentist model) – which seems disingenuous at best! However, in a Bayesian framework, we can rank all possible outcomes in the order of how likely we believe them to be (based on existing data), and we can update this ranking by collecting more data. This is a further benefit of Bayesian approaches, which is often referred to as the updating logic of Bayesian inference.

There are similarities to the scientific method in that we start from a position of prior knowledge based on our experience or previous research. Then, we collect data to test a hypothesis, and we move to a position of posterior knowledge which is a combination of our prior knowledge and the data we have collected.

Bayesian analyses with adequately specified priors are more conservative than classical analyses (Gelman, 2016). Weakly informative priors centred around zero have the effect of shrinking estimates towards zero. This means Bayesian models are usually biased towards a null effect of a variable, meaning that the data must provide sufficient evidence to demonstrate a non-null effect. If you run a Bayesian analysis with flat priors, allocating equal probability to all values across the probability space, it equates to running a classical frequentist model.

Often people are concerned about the subjectivity problem of priors. The priors that researchers select can input the researcher's bias in the analysis. However, in best practice, priors are published along with analyses for other scientists to critique. There is no one perfect or true prior – they are debatable, and we need to provide reasoning to support the ones we select or construct.

> Bayesian analysis does not require approximation assumptions about the data (e.g. homogeneity of variance, normally distributed noise). The inferences from a Bayesian analysis are richer and more informative than NHST because the posterior distribution reveals joint probability of combinations of parameter values. And, of course, there is no reliance on sampling distributions and *p* values to interpret the parameter estimates (Kruschke, 2015, pp. 722–3).

As Kruschke writes above, Bayesian analyses are richer and can be used to ask more refined questions. The results of these analyses give probability ranges for the parameters of interest, given the data, rather than indirectly reporting the value of data, given the null hypothesis, and forcing the researcher to hope they are not making a mistake when they accept the alternative hypothesis.

Model summary statistics alone cannot answer all the specific research questions. I present post hoc pairwise comparisons to test differences between vowels at different time periods. Post hoc comparisons were conducted using the package `emmeans` (Lenth, 2021). In a frequentist framework, this would necessitate correction for multiple comparisons. However, in a Bayesian analysis, we are able to investigate joint probabilities of combinations of parameters in the posterior distribution, and do not have to worry about corrections for multiple comparisons (Gelman, 2016; Gelman & Tuerlinckx, 2000).

Also importantly, there is very limited data for formant values in choral singing and even singing more generally. Other researchers will be able to use the data and posteriors presented in these analyses to establish priors for future analyses. Doing so will allow us to start piecing together a picture using the updating logic of Bayesian analysis to establish how likely it is that there has been a change in choral singing over time.

4.6 Introduction to Bayesian statistics

4.6.1 Bayes' Theorem

$$p(\theta|\mathbf{D}) = p(\theta)\frac{p(\mathbf{D}|\theta)}{p(\mathbf{D})} \tag{4.1}$$

Bayes' theorem is one of the few equations you will encounter in this thesis. It fundamentally expresses a way that we already think intuitively. First, I need to introduce some terminology.

$$\underbrace{p(\theta|\mathbf{D})}_{\text{posterior}} = \underbrace{p(\mathbf{D}|\theta)}_{\text{likelihood}}\,\underbrace{p(\theta)}_{\text{prior}} \div \underbrace{p(\mathbf{D})}_{\text{evidence}}$$

The *prior* $p(\theta)$ is existing information we have about a situation or hypothesis independent of the data we have collected. For example, if we flip a coin believing that the coin is not biased, there is a 50/50 probability of getting one side or the other. In that case, our prior belief, independent of collecting data (flipping the coin), is that the probability of getting Heads or Tails is normally distributed around 0.5. If we have reason to believe, based on existing knowledge, that the coin is heavily biased, for example, that it is rigged to get Heads 80% of the time, then our prior would be normally distributed around a central tendency of 0.8.

After we have considered our prior state of knowledge, we would collect data. In this example, it would involve flipping the coin many times over. The number of times we flip the coin, and the result (either Heads or Tails) is the *evidence* or $p(\mathbf{D})$. The *likelihood* $p(\mathbf{D}|\theta)$ is the probability that the data could be generated by the model with parameter value θ. The thing we are most interested in is the *posterior* $p(\theta|\mathbf{D})$ which is the credibility of the *prior* given the *data*. Figure 4.19 demonstrates how the posterior is a 'weighted combination of the mean of the prior and [the mean of the data]' (Kruschke, 2015, p. 134). Generally speaking, as you will see in the analyses, greater amounts of data lead to an increase in the precision and certainty of the model estimates (Kruschke, 2015, p. 113).

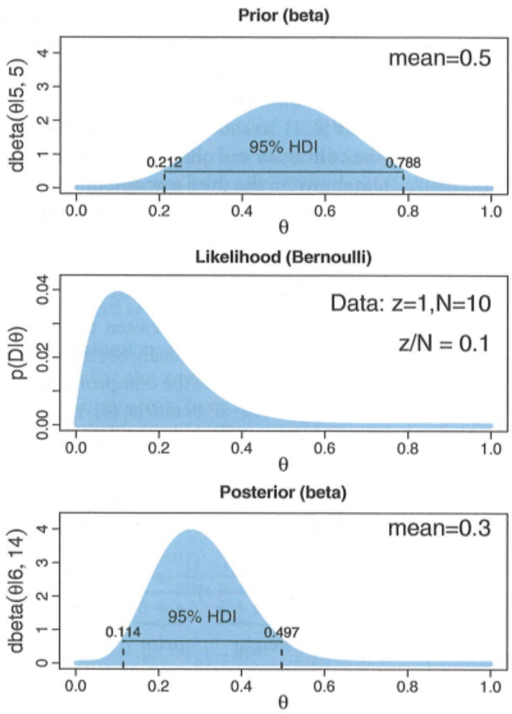


Figure 4.19: Figure 6.3 from Kruschke (2015, p. 134) shows that the mean of the posterior is a weighted combination of the mean of the prior and the mean of the data

4.6.2 Markov Chain Monte Carlo

For a complex parameter space, it is often impossible to compute the integral mathematically. So, we use an approximation which involves 'randomly sampling a large number of representative combinations of parameter values from the posterior distribution' (Kruschke, 2015, p. 115). These are known as Markov Chain Monte Carlo (MCMC) methods. These methods are useful as they can 'generate representative parameter-value combinations from the posterior distribution of complex models *without* computing the integral in Bayes' rule. It is the development of these MCMC methods that has allowed Bayesian statistical methods to gain practical use' (Kruschke, 2015, p. 116).

4.6.3 Model diagnostics

In this thesis, I report the following model diagnostics before the results of each model. Firstly, the effective sample size (ESS) for each term in the model should be greater than one hundred times the number of chains. As I run four chains in parallel, ESS is greater than four hundred for all model terms of each model reported. Secondly, in all models reported, `rhat` is not greater or less than 1 for any model parameter, indicating that the chains have mixed well. Thirdly, I conducted a visual inspection of the chains for each fixed effect of each model, which should look like a 'hairy caterpillar'. Fourthly, I provide graphical posterior predictive checks for each model. The posterior predictive checks plot simulated data generated by the MCMC methods against the actual data so we can evaluate how well the model is performing at generating data that resembles the actual data.

4.6.4 Statistical significance

As far as possible, I have tried to avoid using the word 'significant' in my results chapters to reduce any confusion arising from the term's specific association with frequentist statistics. There are no set conventions yet for reporting the results of Bayesian analyses in linguistics, though I follow recommendations for reporting by (Kruschke, 2015). I will be reporting point estimates (median) and 95% credible intervals. Where 95% credible intervals do not contain zero, the model supports a non-null effect – in other words, the data has provided enough evidence (credibility) to support an effect. The further away from zero, the stronger the effect. I have marked non-null effects in model summary tables using **bold type**.

4.7 Priors for these analyses

As we have seen, Bayesian statistical analysis requires priors. In Bayesian models, we need to set a prior for every single model coefficient (including interaction terms). I initially planned to use `brms` default priors for my first analysis, which are very wide Student t distributions for varying intercepts (e.g. `student_t_(3, 0, 2.5)`), and uniform for fixed effects. However, this approach would be disingenuous as we do have prior knowledge which can be incorporated into the analysis. For example, we know how vowel formant values change over time in different varieties of English. So there are a couple of possible priors based on Received Pronunciation and Standard Scottish English and weakly informative regularising priors.

I conducted the initial analysis by running each of the models reported in Chapter 5 with three sets of priors based on Scottish Standard English, Received Pronunciation, and weakly informative priors. The data sources for the priors can be found in Appendix Table A.2 (Received Pronunciation), Appendix Table A.3 (SSE). The priors specifications created based on these data are shown in Appendix Tables A.4 (front vowel F1, RP), A.5 (front vowel F2, RP), A.6 (front vowel F1, SSE), A.7 (front vowel F2, SSE), A.8 (back vowel F1, RP), A.9 (back vowel F2, RP), A.10 (back vowel F1, SSE), A.11 (back vowel F2, SSE).

Appendix Tables A.12 (front vowel F1 prior model comparison), A.13 (front vowel F2 prior model comparison), A.14 (back vowel F1 prior model comparison), and

A.15 (back vowel F2 prior model comparison) show that, for the most part, there was negligible difference between the models run using different priors. This is a positive thing as it means that the weight of the data is sufficient to overwhelm the effect of the prior. As there was negligible difference between the models, I report models with weakly informative regularising priors, as in Table 4.5. As we have seen, weakly informed priors allocate credibility over a wide range of possible parameter values, meaning that the data will mostly inform the posterior.

Table 4.5: Weakly informative regularising priors

prior	class	coef	source
normal(0, 1)	b		user
student_t(3, 0, 1)	Intercept		user
student_t(3, 0, 1)	sd		user

4.8 Hierarchical modelling

In linguistic experiments, we are used to taking into account the effects of Speaker or Item. There may be clustering within the data that is not accounted for by our variables of interest. For example, in experiments, responses tend to cluster by participants. If we were investigating reaction time, we would expect certain participants to be faster than others overall and that their individual responses would likely pattern together. We need to take into account this patterning by individual.

We also have what is often referred to as an Item effect. This is where participants are presented with or produce certain words, for example, and the word they are reacting to or producing may impact the results. We can take into account the effects of these hypothetical speakers and words by using varying or group-level effects (known as random effects in classical statistics). I outline the full model structure, including hierarchical varying effects, in Chapter 5.

4.9 Summary

This thesis seeks to determine whether recordings of choral singing differ by dialect area or by choir director and over time. In this methodology chapter, I have outlined the two main methods of analysis adopted in this thesis, as well as the Bayesian statistical approach employed throughout. In the following chapter (Chapter 5), I present the results of the first acoustic analysis of choral vowel quality in recordings from the Glasgow Corpus.

Chapter 5

Variation and change over time in Glasgow choral vowel quality [1]

In Chapter 1, I laid out this thesis's principal concerns, which are to investigate variation and change in choral singing. One branch of the research questions relates to change over time (RQ 3a), which is this chapter's primary area of interest. Specifically, this chapter investigates vowel quality over almost a century of recordings of Scottish choirs from Glasgow. The Glasgow corpus contains recordings of the Glasgow Orpheus Choir and the Glasgow Phoenix Choir. The choirs were both comprised of singers predominantly from Glasgow, and membership of these choirs remained relatively stable over time. The Orpheus choir was in operation from 1901–1951, and there are recordings of the Orpheus from 1925–1951. Founded when the Orpheus choir was disbanded, the Glasgow Phoenix Choir initially comprised Orpheus members that wanted to continue singing at a high level. When this analysis was embarked upon, there were commercially released recordings of the Phoenix Choir from 1959–2016. This chapter demonstrates that vowel quality in Glasgow choral singing has changed over time. Some possible causes for this change are discussed.

5.1 A brief history of singing in Glasgow

Glasgow has a chequered history of choral singing. In 1588 the medieval Sang School collapsed as it 'was sold to defray the expenses incidental to a heavy visitation of the plague!' (Musical Times, 1901). Due to the Reformation in Scotland, apart from metrical psalm singing in the kirk, there is little documentation of Glasgow's choral history until an explosion of choral activity

[1] An earlier version of some of the sections of this chapter will appear in Marshall et al. (2024).

from the mid-nineteenth century. Large-scale choral societies were formed in the Central Belt of Scotland, including the Royal Scottish National Orchestra Chorus in Glasgow, founded in 1843 (under a different name), the Edinburgh Royal Choral Union (founded 1858), and Ayr Choral Union (founded 1876). This explosion of choral activity coincided with a major expansion of the population in the Central Belt, from 77,000 in 1801 to 762,000 by 1901 (Glasgow Centre for Population Health, 2014). These choirs still exist today in one guise or another, but their advent set the scene for the much faster proliferation of choirs in the twentieth century. *In Orpheus with his lute: A Glasgow Orpheus Choir Anthology*, Hugh S. Roberton, the founder and director of the Glasgow Orpheus Choir, writes that:

> Round about 1901 the problem of problems in Scotland was voices. We were not rich in choral tradition as was, say Lancashire or Yorkshire or South Wales. We were, in a sense, beginners, first generationists. More than likely this state of affairs was a belated hangover from the Reformation; that revolution which, whatever benefits it brought to Scotland, certainly struck a damaging blow at singing, as it did at many other pleasurable recreations (Roberton, 1963, p. 12).

In the context of the choral societies as mentioned, it seems that Roberton was being a touch poetical about the absence of voices in Scotland. However, the Reformation did limit the singing that was permitted in society. For example, Mallinson writes that:

> The Protestant Reformation … effectively ended all cultural activity identified with the Roman Catholic church. Music in particular was badly affected. In the Presbyterian Calvinist church, music was limited to the plainest singing … The use of elevated liturgical music continued solely in the Scottish Episcopal Church, whose musicians tended to be imported from England (Mallinson, 2015, p. 71).

Mallinson also notes that in Scotland, there was not the same degree of separation between folk and classical music as there was in other countries.

> The cities of Glasgow and Edinburgh each had their élite choral society – the Glasgow Choral Union and the Edinburgh Choral Union – while less prestigious local societies were found in most of the cities' districts. For example, in Glasgow, there were local choral societies in the districts of Bridgeton, Crosshill, Dennistoun, Hillhead, Maryhill, Mount Vernon, Partick, Pollokshields, Queen's Park, and Springburn (Mallinson, 2015, p. 76).

Mallinson describes the repertoire of Scottish choral societies as not substantially different to English choral societies of the same period, writing that 'this is hardly surprising, given that London was the cultural capital of the United Kingdom and exerted a very strong influence over regional cultural affairs and activities' (Mallinson, 2015, p. 77). However, she later notes that there were also arrangements of traditional Scottish folk songs and compositions by Scottish composers. Did London's 'strong influence' spill over into the pronunciation of these choral societies? What did they sound like? Unfortunately, this is not something we can test empirically, as the ability to make audio recordings did not come till later in the nineteenth century and was not widespread until the early twentieth century. These choral societies had 'an educational and social intent' (Mallinson, 2015, p. 82).

5.1.1 Sample

The sample examined in this chapter is outlined in full in the Methodology Chapter Section 4.1. *This chapter reports variation and change in choral singing from Glasgow. The Glasgow Corpus features commercially released recordings of the Glasgow Orpheus Choir (1925–1951) and the Glasgow Phoenix Choir (1959–2016). The corpus includes extracts from 178 tracks (songs) from 28 albums. The Glasgow choirs were selected due to the Glasgow Orpheus Choir's prestige and broadcast history and the consistent recording of repertoire. Note that I will occasionally refer to the Glasgow Orpheus Choir and the Glasgow Phoenix Choir as the Orpheus, and Phoenix, respectively.*

The Glasgow Orpheus Choir achieved international fame at a time before this was commonplace for choirs. The choir sang a repertoire which featured choral arrangements of Scottish folk songs, music popular in the Scottish Protestant church, and secular part songs and choral arrangements of folk songs from other cultures. The Glasgow Phoenix Choir was founded when Hugh S. Roberton stood down as director of the Orpheus in 1951. They continued singing a similar mixture of repertoire with choral arrangements of Scottish folk tunes and popular Scottish hymns and psalms to the present day.

5.2 Predictions

As we saw in Chapters 1 and 2, classical singing in English is thought to be based on Received Pronunciation or the 'High form of the language' (Potter, 1998). We also saw in Chapter 3, that earlier in the twentieth century there was a 'hyper-RP' Scottish variety of English known as the Morningside/Kelvinside accent (Johnston, 1985). This variety was characterised by extremely high front vowels and extremely backed realisation of the GOOSE vowel.

Table 5.1: SSE and SSBE vowel system comparison

<table>
<tr><th>Keyword</th><th>SSE (Scottish)</th><th>SSBE (English)</th></tr>
<tr><td>FLEECE</td><td>i</td><td>i</td></tr>
<tr><td>KIT</td><td>ɪ</td><td>ɪ</td></tr>
<tr><td>DRESS</td><td>ɛ</td><td>ɛ</td></tr>
<tr><td>TRAP</td><td rowspan="2">a</td><td>a</td></tr>
<tr><td>BATH</td><td>ɑ</td></tr>
<tr><td>LOT</td><td rowspan="2">ɔ</td><td>ɒ</td></tr>
<tr><td>THOUGHT</td><td>ɔ</td></tr>
<tr><td>FOOT</td><td rowspan="2">u</td><td>ʊ</td></tr>
<tr><td>GOOSE</td><td>u</td></tr>
<tr><td>STRUT</td><td>ʌ</td><td>ʌ</td></tr>
</table>

Wilson (2014) found that singers and conductors in Trinidad were aiming for standard ‘British’ norms or a non-national accent of choral singing. If the data reported here support these views, what would they look like? Table 5.1 is adapted from Abercrombie (Figure 5.1 1979, p. 72) using Wells’s lexical sets (Wells, 1982a), including only the vowel sets that are analysed in this chapter.

As seen in Table 5.1, if the vowel inventory of choral singing is related to regional vowel phonology, we would expect there to be no differences between the vowel pairs TRAP–BATH, LOT–THOUGHT and FOOT–GOOSE in Glasgow choir singing, as Scottish varieties of English do not distinguish them. Abercrombie tells us that speakers of SSE may have all of these categories merged, or split, or a mixture of the two. Johnston also states the same of speakers of M/K English. However, if we find any merged categories in the choral data, this would support a regional accent based on Standard Scottish English. If we find all vowel pairs distinct, perhaps this is evidence of a choral norm based on Southern Standard British English.

This chapter seeks to answer research questions 3)a–c (see Section 1.3) and explores whether vowel quality changes over time in the recordings of the Glasgow Orpheus and Glasgow Phoenix choirs. This analysis is exploratory, as there is no basis for strong predictions about the direction of change at this stage.

5.3 Variables and coding

5.3.1 Time/Director

Time is the variable of greatest interest in the models reported in this chapter. There are several different ways of coding time which I considered. I could include Time as a linear numerical variable, which is often done in analyses of this kind. Alternatively, Time could be included as a factor variable with a level containing the year each Song or Album was recorded. However, there are very few tokens per year and many years with no recordings, so I decided to demarcate more extended periods of time as a factor. I also considered coding Time as Director, with each Director occupying a certain Time period (as Time and Director of the choir are completely overlapping). However, for one Director, Peter S. Shand, there were too few tokens to produce reliable estimates, as seen in Figure 5.1.

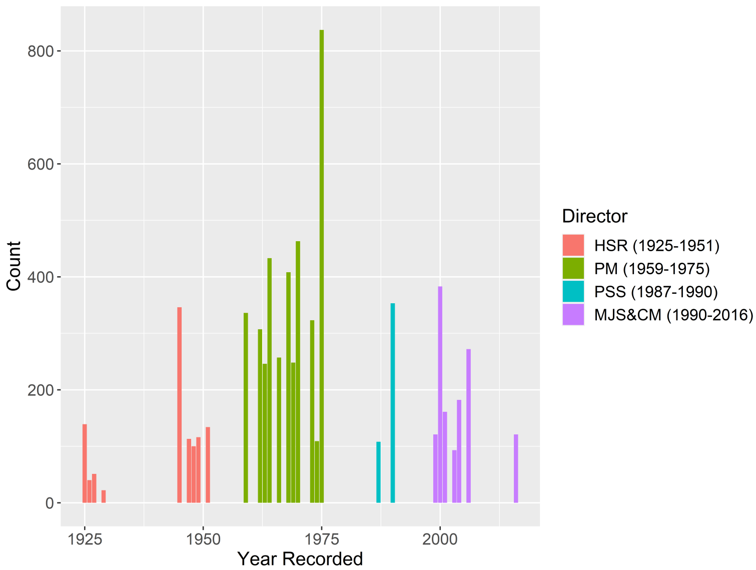


Figure 5.1: Glasgow: Number of tokens per year by Director. 'HSR' = Hugh S. Roberton; 'PM' = Peter Mooney; 'PSS' = Peter S. Shand; 'MJS&CM' = Marilyn J. Smith and Cameron Murdoch

As described in the introduction, the choir recordings analysed here are from the Glasgow Orpheus and Glasgow Phoenix choirs. As seen in Table 5.2, the Orpheus Choir was conducted only by Hugh S. Roberton throughout its existence; however, the Phoenix Choir has been directed by four people since its foundation in 1951. It is impossible to separate the effects of Time and Director when using historical choir recordings, so this variable is referred to as Time/Director throughout this thesis.

Finally, I decided to group the time periods into three Time/Director pairs: HSR (1925–1951), PM (1957–1975), and MJS (1987–2016). As seen in Figure 5.1, these relatively equal time periods reflect the distribution of the tokens. Orange

Table 5.2: Glasgow corpus choir director tenure

Corpus	Dates active	Director	Coding
Glasgow Orpheus Choir	1901–1951	Hugh S. Roberton	HSR 1925–1951
Glasgow Phoenix Choir	1955–1983	Peter Mooney	PM 1959–1975
	1983–1990	Peter S. Shand	MJS 1987–2016
	1991–2016	Marilyn J. Smith	
	2018–Present	Cameron Murdoch	

tokens were recorded by Hugh S. Roberton in two bursts (in the late 1920s) followed by a long hiatus and a period of increased productivity between 1945–1951, just before his retirement. The largest body of the data (in blue) falls between 1959–1975, directed by Peter Mooney. The later period is all recordings from 1987–2016, directed first by Peter S. Shand (purple) and then by Marilyn J. Smith and Cameron Morris (green). Cameron Morris was the accompanist of the Phoenix choir during Marilyn J. Smith's tenure as conductor, so there may be a degree of continuity in the sound they elicited. Due to the number of tokens available and their uneven distribution, for modelling purposes, the Glasgow data will be split into three Time/Director pairs:

1. HSR (1925–1951) – Glasgow Orpheus directed by Hugh S. Roberton

2. PM (1959–1980) – Glasgow Phoenix directed by Peter Mooney

3. MJS (1987–2016) – Glasgow Phoenix directed by Peter S. Shand, Marilyn J. Smith and Cameron Murdoch

In each analysis reported, Time/Director is sum coded such that PM (1957–1975) and MJS (1987–2016) are compared to the grand mean (mean of all three levels). This gets us some way towards answering the research questions, but direct comparisons will be made between the different Time/Directors using post hoc pairwise comparisons.

5.3.2 Vowel

The levels of the factor variable Vowel vary depending on the model. Throughout this thesis vowels are referred to using keywords as in Wells (1982a). For the front vowel analysis, the levels are: FLEECE /i/, KIT /ɪ/, DRESS /ɛ/ and TRAP /a/. For the back vowels analysis the levels are: BATH /ɑ/, STRUT /ʌ/, LOT /ɒ/, THOUGHT /ɔ/, FOOT /ʊ/, and GOOSE /u/. For the TRAP–BATH model, the vowel factor is binary

(TRAP versus BATH). For the vowel duration model, all front and back vowels are included. In all models, Vowel is sum coded, such that each level is compared to the grand mean (mean of all vowels) for the ease of interpreting interactions.

In these analyses, I have included short vowels often reduced in English speech (KIT, STRUT and FOOT) as it will be interesting to see if their realisation changes over time. From a musical standpoint, there are different ways of approaching the phonologically short vowels, as anecdotally, they are challenging to produce for an extended period of time (as required in singing). Singing is different to speech in many ways, for example, vowel duration and amplitude may be prescribed by the music. Consequently, unstressed vowels of English speech, like schwa, can often be stressed when sung. Anecdotally, singers, choral singers and choir directors have multiple different 'repair' strategies when working with short vowels. They may modify the vowel towards an adjacent long vowel, for example, shifting KIT towards FLEECE. Short vowels are well-represented in the corpus, so it will be possible to investigate the effect of Vowel Duration on the vowel quality of short vowels.

5.3.3 Vowel duration (log ms)

Vowel duration is a typical linguistic control variable when investigating formant data. It has been observed that in speech, the longer a vowel is, the more peripheral the vowel quality and the shorter a vowel is, the more central the quality (e.g. Fourakis, 1991). I expect a similar main effect in the singing data. Though, as mentioned above, vowel duration is at least partly prescribed by the musical context.

5.3.4 Genre

Genre is musically and linguistically motivated. We know that vowel realisation can be conditioned by register and style. There are also different accepted ways of singing in different styles of music. In this analysis, Genre is coded as a factor variable with the levels: Church Music, Scottish Vernacular, and Other Popular. These categories arose from the data; The music falls predominantly into these three categories, with the majority within Church Music. I kept the number of levels of the factor low so that it would be possible to investigate possible interactions with Vowel and Time. Scottish Vernacular also accounts for all words in Scots rather than in English. Genre was also sum coded such that Scottish Vernacular and Other Popular are compared to the grand mean of the three levels.

5.3.5 Preceding manner and following segment

Preceding manner and following segment were included as linguistic control variables. Preceding manner is the phonetic manner of articulation of the preceding segment, that is, the mechanism of how the sound was produced, which had the levels: plosive, fricative, approximant, nasal, pause, and vowel and was also sum coded. For Following Segment, the levels of the factor vary across models as the following context is vowel-specific. The complete levels for each model are listed in Appendix D. This factor was also sum coded.

5.3.6 Varying (random) effects

There is theoretically motivated systematic variability in the data relating to three sources that can be modelled with the data collected. These include varying intercepts for **Word**, which operates as the linguistic varying effect for item. As I am working with corpus data, there are repetitions of words, and the number of tokens of each word is unbalanced. Consequently, word variances must be pooled to ensure that one particular word-item is not skewing the distribution of vowel formant data.

Song in this context is the title of the work recorded. This varying effect functions similarly to Word as a linguistic item – think of Song as a read-passage. As mentioned, some pieces of music have been recorded multiple times over the century of recordings. For example, ‘All in the April evening’ features nine times in the corpus recorded between 1945–2001. From a musical and linguistic standpoint, it is conceivable that the song itself has a manner of singing associated with it. Therefore variances for different songs will be pooled. In these analyses, Song does not take into account different musical arrangements of the same text. Many kinds of music can have the same texts set to different tunes with examples in both church music and popular culture. For example, in this corpus, Psalm 23, ‘The Lord is my shepherd’, is sung to the tunes Crimond and Brother James’ Air. Ideally, the tune or arrangement would also be accounted for, as the rise and fall of the melody could affect the vowel quality. However, this will have to be returned to in future research. I believe the varying effect of **Song**-as-text soaks up most of the variability.

The final varying intercept is that of **Album**, which, in this context, is the title of a commercial release. Album serves as the linguistic varying effect for subject. The reason for including Album as a varying effect is that we do not have the data to include variables like the type of microphone, microphone placement, acoustic of venue, recording engineer, reverb added, how the choir felt on the day, medium, and many more. Album serves as a catch-all varying effect for these sources of unknown variability. Ideally, we would explicitly code all of these possible sources of systematic variability separately, but complete data is not available for all recordings.

After considering these data's maximal varying effects structure, I think it makes sense to include only varying intercepts. For the two main variables of interest, Time/Director and Vowel, it does not make sense to include slopes as they would be largely undefined. That is, we cannot allow intercepts for Word to vary by Vowel as each word has a defined set of vowels, likewise for Song. It would theoretically make sense to allow intercepts for Word to vary by Time/Director in an experimental design. However, as I am working with corpus data, many words have few tokens. Consequently, I decided to omit slopes for the vowel formant models.

I also included nesting terms reflecting the structure that each Word belongs to a Song item which belongs to an Album. Two nesting terms **Song:Word** and **Album:Song** were included.

Analysis was carried out using R (R Core Team, 2021) in R Studio (RStudio Team, 2020). Bayesian models were run using the `brms` package (Bürkener, 2018) which is based on `rstan` (Stan Development Team, 2020). The following tables were produced using the `xtable` package (Dahl et al., 2019), or `BayesPostEst` (Karreth et al., 2021) via `texreg` (Leifeld, 2013). Plots were produced using `brms`, `ggplot2` (Wickham, 2016) and `BayesTestR` (Makowski et al., 2019).

5.4 Modelling approach

Table 5.3 shows the fixed effects that were included in the vowel formant models, the type of effect, levels/units of variables, and coding schemes (if applicable).

5.4.1 Priors

The priors for this analysis and those subsequent in the Glasgow Choir Project were weakly informative regularising priors: `normal(0, 1)` for fixed effects and `student_t(3, 0, 1)` for varying intercepts as recommended by Gelman (2020). All categorical variables were sum coded for ease of interpreting model coefficients.

Using weakly informative priors for this analysis could be considered disingenuous as we have existing knowledge about the vowel space from studies in speech. As shown in Appendix A, priors based on Received Pronunciation and Scottish

Table 5.3: Fixed effects, interactions, and varying effects structure for modelling

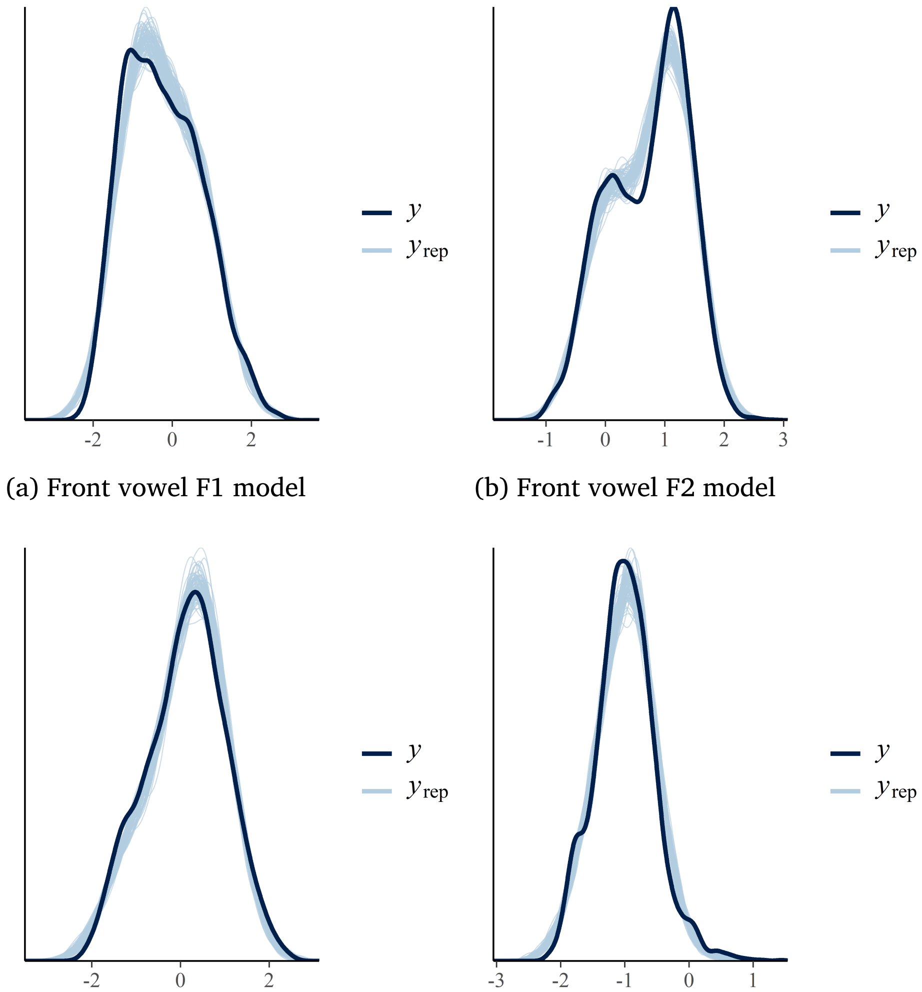
Predictor	Type	Levels/Units
Time/Director	Factor	HSR (1925–1951), PM (1959–1975), MJS (1987–2016)
Vowel	Factor	Front: FLEECE, KIT, DRESS, TRAP; Back: BATH, STRUT, LOT, THOUGHT, FOOT, GOOSE; TRAP–BATH
Vowel Duration	Contin.	Log ms
Following Segment	Factor	See Appendix D
Genre	Factor	Church Music, Scottish Vernacular, Other Popular
Vowel:Time/Director Vowel:Duration Time/Director:Duration Genre:Duration	Interaction Interaction Interaction Interaction	
(1|Word) (1|Song) (1|Album) (1|Song:Word) (1|Album:Song)	Varying effect Varying effect Varying effect Nesting effect Nesting effect	

Standard English yielded results that were almost identical to models run with weakly informative priors. In on sense, this is good as it indicates that the results are not sensitive to prior choice, meaning the weight of evidence from the likelihood (the data collected) outweighs the impact of any of the three sets of priors. Therefore, I am confident that prior choice has not biased the results. However, I am left with the question of which set of models to report. As there was next to no difference between the models with different priors I opted to report the models run with weakly informative priors.

On reflection, I believe that the informative priors I specified were inappropriate, as they were based on speech data and may not accurately reflect the distribution of the vowels in singing. For example, in popular styles of singing, the vowel space has been found to be lower overall compared to in participants' speech (Gibson & Bell, 2012). As Morrissey (2008) comments, 'it is a truism that singing is not speaking and that singing style and speaking style are therefore subject to different parameters.' (Morrissey, 2008, p. 213). Consequently, I hope future analyses of choral singing can use priors based on the analyses reported in this thesis. Even though speech variety and the director's aesthetic differ widely between choirs, using choral data as priors will more closely match the vowels produced by other choirs.

In addition, in an ideal world, prior selection should be conducted using Bayes Factor analysis, where where the same model structure is compared with different priors. Bayes Factors are sensitive to changes in the prior, and the results should give you the weight of evidence for or against one prior over another. Unfortunately, as above, this method was too computationally demanding for me to use in this thesis. Additionally, Bayes Factor analysis is not without its controversy within the statistical community and has been called a Bayesian p-value when applied for NHST purposes[2]. In any case, in this study, there was negligible difference between the estimates of the models run with the different priors; therefore, I opted to report models run with weakly informative regularizing priors.

5.4.2 Model convergence criteria

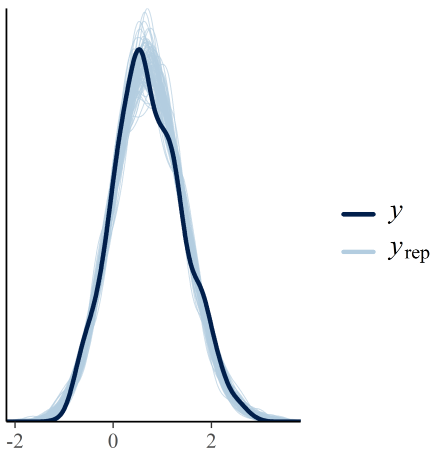


(a) Front vowel F1 model
(b) Front vowel F2 model
(c) Back vowel F1 model
(d) Back vowel F2 model

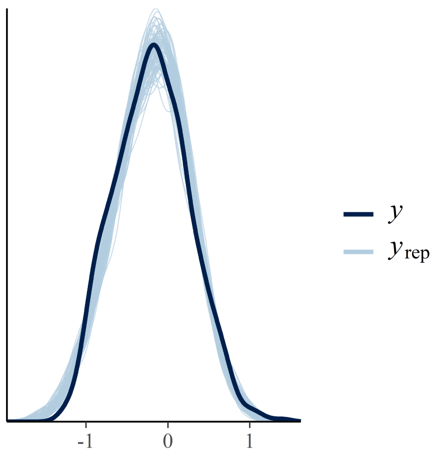
Figure 5.2: Posterior predictive checks for Glasgow Front and Back vowel formant models

[2]See Andrew Gelman's musings in blog form here: `https://statmodeling.stat.columbia.edu/2019/09/10/i-hate-bayes-factors-when-theyre-used-for-null-hypothesis-significance-testing/`

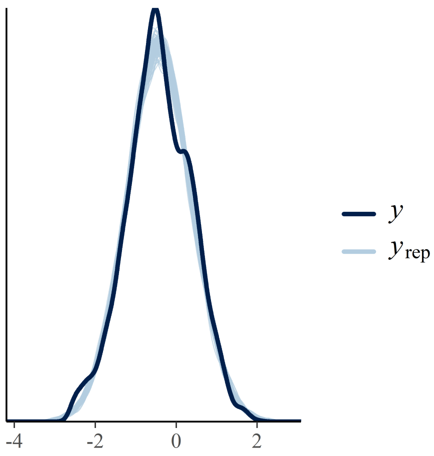
Figure 5.2 contains posterior predictive checks for the models reported in this chapter. The dark lines show the actual data and the light lines show data simulated by the model. Models (a), (c) & (d) appear to generate simulated data which fits the actual data very well, so we can be reasonably confident in the model output. I am slightly concerned about the posterior predictive check for front vowel F2 (b). The model is getting the overall shape of the distribution fairly well. The posterior predictive checks might be improved by introducing slopes for varying effects – this is not something that I have done so far mainly for preserving computation time. This is something I will revisit later if there is time. Figure 5.3 contains posterior predictive checks for the TRAP–BATH and Duration models. Again, I am satisfied with each.



(a) TRAP–BATH F1 model



(b) TRAP–BATH F2 model



(c) Duration model

Figure 5.3: Posterior predictive checks for Glasgow TRAP–BATH and Duration models

Rhat was 1 for all coefficients, and the minimum effective sample size for beta coefficients was greater than 100 $\times$ the number of chains. This means that we have not had any convergence issues, as briefly discussed at the end of the methodology, and we have easily enough samples to have confidence in the output. Each model's chains were also manually visually inspected to ensure they mixed well. All of the model diagnostic criteria were met. So, I am satisfied that the models converged successfully and that the posteriors are amenable to interpretation.

5.5 Results

The raw data, code and models reported in this chapter can be found on the OSF at osf.io/965tu.

In model summary tables and estimated marginal means tables, significant results (non-null effects, where 95% credible intervals do not include zero) are indicated by **bold type**. Only non-null effects are reported in the text.

5.5.1 Glasgow: Front vowel system

This section presents the analysis of F1 (height) and F2 (backness) for FLEECE (862 tokens), KIT (1,765 tokens), DRESS (645 tokens) and TRAP (923 tokens) produced by the Glasgow choirs. Table 5.4 presents the number of tokens of each vowel (N), means and standard deviations for F1 (Hz), F2 (Hz), and Duration (Secs) for the front vowel raw data grouped by Vowel and Time/Director. Then I present the results of the front vowel F1 model, as seen in Table 5.5. The acoustic variable F1 relates to how high the tongue is in the mouth. The greater F1 is, the lower the tongue and jaw configuration. Conversely, the lower F1 is, the closer the tongue is to the roof of the mouth. Therefore, this model asks how the independent variables (Time/Director, Vowel, Vowel Duration etc.) affect tongue height.

Table 5.4: Glasgow: Front vowel raw formant and duration data by Time/Director

			F1 (Hz)		F2 (Hz)		Duration (ms)	
Vowel	Time/Director	N	Mean	SD	Mean	SD	Mean	SD
FLEECE	HSR 1925–1951	131	424	91	1961	93	1420	1330
FLEECE	PM 1959–1975	497	440	91	1904	116	1210	980
FLEECE	MJS 1987–2016	234	426	67	2005	147	1220	1030
KIT	HSR 1925–1951	321	446	95	1889	140	810	860
KIT	PM 1959–1975	1030	471	96	1813	128	730	580
KIT	MJS 1987–2016	414	499	104	1793	192	610	490
DRESS	HSR 1925–1951	98	629	77	1628	132	1020	920
DRESS	PM 1959–1975	406	637	81	1507	131	910	630
DRESS	MJS 1987–2016	141	677	96	1517	129	770	760
TRAP	HSR 1925–1951	144	636	100	1477	164	850	970
TRAP	PM 1959–1975	547	658	95	1445	134	690	560
TRAP	MJS 1987–2016	232	712	102	1381	135	710	650

Table 5.5: Glasgow: Front vowel F1 model posterior summary

	Estimate	95% CI	
Intercept	−0.05	−0.14	0.04
directorPM1959–1975	−0.03	−0.12	0.07
directorMJS1987–2016	**0.18**	**0.08**	**0.28**
vowelKIT	**−0.62**	**−0.67**	**−0.58**
vowelDRESS	**0.57**	**0.51**	**0.63**
vowelTRAP	**0.88**	**0.82**	**0.94**
VowelDuration (log)	**−0.03**	**−0.06**	**−0.00**
genreOtherPopular	−0.02	−0.11	0.08
genreScottishVernacular	0.00	−0.09	0.10
directorPM1959–1975:vowelKIT	0.01	−0.03	0.05
directorMJS1987–2016:vowelKIT	0.00	−0.04	0.05
directorPM1959–1975:vowelDRESS	−0.04	−0.09	0.02
directorMJS1987–2016:vowelDRESS	0.05	−0.01	0.12
directorPM1959–1975:vowelTRAP	**−0.09**	**−0.14**	**−0.04**
directorMJS1987–2016:vowelTRAP	**0.11**	**0.05**	**0.17**
vowelKIT:vdur_log	**−0.07**	**−0.11**	**−0.03**
vowelDRESS:vdur_log	**0.05**	**0.00**	**0.11**
vowelTRAP:vdur_log	**0.06**	**0.01**	**0.11**

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

For front vowels produced under Time/Director MJS (1987–2016), F1 is higher than the grand mean for Time/Director (median 0.18, CI $[0.08; 0.28]$), meaning that the front vowels are produced with a lower tongue/jaw configuration. Time/Director MJS has a higher F1 (tongue = lower) than earlier recordings.

There is a main effect of Vowel Duration which appears to increase tongue height. However, we must be careful interpreting this simple effect due to the interaction term Vowel:Vowel Duration. For the KIT vowel, F1 decreases (tongue raises) as duration increases (median -0.07, CI $[-0.11; -0.03]$). FLEECE and KIT may be driving the main effect of Vowel Duration on F1. While the credible intervals include zero, there is a trend for DRESS and TRAP to move in the opposite direction, such that the longer the vowel, the greater F1 (the lower the tongue). In other words, high vowels stay high or raise, whereas low vowels stay low or lower as duration increases, which could increase intelligibility for long vowels. The interaction of Vowel by Vowel Duration is visualised in Figure 5.4.

For Time/Director PM (1959–1975), TRAP F1 is lower than the grand mean (median -0.09, CI $[-0.14; -0.04]$), meaning the tongue is likely higher in the mouth. For Time/Director MJS (1987–2016), TRAP F1 is higher than the grand mean (median 0.11, CI $[0.05; 0.17]$), meaning the tongue is likely lower in the mouth. I couch these results with the word ‘likely’ because we know that acoustically similar sounds can be produced with different vocal tract configurations (see Lawson et al., 2019).

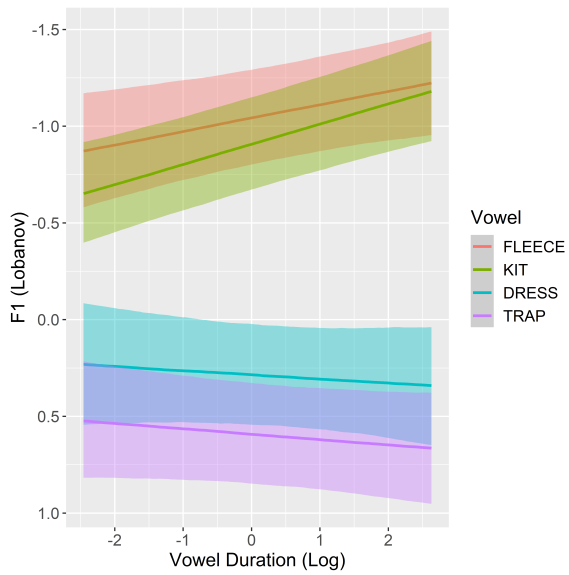


Figure 5.4: Glasgow: Front vowel F1 model, Vowel by Vowel Duration interaction

The model output does not directly answer all of the questions that we want to answer. We are principally interested in whether there has there been a change in tongue height over time. In order to examine this, we want to know where there is a difference in vowel quality between the Time/Director pairs Marilyn J. Smith (1987–2016) and Peter Mooney (1959–1975) compared to Hugh S. Roberton

(1925–1951). Appendix Table C.1 contains estimated marginal means with pairwise contrasts for Time/Director by Vowel interaction visualised in 5.5. Least squares means were computed using the `emmeans` package in R (Lenth, 2021).

There is no evidence of a change taking place over time for FLEECE. For Time/Director Marilyn J. Smith (1987–2016), KIT is more open compared to Hugh S. Roberton (1925–1951) (median 0.3447, CI $[0.1477; 0.5592]$), and Peter Mooney (1959–1975) (median 0.1925, CI $[0.0355; 0.3584]$). F1 is higher for MJS than the previous Time/Director pairs, meaning KIT is produced with a lower tongue/jaw configuration. The same pattern is found for the DRESS vowel; MJS (1987–2016) is more open compared to HSR (1925–1951) (median 0.3998, CI $[0.1635; 0.6459]$) and PM (1959–1975) (median 0.2925, CI $[0.0949; 0.4711]$). Again, F1 is higher meaning that the vowel is produced with a lower tongue/jaw configuration. TRAP reveals the same pattern of lowering over time, where Time/Director MJS (1987–2016) is different to HSR (1925–1951) (median 0.4564, CI $[0.2154; 0.6797]$) and PM (1959–1975) (median 0.4023, CI $[0.2164; 0.5728]$). From these post hoc pairwise comparisons, we can conclude that there has been a positive shift in the F1 dimension over time for KIT, DRESS and TRAP. Based on the priors, data and the model, the tongue/jaw position is lower for KIT, DRESS and TRAP for MJS (1987–2016) than in recordings made under HSR (1925–1975).

There is no evidence of a difference between Peter Mooney (1959–1975) and Hugh S. Roberton (1925–1951), so the model does not support a continuous trajectory of change. However, the existence of a trajectory is plausible, as the difference between Marilyn J. Smith (1987–2016) and PM (1959–1975) is always in the same direction and smaller than the difference between MJS and HSR. The interaction of Vowel by Time/Director is visualised in Figure 5.5.

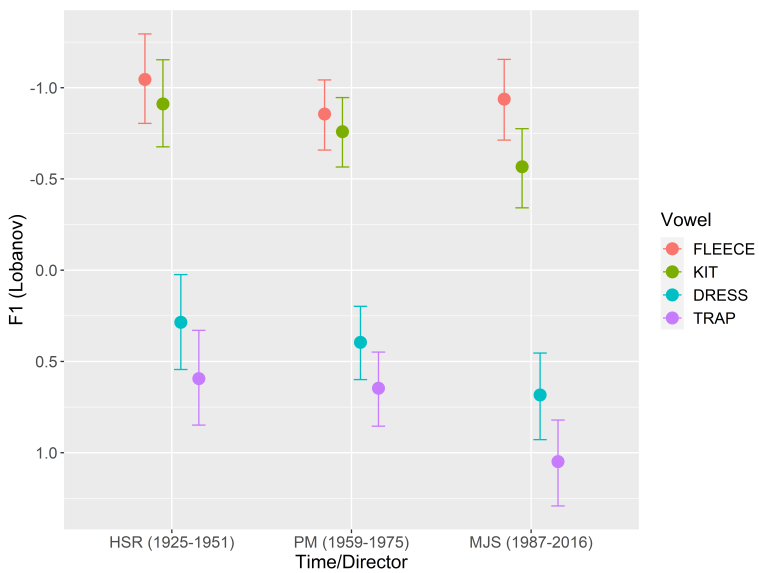


Figure 5.5: Glasgow: Front vowel F1 model: Vowel by Time/Director interaction

The second model I report is the F2 front vowel model. Reminder: the acoustic variable F2 is correlated with the frontness–backness dimension – how forward the tongue is in the mouth. The more forward the tongue, the higher F2. The further back the tongue, the lower F2, such that FLEECE has a very high F2 and GOOSE has a very low F2.

Table 5.6: Glasgow: Front vowel F2 model posterior summary

	Estimate	95% CI	
Intercept	**0.64**	**0.59**	**0.70**
directorPM1959–1975	**−0.07**	**−0.14**	**−0.01**
directorMJS1987–2016	−0.06	−0.13	0.00
vowelKIT	**0.37**	**0.34**	**0.40**
vowelDRESS	**−0.35**	**−0.39**	**−0.32**
vowelTRAP	**−0.74**	**−0.79**	**−0.70**
vowelDuration (log)	**−0.05**	**−0.07**	**−0.03**
genreOP	**0.04**	**0.00**	**0.08**
genreSV	−0.01	−0.05	0.03
directorPM1959–1975:vowelKIT	0.02	−0.01	0.04
directorMJS1987–2016:vowelKIT	**−0.04**	**−0.06**	**−0.01**
directorPM1959–1975:vowelDRESS	−0.01	−0.04	0.02
directorMJS1987–2016:vowelDRESS	**−0.06**	**−0.10**	**−0.02**
directorPM1959–1975:vowelTRAP	**0.06**	**0.04**	**0.09**
directorMJS1987–2016:vowelTRAP	**−0.09**	**−0.12**	**−0.05**
vowelKIT:vdur_log	**0.09**	**0.07**	**0.11**
vowelDRESS:vdur_log	**−0.05**	**−0.08**	**−0.02**
vowelTRAP:vdur_log	**−0.11**	**−0.13**	**−0.08**

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

The model reveals a negative effect of Vowel Duration (median -0.05, CI $[-0.07; -0.03]$). However, again, we must be careful when interpreting this due to the interaction of Vowel:VowelDuration (as for the F1 model). As shown in Figure 5.6, the longer the Vowel Duration the fronter KIT becomes (median 0.09, CI $[0.07; 0.11]$). In contrast, the longer DRESS (median -0.05, CI $[-0.08; -0.02]$) and TRAP (median -0.11, CI $[-0.13; -0.08]$) are, the more retracted they become (that is, the further the tongue moves back in the mouth).

The interaction Time/Director by Vowel (see Figure 5.7) has a similar pattern as in the F1 dimension. DRESS for Time/Director Marilyn J. Smith (1987–2016) is more retracted than the grand mean for Time/Director (median -0.06, CI $[-0.13; 0.00]$). TRAP is fronter for Time/Director Peter Mooney (1959–1975) compared to the grand mean (median 0.06, CI $[0.04; 0.09]$), contrasting with Time/Director MJS (1987–2016), where TRAP is more retracted than the grand mean (median -0.09, CI $[-0.12; -0.05]$). This interaction is visualised in Figure 5.7, which shows that

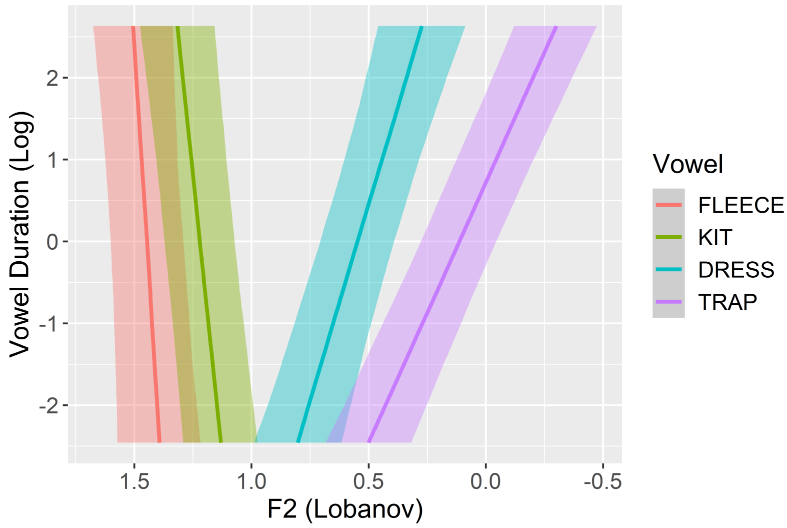


Figure 5.6: Glasgow: Front vowel F2 model, Vowel by Vowel Duration interaction

PM (1959–1975) and MJS (1987–2016) appear to pattern together for KIT and DRESS, but, for TRAP, there is a clear separation between each Time/Director.

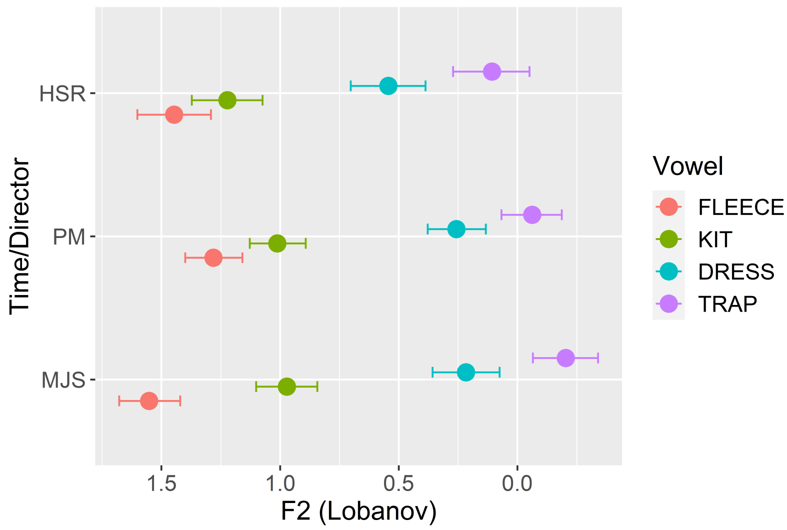


Figure 5.7: Glasgow: Front vowel F2 model, Vowel by Time/Director interaction

Post hoc comparisons of Vowel by Time/Director are presented in Appendix Table C.2. The interaction is visualised in Figure 5.7. FLEECE has wobbled around the front high area of the vowel space. There does not appear to have been any systematic change. For KIT, there is a difference between Time/Director Peter Mooney (1959–1975) and Hugh S. Roberton (1925–1951) (median -0.2079 CI $[-0.3420; -0.0811]$) and between Marilyn J. Smith (1987–2016) and HSR (1925–1951) (median -0.2499, CI $[-0.3839; -0.1161]$). Both differences are in the same direction, and the difference is more substantial between MJS and HSR. However, there is no difference between MJS and PM. KIT is more retracted, meaning it is produced with the tongue further back in the mouth for recordings produced under PM and MJS. DRESS follows a similar pattern to KIT, such that PM (1959–1975) is different to HSR (1925–1951) (median -0.2854, CI

[$-0.4294; -0.1464$] and MJS (1987–2016) is different to HSR (median -0.3266, CI [$-0.4833; -0.1734$]). However, there is no difference between the PM and MJS. DRESS is produced with the tongue more retracted for recordings made under Time/Director PM and MJS compared to HSR. TRAP, however, is statistically different for all three pairwise comparisons. That is, there is a difference between the PM (1959–1975) and HSR (1925–1951) (median -0.1688, CI [$-0.3128; -0.0345$]). There is also a difference between MJS and HSR (1987–2016) (median -0.3107, CI [$-0.4643; -0.1680$]). Finally, there is also a difference between MJS and PM (median -0.1428, CI [$-0.2510; -0.0207$]), demonstrating a complete trajectory of change, where TRAP has become more retracted over time for each Time/Director analysed.

5.5.2 Glasgow: Back vowel system

Table 5.7 presents the N, mean and standard deviations for F1 (Hz), F2 (Hz), and Duration (ms) for the back vowel raw data grouped by vowel and Time/Director. This is followed by the results for the F1 back vowel model.

As a reminder, we are returning to the F1 domain. The acoustic variable F1 relates to how high the tongue is in the mouth. The higher F1 is, the closer the tongue is to the roof of the mouth. Therefore, the model asks how the independent variables (Time/Director, Vowel, Vowel Duration etc.) affect tongue height.

Results presented here are displayed in Table 5.8. The interaction Time/Director by Vowel is driven by THOUGHT for Marilyn J. Smith (1987–2016) where F1 is higher than the grand mean (median 0.10, CI [$0.03; 0.17$]), meaning that the tongue/jaw configuration is likely lower. As seen in Figure 5.8, there is an interaction of Vowel by Vowel Duration. The longer LOT (median -0.15, CI [$-0.22; -0.08$]) and THOUGHT (median -0.10, CI [$-0.17; -0.04$]), the more raised they become. In contrast, the longer FOOT is, the lower it becomes (median 0.18, CI [$0.00; 0.35$]).

As can be seen in Appendix Table C.3 (and visualised in Figure 5.9), BATH, STRUT, and THOUGHT are all significantly higher (meaning the tongue position is lower in the mouth) for Marilyn J. Smith (1987–2016) compared to Peter Mooney (1959–1975). THOUGHT is also higher for MJS (1959–1975) than for Hugh S. Roberton (1925–1951) (median 0.3234, CI [$0.0559; 0.6260$]). This demonstrates a trajectory of lowering over time for THOUGHT. There is no change in tongue height for FOOT and GOOSE over time.

As shown in Appendix Table C.4, BATH–LOT are distinct in height for all

Table 5.7: Glasgow: back vowel raw formant and duration data by Time/Director

			F1 (Hz)		F2 (Hz)		Duration (ms)	
Vowel	Time/Director	N	Mean	SD	Mean	SD	Mean	SD
BATH	HSR 1925–1951	59	679	79	1322	213	990	770
BATH	PM 1959–1975	137	640	88	1236	121	1180	1050
BATH	MJS 1987–2016	81	657	104	1217	115	770	520
STRUT	HSR 1925–1951	60	646	111	1223	145	1080	1220
STRUT	PM 1959–1975	275	641	89	1174	103	850	620
STRUT	MJS 1987–2016	112	677	83	1213	104	880	620
LOT	HSR 1925–1951	73	610	82	1128	134	1000	1090
LOT	PM 1959–1975	401	611	88	1137	155	920	840
LOT	MJS 1987–2016	196	636	103	1112	123	910	910
THOUGHT	HSR 1925–1951	99	589	93	1127	172	1260	1100
THOUGHT	PM 1959–1975	357	598	90	1111	146	1100	740
THOUGHT	MJS 1987–2016	225	613	101	1098	122	900	750
FOOT	HSR 1925–1951	14	432	79	967	153	490	400
FOOT	PM 1959–1975	49	429	74	942	114	620	410
FOOT	MJS 1987–2016	16	442	41	938	71	590	310
GOOSE	HSR 1925–1951	62	410	57	899	103	890	690
GOOSE	PM 1959–1975	268	412	67	910	121	830	650
GOOSE	MJS 1987–2016	143	422	77	941	127	820	560

Table 5.8: Glasgow: Back vowel F1 model posterior summary

	Estimate	95% CI	
Intercept	0.11	−0.00	0.23
directorPM1959–1975	−0.09	−0.21	0.04
directorMJS1987–2016	0.11	−0.03	0.24
vowelBATH	**0.68**	**0.59**	**0.77**
vowelLOT	**0.33**	**0.26**	**0.41**
vowelTHOUGHT	**0.39**	**0.32**	**0.46**
vowelFOOT	**−0.89**	**−1.03**	**−0.74**
vowelGOOSE	**−1.07**	**−1.16**	**−0.99**
vowelDuration (log)	**−0.05**	**−0.09**	**−0.00**
genreOP	0.02	−0.08	0.13
genreSV	0.02	−0.08	0.12
directorPM1959–1975:vowelBATH	−0.06	−0.15	0.02
directorMJS1987–2016:vowelBATH	0.01	−0.09	0.11
directorPM1959–1975:vowelLOT	0.05	−0.02	0.11
directorMJS1987–2016:vowelLOT	0.05	−0.03	0.13
directorPM1959–1975:vowelTHOUGHT	−0.01	−0.07	0.06
directorMJS1987–2016:vowelTHOUGHT	**0.10**	**0.03**	**0.17**
directorPM1959–1975:vowelFOOT	0.03	−0.12	0.17
directorMJS1987–2016:vowelFOOT	−0.14	−0.33	0.06
directorPM1959–1975:vowelGOOSE	0.06	−0.01	0.13
directorMJS1987–2016:vowelGOOSE	−0.08	−0.17	0.01
vowelBATH:vdur_log	**0.09**	**0.01**	**0.17**
vowelLOT:vdur_log	**−0.15**	**−0.22**	**−0.08**
vowelTHOUGHT:vdur_log	**−0.10**	**−0.17**	**−0.04**
vowelFOOT:vdur_log	**0.18**	**0.00**	**0.35**
vowelGOOSE:vdur_log	0.05	−0.02	0.14

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

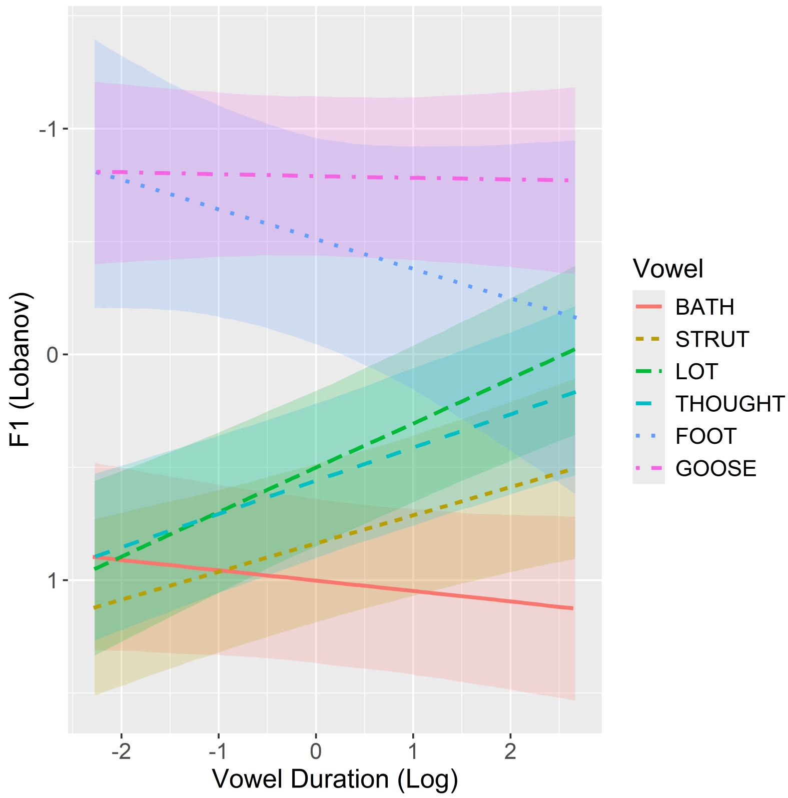


Figure 5.8: Glasgow: Back vowel F1 model, Vowel by Vowel Duration interaction

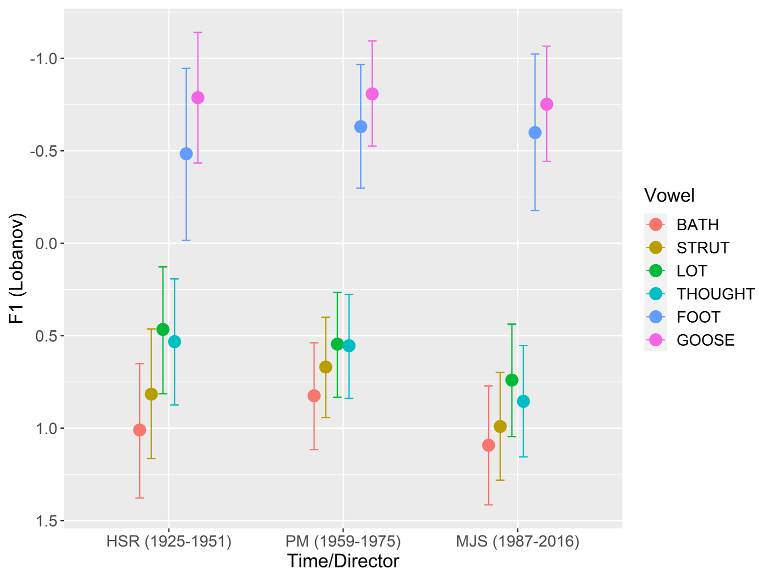


Figure 5.9: Glasgow: Back vowel F1 model, Vowel by Time/Director interaction

Time/Directors. BATH–STRUT are distinct in height for Time/Director PM (1959–1975) (median 0.1550, CI [0.0237, 0.2952]), but not for Hugh S. Roberton or Marilyn J. Smith. Neither LOT–THOUGHT nor FOOT–GOOSE are distinct in height (F1 dimension) for any Time/Director pairs.

I will now summarise the results of the back vowel F2 model. The acoustic variable F2 is correlated with the frontness–backness dimension – how forward the tongue is in the mouth. The more forward the tongue, the higher F2 and vice versa. Of the back vowel set, BATH has a higher F2 because it is more forward in the mouth, whereas GOOSE has a comparatively lower F2 because it is produced very far back in the mouth.

Table 5.9: Glasgow: Back vowel F2 model posterior summary

	Estimate	95% CI	
Intercept	**−0.99**	**−1.04**	**−0.93**
directorPM1959–1975	−0.02	−0.08	0.03
directorMJS1987–2016	−0.02	−0.08	0.04
vowelBATH	**0.43**	**0.37**	**0.48**
vowelLOT	**0.09**	**0.04**	**0.13**
vowelTHOUGHT	**0.07**	**0.03**	**0.12**
vowelFOOT	**−0.37**	**−0.47**	**−0.28**
vowelGOOSE	**−0.50**	**−0.55**	**−0.44**
vowelDuration (log)	**−0.06**	**−0.09**	**−0.04**
genreOP	−0.00	−0.05	0.05
genreSV	0.03	−0.02	0.07
directorPM1959–1975:vowelBATH	0.01	−0.05	0.06
directorMJS1987–2016:vowelBATH	**−0.07**	**−0.13**	**−0.01**
directorPM1959–1975:vowelLOT	0.02	−0.02	0.06
directorMJS1987–2016:vowelLOT	0.00	−0.05	0.05
directorPM1959–1975:vowelTHOUGHT	**0.05**	**0.01**	**0.09**
directorMJS1987–2016:vowelTHOUGHT	−0.01	−0.06	0.04
directorPM1959–1975:vowelFOOT	0.02	−0.07	0.11
directorMJS1987–2016:vowelFOOT	−0.04	−0.17	0.08
directorPM1959–1975:vowelGOOSE	−0.02	−0.07	0.02
directorMJS1987–2016:vowelGOOSE	**0.08**	**0.02**	**0.13**
vowelBATH:vdur_log	**−0.09**	**−0.14**	**−0.04**
vowelLOT:vdur_log	−0.01	−0.06	0.03
vowelTHOUGHT:vdur_log	0.03	−0.01	0.08
vowelFOOT:vdur_log	0.08	−0.04	0.19
vowelGOOSE:vdur_log	0.01	−0.04	0.06

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

BATH has a lower F2 for Marilyn J. Smith (1987–2016) compared to the grand mean (median -0.07, CI $[-0.13; -0.01]$), meaning that it is produced with the tongue further back in the mouth. THOUGHT has a higher F2 for Peter Mooney (1959–1975) compared to the grand mean (median 0.05, CI $[0.01; 0.09]$, meaning that THOUGHT is produced with the tongue further forward in the mouth. GOOSE has a higher F2 for Marilyn J. Smith (median 0.08, CI $[0.02; 0.13]$) compared to the grand mean. There is an interaction of Vowel by Vowel Duration, driven by BATH, where an increase in duration leads to retraction (median -0.09, CI $[-0.14, -0.04]$) compared to the grand mean. Figure 5.10 shows the Vowel by Vowel Duration interaction.

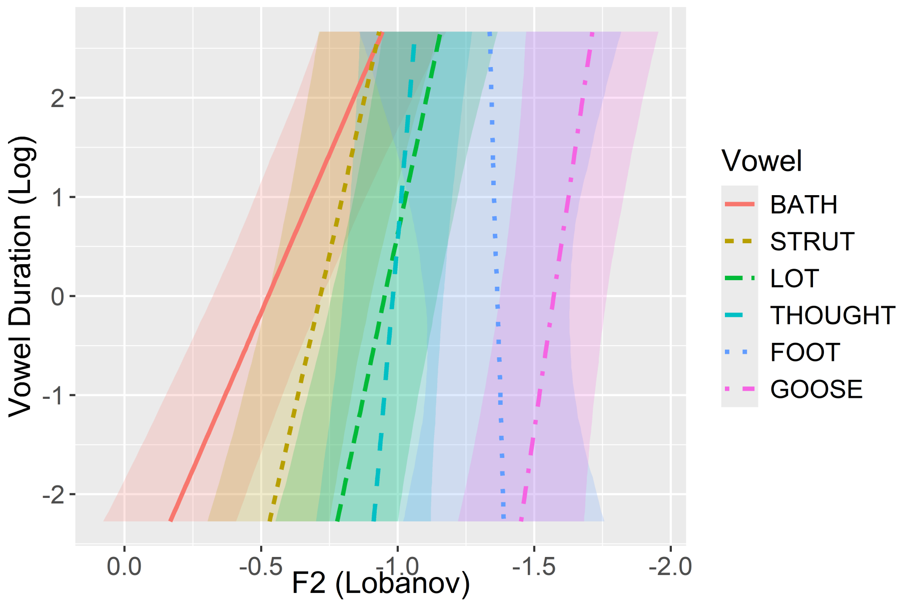


Figure 5.10: Glasgow: Back vowel F2 model, Vowel by Vowel Duration interaction

As seen in Appendix Table C.5, BATH has a lower F2 (is produced with the tongue further back in the mouth) for Marilyn J. Smith (1987–2016) compared to Hugh S. Roberton (1925–1951) (median -0.2027, CI $[-0.3691; -0.0460]$). STRUT is more retracted for Peter Mooney (1959–1975) than for HSR (1925–1951) (median -0.1437, CI $[-0.2825; -0.0109]$).

As seen in Appendix Table C.6, BATH and STRUT are acoustically distinct in F2, with BATH fronter than STRUT for Hugh S. Roberton (1925–1951) (median 0.175, CI $[0.0398; 0.3164]$) and Peter Mooney (1959–1975) (median 0.1951, CI $[0.1053; 0.2818]$), but not for Marilyn J. Smith (1987–2016). BATH and LOT are statistically different for all Time/Director pairs in the same direction, with BATH fronter than LOT. LOT and THOUGHT are not different in F2 for any Time/Director. FOOT and GOOSE are only statistically different in F2 for PM (median 0.1764, CI $[0.0377; 0.3118]$), though this could be because the Time/Director PM (1959–1975) has the greatest number of tokens for FOOT and GOOSE.

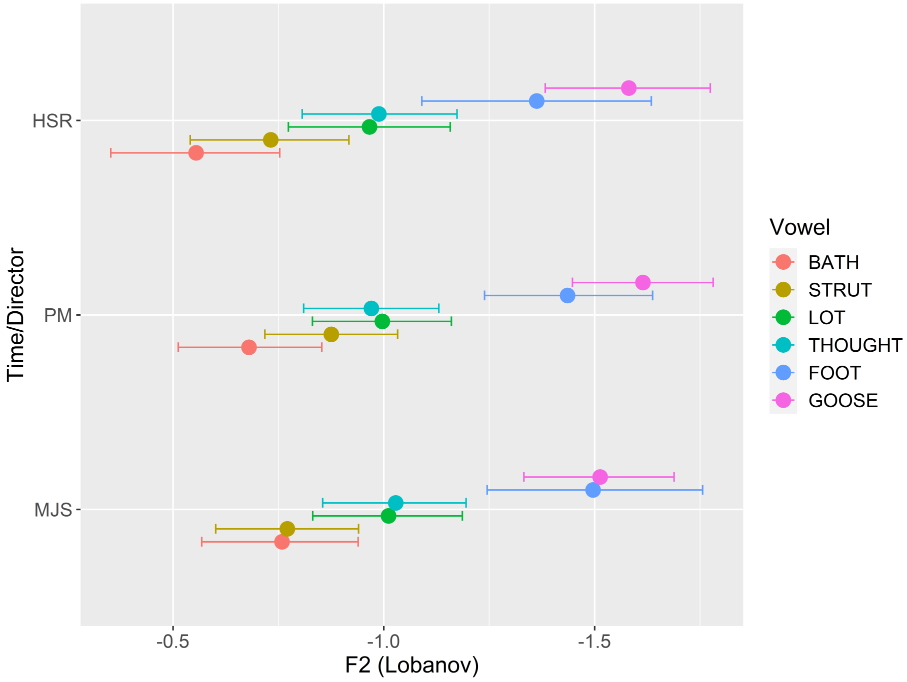


Figure 5.11: Glasgow: Back vowel F2 model, Vowel by Time/Director interaction

5.5.3 Glasgow: TRAP–BATH models

In order to investigate the underlying vowel phonology fully, I also needed to compare the TRAP–BATH lexical sets. These are particularly interesting, as there is no TRAP–BATH contrast in Glasgow Vernacular English, and typically not in Standard Scottish English. There is only one lexical set, sometimes called CAT (Stuart-Smith, 1999), whereas in Standard Southern British English and Received Pronunciation, there are two distinct lexical sets (Wells, 1982a).

Table 5.10 shows no effect of Time/Director for TRAP–BATH height. Post hoc pairwise comparisons show that TRAP and BATH are not distinct in tongue height for any Time/Director (see Appendix Table C.7). However, in Appendix Table C.8, as we found with the previous models, BATH is lower for Marilyn J. Smith (1987–2016) than for Peter Mooney (1959–1975) (median 0.3086, CI $[0.0061; 0.6017]$), and TRAP is significantly lower for MJS than for both Hugh S. Roberton (median 0.4517, CI $[0.0989; 0.7798]$) and PM (median 0.3745, CI $[0.1117; 0.6480]$).

Returning to the F2 (backness) domain, as seen in Table 5.11, TRAP has a significantly higher F2 than BATH (median 0.34, CI $[0.25; 0.44]$), meaning that it is produced with the tongue significantly fronter in the mouth. There is a main effect of Vowel Duration: the longer TRAP–BATH, the more retracted they are (median -0.14, CI $[-0.19, -0.09]$). There is also an interaction of Vowel by Time/Director, with TRAP for Marilyn J. Smith (1987–2016) produced significantly backer than the grand mean (median -0.09, CI $[-0.16; -0.01]$).

Table 5.10: Glasgow: TRAP–BATH F1 model posterior summary

	Estimate	95% CI	
Intercept	**0.80**	**0.63**	**0.98**
directorPM1959–1975	−0.16	−0.33	0.02
directorMJS1987–2016	0.15	−0.04	0.35
vowelTRAP	0.05	−0.11	0.21
VowelDuration (log)	0.06	−0.03	0.16
genreOP	0.03	−0.10	0.16
genreSV	−0.03	−0.16	0.09
directorPM1959–1975:vowelTRAP	0.06	−0.06	0.18
directorMJS1987–2016:vowelTRAP	0.13	−0.02	0.27
vowelTRAP:vdur_log	−0.04	−0.15	0.07

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

Table 5.11: Glasgow TRAP–BATH F2 model posterior summary

	Estimate	95% CI	
Intercept	**−0.50**	**−0.59**	**−0.41**
directorPM1959–1975	−0.03	−0.12	0.06
directorMJS1987–2016	−0.07	−0.16	0.02
vowelTRAP	**0.34**	**0.25**	**0.44**
VowelDuration (log)	**−0.14**	**−0.19**	**−0.09**
genreOP	0.04	−0.01	0.10
genreSV	−0.00	−0.06	0.05
directorPM1959–1975:vowelTRAP	0.04	−0.02	0.10
directorMJS1987–2016:vowelTRAP	**−0.09**	**−0.16**	**−0.01**
vowelTRAP:vdur_log	−0.01	−0.06	0.05

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

In Appendix Table C.9, post hoc pairwise comparisons show that TRAP and BATH are distinct in the F2 (backness) dimension for all Time/Director pairs; however, qualitatively, this distinction appears to be lessening over time. Appendix Table C.10 shows that TRAP is more retracted for Marilyn J. Smith (1987–2016) compared to both Hugh S. Roberton (1925–1951) (median -0.2967, CI $[-0.4492; -0.1497]$) and Peter Mooney (1959–1975) (median -0.1649, CI $[-0.2753; -0.0392]$).

5.5.4 Glasgow: Vowel duration model

In speech, vowel identity is cued by vowel quality (F1, height; F2, backness) and vowel quantity (vowel duration). Vowel duration is a particularly interesting variable in singing research, as the composer and conductor somewhat specify the duration, but we also have vowel identity at play. As suggested in Section 1.3, the questions are as follows: Does vowel duration vary by phoneme as we would expect based on the phonology of spoken English? Does the data provide evidence of long–short vowel contrasts (e.g. FLEECE–KIT), despite duration being constrained by musical duration? Separately, musicologists report a shift over the twentieth century with performances becoming faster, more faithful to the notation, and recordings exhibiting less rubato Leech-Wilkinson (2009a). Is this pattern supported in the recordings of choral singing analysed in this chapter? While I cannot investigate bar-for-bar (or measure-for-measure) change over time, I have broad aggregate measures of vowel duration. The variables included for the analysis of vowel duration are Vowel, Time/Director, Genre, Preceding Manner, Following Segment, and the interaction Vowel by Genre. The varying effects structure stays the same as for the previous models.

Table 5.12: Glasgow: Vowel Duration model posterior summary

	Estimate	95% CI	
Intercept	**−0.38**	**−0.48**	**−0.27**
directorPM1959–1975	0.01	−0.05	0.07
directorMJS1987–2016	**−0.10**	**−0.17**	**−0.03**
vowelKIT	**−0.33**	**−0.39**	**−0.28**
vowelDRESS	0.05	−0.02	0.12
vowelTRAP	0.01	−0.08	0.10
vowelBATH	**0.24**	**0.12**	**0.36**
vowelSTRUT	0.01	−0.09	0.11
vowelLOT	**0.12**	**0.02**	**0.21**
vowelTHOUGHT	**0.15**	**0.05**	**0.26**
vowelFOOT	**−0.43**	**−0.59**	**−0.27**
vowelGOOSE	**−0.14**	**−0.24**	**−0.03**
genreOP	**−0.14**	**−0.26**	**−0.02**
genreSV	−0.06	−0.19	0.06

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

As seen in Table 5.12, there is a main effect of Time/Director such that vowel duration for Marilyn J. Smith (1987–2016) is shorter than the grand mean (median -0.10, CI $[-0.17; -0.03]$). KIT, FOOT and GOOSE are shorter than the grand mean for Vowel. Whereas BATH, LOT, and THOUGHT are longer than the grand mean. The Genre Other Popular is shorter than the grand mean for Genre (median -0.14, CI $[-0.26, -0.02]$). In Appendix Table C.11, post hoc comparisons show that vowel duration is shorter for Time/Director Marilyn J. Smith (1987–2016) compared to both Hugh S. Roberton (1925–1951) (median -0.1950, CI $[-0.3288; -0.0552]$) and Peter Mooney (1959–1975) (median -0.1155, CI $[-0.2199; -0.0121]$). These results support the previous musicological findings of shortening over time.

Appendix Table C.12 shows that FLEECE is considerably longer than KIT (median 0.6518, CI $0.5566; 0.7479]$ which is to be expected and is consistent with the phonetic and phonology literature. TRAP is significantly shorter than BATH (median -0.2248, CI $[-0.3864; -0.0593]$). BATH is longer than STRUT (median 0.2238, CI $[0.0568; 0.3965]$). FOOT is shorter than GOOSE (median -0.2926, CI $[-0.5009; -0.0864]$), as expected. BATH–LOT and LOT–THOUGHT do not differ in duration in this model.

Finally, as seen in Appendix Table C.13, vowels in the Other Popular Genre are shorter than for Church Music (median -0.3428, CI $[-0.5471; -0.1494]$. Likewise, vowels in the Scottish Vernacular Genre are significantly shorter than in Church Music (median -0.2682, CI $[-0.4652; -0.0518]$). There was no difference between the two popular genres, reflecting my intuitions about the general effect the popular reference style may have more widely.

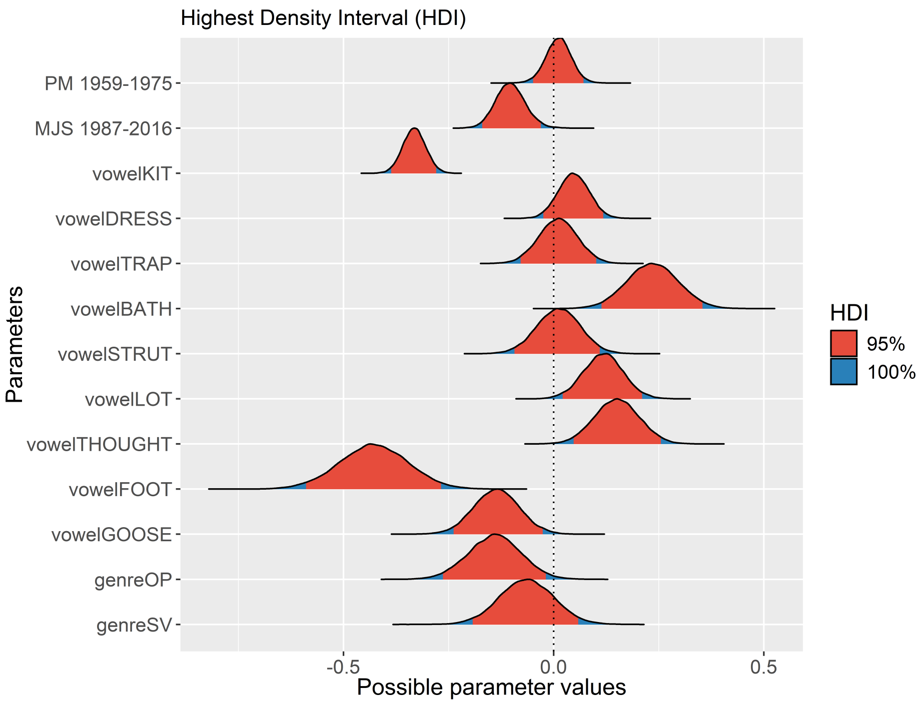


Figure 5.12: Highest Density Intervals for Duration model fixed effects

Figure 5.12 is a visualisation of the model estimates showing there is a small effect of Time/Director with Marilyn J. Smith 1987–2016 having a shorter vowel duration / faster tempo overall as predicted. There is a much larger effect of vowel, which shows that vowel duration may be a cue to vowel identity, even when formants do not differ significantly, for example in the case of FOOT and GOOSE. TRAP and BATH also appear distinct in duration and we can infer that FLEECE and KIT also differ quite strongly in duration. Finally, there is a small effect of genre with the ‘Other Popular’ category having a shorter duration overall.

5.6 Discussion

This chapter investigated variation and change over time in vowel quality in recordings of Glasgow choirs. The models and data support change over time. TRAP, DRESS and KIT appear to have lowered and retracted over time, mirroring the pattern presented by the shift from Morningside/Kelvinside accent to Scottish Standard English over the twentieth century. Johnston (1985) regarded M/K as a combination of 'hyper-RP' and Scottish features.

Of RP, Bjelaković (2017) writes, 'The vowel in this lexical set [TRAP] was lowering throughout the mid-to-late twentieth century' (Bjelaković, 2017, p. 3.4). From the data Bjelaković (2017) present, it appears that TRAP was also retracting throughout this period, though not as strongly as it lowered. While TRAP lowering was not a controversial finding for Bjelaković (2017), finding it in this chapter provides evidence of a sociolinguistic change occurring in a speech variety affecting the accent of choral singing.

Cruttenden (2014) tells us that RP [eə] became SSBE [ɛː], as in *fare*, *tear*, which could account for the DRESS lowering that we have found. In addition, Cruttenden also writes that one more recent trend is that '/e/ is lowered, following the pattern of /a/ i.e. it is being pulled downwards' (2014, p. 85). This may explain why the other front vowels are lowering – it could be that they, too, are being 'pulled' down by TRAP lowering. Interestingly, there is little discussion of front vowels retracting in the literature. There are some trends, for example, in Hawkins & Midgley (2005); however, the effect was not significant. As BATH also significantly retracted over time, this could have pulled the front vowels back while TRAP caused them to lower.

KIT lowering could be attributable to what is known as the weak vowel merger. As Lindsey writes 'RP made extensive use of the KIT vowel and the FOOT vowel in weak syllables before consonants. There's an increasing tendency to replace these with schwa' (2019, p. 39). This would mean that KIT in weak syllables could be more schwa-like. This explanation is plausible as KIT is lowering and retracting, moving closer to the centre of the vowel space.

The models revealed an interaction of Vowel by Vowel Duration, such that the longer KIT is, the more front and raised it becomes. In contrast, DRESS and TRAP tend to lower and retract as Vowel Duration increases. These findings make sense from a Western classical singing perspective. TRAP is considered quite 'bright' (front) in quality, and when sung for longer durations, it may be considered more aesthetically pleasing to 'darken' the vowel quality by retracting towards BATH.

This is the opposite pattern to that reported for British popular artists, which may adopt American long /a/ – that is, make use of a low front vowel [æ] or [a] for BATH lexical set (which are canonically longer than TRAP set) (e.g. Flanagan, 2019) – demonstrating that these patterns are arbitrary and genre-specific.

In the Glasgow choral data, TRAP and BATH are not statistically distinct in vowel height for any Time/Director. However, there is a difference in backness for each, though this difference appears to have decreased over time. There is also a difference in duration. This is surprising, as in Standard Scottish English, we would expect TRAP and BATH (or PALM) to be represented by the same phoneme /a/ (Abercrombie, 1979; Stuart-Smith, 1999, 2008). This means that the Glasgow choral front-vowel phonology is more similar to Southern Standard British English than Scottish Standard English. This means that for choral singing, Glasgow choir members must acquire a different phonology to that of their spoken accent. This finding supports the outgroup referee design of choral singing proposed by Wilson (2014) that the underlying phonology of choral singing is based on a Standard Southern British accent. This link between SSBE accent and choral singing is intuitive to me as a singer, as in choral singing, there are 'correct' ways of singing words, and these have to be learnt by experience or instruction as part of the choral singers' enculturation process (Wilson, 2014). From a linguist's perspective, it is surprising that a choir of middle-class Glaswegians in the early twentieth century had a TRAP–BATH distinction in their singing when they would have had to have learned which words to use TRAP and which to use BATH. Even though some members may have had elocution lessons, as Lindsey puts it, 'BATH broadening can be tricky to learn. Not only is it hard to explain why words did or did not broaden; there are also words which have broadened more recently, such as *graph*' (2019, p. 42).

The realisation of vowels in the early period may have been influenced by Received Pronunciation. Alternatively, it is possible, particularly in the case of TRAP, that vowel realisation could be related to the prestigious middle-class Morningside/Kelvinside accents where the high TRAP vowel was particularly salient, perhaps even more raised than in RP (Johnston, 1985).

BATH and LOT have backed over time. As mentioned above, this may have had something to do with the backing of the front vowels, though, at this stage, that is conjecture. BATH, STRUT, LOT and THOUGHT are lower for Marilyn J. Smith (1987–2016) compared to Hugh S. Roberton (1925–1951).

GOOSE is known to have fronted in RP over the Twentieth Century (Bjelaković, 2017; Cruttenden, 2014; Wells, 1982a). However, I have found that GOOSE in recordings of Glasgow choral singing is extremely backed and cardinal-like in quality. Only in the late recordings under Marilyn J. Smith (1987–2016) is GOOSE fronter than the grand mean for the back vowel set, but even in the late period, it remains particularly backed in quality. Why is this the case? This very backed realisation of GOOSE cannot be attributed to either Standard Southern British English or Standard Scottish English, which both have a much fronter realisation of GOOSE.

The backed GOOSE realisation may provide evidence of the Morningside/Kelvinside accent influence on choral singing in Glasgow. GOOSE is particularly socially salient in Glasgow, with Glasgow vernacular realisations fronter (and lower) than [ʉ] (Scobbie et al., 2012). In choral performance, the choral singers could be defining their sound against that extremely front quality prominent in working-class Glasgow vernacular English by adopting the 'hyper-RP' M/K realisation [u̞].

An alternative possible explanation may relate to Western classical singing technique and the resonance quality caused by the formants clustering together (with very low F1 and F2). It could also be due to the peripherality itself being useful as a percept for audiences.

There is also an interaction of Vowel by Vowel Duration back vowels. The longer LOT and THOUGHT are, the more raised they become, presumably to differentiate from BATH. Conversely, the longer FOOT is, the lower it becomes. There is not enough evidence of FOOT fronting; however, it appears to be going in that direction – and we have to bear in mind that the credible intervals for FOOT are inflated by shrinkage towards the prior due to the small number of tokens. With more tokens, we might find that FOOT lowers and fronts moving towards COMMA (schwa) or STRUT. I am surprised that FOOT does not behave the same way as KIT and become more GOOSE-like the longer it is. However, it is also not surprising that FOOT moves towards COMMA.

Overall, there was a main effect of Time/Director consistent with the musicological literature. Vowel duration has reduced over time, meaning the music has become faster. The main effect of Vowel is consistent with the phonetics and phonology literature; short vowels still tend to be shorter than long vowels, as in speech. There was also a main effect of Genre. Both popular genres (Scottish Vernacular, Other Popular) appear to have shorter vowel duration than Church Music. This corresponds broadly to popular music being faster than church music in this corpus.

The data provides evidence of changes in the musical practices of these choirs over time. There has been a significant shortening of vowel duration overall over time. This is in keeping with findings in musicology. As Day writes, ‘The interpretation of rhythm has become ever more literal…and there is much less flexibility in tempo’ (2000, p. 150). I suspect that the effect of Time/Director on duration may be due to less flexibility of tempo and the decreased use of rubato in later recordings. This is noticeable in the Glasgow corpus when comparing the final line of the Orpheus recording of *All in the April evening* with more recent recordings.

The pattern of vowel duration in speech is largely preserved in choral singing. This means that composers, conductors and singers are, to some extent, aware of the phonological distinctions between short and long vowels. KIT is a short vowel, and so when it is stretched out longer in music, it raises and fronts to become FLEECE-like. This change is both a linguistic and aesthetic consideration. TRAP is also a phonologically short vowel, so it makes sense that when it is long, there is significant backing, and it becomes BATH.

5.7 Conclusion

This chapter provides the first evidence that vowel quality in recordings of choral singing has changed over time. The change in front vowel height appears to move in the same direction as M/K to SSE over a similar period of time. This suggests the possibility that the way we speak influences the way we sing together.

The standard choral accent appears to have tracked a shift in the front vowels of English language choral singing more widely, reflecting a shift in referee. In Chapter 6, I discuss whether the same change can be found in recordings of the Choir of King’s College, Cambridge. If this change is found in the King’s data, then it seems likely that this lowering and retraction may be part of a wider shift in choral singing practices as the referee of British choral singing has changed from Received Pronunciation to Southern Standard British English. In addition, if the change did occur at King’s in a similar time frame, it is plausible that King’s contributed to disseminating that change more broadly, considering the social and cultural importance of the Service of Nine Lessons and Carols that has been broadcast from King’s nearly every year since Christmas Eve 1918. The influence of King’s on choral performance practice more broadly has also been suggested by Potter (1998, p. 117) ‘such was the eminence of the choir that these quirks of style and pronunciation became the norm for parish church choirs throughout the land (and generally remain so)’, and also Day (2018).

Chapter 6

Singing the King's English: Variation and change over time in recordings of the Choir of King's College, Cambridge[1]

Chapter 5 demonstrated that vowel quality appears to have changed over time in Glasgow. Front vowels, in particular, have lowered over time, seemingly following a shift in referee from Received Pronunciation to Standard Southern British English. This chapter seeks to explore the vowel quality of the Choir of King's College, Cambridge, and whether that quality has changed throughout the recorded history of the choir to answer research questions 3)a–c (Section 1.3) for the King's corpus. Occasionally in the text, I will refer to the corpus of recordings produced by the choir as 'King's'.

If the referee of British choral singing is based on the 'High' form of the language, surely traces of this High pronunciation would be found at an institution like King's, whose sound has often popularly been considered ancient (Grace, 1917). While the singers may not speak with the same accent that they learn to sing at choirs like King's, the 'High' form of singing is likely fostered in the singers at these choral institutions.

What does singing in the High form of the language mean? As summarized in Chapter 3, there was a significant shift in the High spoken forms of Southern British English, and Scottish English, in the twentieth century shifting from

[1] An earlier version of some of the sections of this chapter will appear in Marshall et al. (2024).

Received Pronunciation to Southern Standard British English and from Morningside/Kelvinside English to Standard Scottish English. These shifts were both characterised by the lowering of the front vowels KIT, DRESS and TRAP. In Chapter 5, I found a similar lowering in Glasgow's front vowels in recordings of choral singing, suggesting that the referee for British classical choral singing has changed over time. Therefore, we might expect the same pattern in recordings of the Choir of King's College, Cambridge. If these data support the referee design model of British classical choral singing, we should expect to find a similar pattern of front vowel lowering at King's. However, considering these differences in choir membership in both gender and age of singers, is the pattern of front vowel lowering and retraction also found in recordings of the Choir of King's College, Cambridge? For a comprehensive overview of the sample, see Methodology Section 4.1.2. In the next section, I review the musicological descriptions of the sound of the Choir of King's College, Cambridge.

6.1 Musicological descriptions of King's sound

As we saw in Chapter 4 Section 4.1.2, due to the prominence of the King's, and the frequent LP output under David Willcocks, there are a number of musicological descriptions of the choir's sound. The choir's role in the development of the vocal early music movement is documented and evaluated in Sagrans (2016). The history of the choir has been the subject of a number of publications, including most recently *I saw eternity the other night* (Day, 2018).

As we saw in the Literature Review, there are different accounts of the choir's sound, with some musicologists suggesting that King's sound has been relatively stable over time (Sagrans, 2016). Other authors have reported that the choir's Directors of Music themselves noted that the style changed over time (Day, 2018). Furthermore, there have been suggestions that elite choral singing has stylistically altered since the 1960s (Rugen, 2013). Day (2018) writes:

> Many writers and commentators did indeed seem to give particular authority to the distinctiveness of King's College Choir in the middle of the century. It was the style of Willcocks's choir and not just of King's that remained a touchstone. Earthly choirs may have sung of 'eternal changelessness' but their singing could not but change, from year to year, from day to day. And any musicians didn't wish to copy but to be different.(Day, 2018, p. 239)

Sagrans describes the sound of King's as 'light, bright, breathy, evenly balanced, and that there is a high level of blend within sections, minimal variation in dynamics and tempo, minimal vibrato, and mostly legato articulation for melismas' (2016, p. 38). Day (2018) writes that the King's style could be characterised by blend, discipline and precision of consonant placement; 'Expressive gestures were intense but subdued. Tempos were almost invariably steady. Vibrato was avoided. The tuning was immaculate. The sounds shone with an unearthly silvery glitter' (Day, 2018, p. 7). Both Sagrans and Day suggest that the sound of King's is a particularly prominent example of a wider 'English' sound, which perhaps points in the direction of a referee for English choral singing. In sociolinguistic terms, the musicologists suggest a standard accent of English choral singing. What is this accent like?

6.2 Choir director

In this chapter, I present an analysis of vowel quality from commercially-released and broadcast recordings of the Choir of King's College, Cambridge. King's was selected for its status as the prototypical collegiate choir. Sagrans (2016) argues that 'the King's sound is a particularly high-profile example of a broader "English sound" for choral performance' (Sagrans, 2016, p. 29). Musicologists have remarked that the development of the King's style and their frequent broadcasts led to a shift in choral singing practices in church choirs across the country (Day, 2018; Potter, 1998). Sagrans (2016) describes how the King's sound is similar to a wider English sound found in British early music vocal ensembles. This similarity is attributed to King's early recorded output containing a large proportion of early music, as well as the fact that many of the members of these new early ensembles came from the universities of Oxford and Cambridge. If there were a place where a standard spoken accent was contributing to changes in choral singing style, surely it would be found at King's.

The musicological literature suggests that the different choir directors at King's elicited specific accents. Particularly, Day (2018) suggests that David Willcocks (1959–1975) 'cultivated certain sounds which reflected his own style of spoken English, perhaps more the received pronunciation of English he heard as a chorister at Westminster Abbey in the 1930s than that of the 1960s. So *alleluia* became "e-lleluia". "I know thett my Redeemer liveth, ent thett he shell stent…".' (Day, 2018, p. 261). Therefore, we might expect to find the vowel height raised for recordings made under David Willcocks, and from the quote, particularly the TRAP vowel (the altered vowel in *alleluia, that, and, that, stand*). Day (2018) supports a shift in the style of the King's sound changing over time, writing:

> Willcocks certainly thought that a choir had a vocal identity, like a singer, and that it would be 'fussy and pernickety' to expect a choir to vary the tone-quality it produced. Nevertheless, even under his

> disciplined control, recordings confirm that the style evolved (Day, 2018, p. 173).

In contrast, Day (2018) reports that Cleobury 'thought that if the sound of the choir had changed…it might be because he had encouraged the choir to sing "with a bright forward tone" and that even when they were singing in English he had encouraged them to sing with Italian vowel sounds wherever possible' (Day, 2018, p. 261). This 'bright forward tone' and Italian vowel sounds in choral singing need investigating further. The primary Italian vowels of singing are /i, e, ɛ, a, ɔ, o, u/. These phonemes are noted for their 'purity' or for being realised as monophthongs. However, the Italian /ɛ/ and /a/ phonemes are phonetically realised as fronter and higher than the DRESS and TRAP vowels of standard sung English (Adams, 2008, p. 6). If Cleobury did succeed in cultivating Italian-like front vowels, we would expect them to be more peripheral in quality.

As mentioned in Chapter 5, and in Chapter 4, the effects of Time and Choir Director are inherently confounded in historical choir recordings. Therefore, they are inseparable in these analyses. However, I hope that we can garner some insight into the effect a Director may have on a choir's sound.

6.3 Adapted method

Following the method outlined previously, F1, F2 and Vowel Duration were extracted using Praat from the corpus constructed in LaBB-CAT for all monophthongs: FLEECE, KIT, DRESS, TRAP, BATH, STRUT, LOT, THOUGHT, FOOT, GOOSE and COMMA (schwa). F1, F2 and Vowel Duration were modelled using Bayesian statistical methods. As seen in the research questions above, one reason for carrying out this part of the study is to replicate the findings of Chapter 5 with more data. Another is to integrate these findings within the musicological literature using the more familiar sound world of a choir, which is present in popular and academic literature. Similar to the Glasgow vowels analyses, I am primarily looking for any evidence of change over time in the F1 or F2 dimensions. For the most part, the method for this chapter is identical to the acoustic method outlined in Chapter 4. However, there were a few differences which I detail below.

6.3.1 Time/Director

Table 6.1 is a reminder of the Time/Director coding for recordings of the Choir of King's College, Cambridge. Year spans show when there are recordings made (not director tenure).

Table 6.1: Choir of King's College, Cambridge Time/Director

Corpus	Dates active	Director	Coding
King's	1929–1958	Boris Ord	BO 1945–1958
	1957–1974	David Willcocks	DW 1959–1974
	1974–1982	Philip Ledger	PL 1976–1982
	1982–2019	Stephen Cleobury	SC 1984–2019

There is one recording made under Harold Darke during Boris Ord's service in the RAF from 1941–1945, which is included under Boris Ord (1945–1958). As there was only one album recorded by the Choir of King's College under the direction of Daniel Hyde at the time of analysis, the record was collapsed into the factor level Stephen Cleobury (1984–2019). Thus, for modelling purposes, Time/Director is coded as a four-level factor for King's: BO = 1945–1958 Boris Ord; DW = 1959–1974 David Willcocks; PL = 1976–1982 Philip Ledger; and, SC = 1984–2019 Stephen Cleobury.

6.3.2 Genre coding

For the King's corpus, Genre has two levels 'Evensong' and 'Carols'. This contrasts with the Glasgow genre factor, which had three levels: 'Church Music', 'Scottish Vernacular' and 'Other Popular'. This difference is due to the types of repertoire recorded by the choirs. In the Glasgow corpus, all of the data was of homophonic choir singing and always had multiple singers at any one point, even when only one section of the choir was singing. However, in the King's corpus, this is not the case, as there are cantors, occasionally tenor or bass soloists, and frequent treble solos.

There is something fundamentally different about the way singers sing when cantoring compared to when performing a solo in an anthem or carol (for example, whether a boy treble solo in 'Once in Royal David's City' or as a tenor solo in Harold Darke's version of 'In the Bleak Midwinter'). When cantoring, the rhythm is usually not specified and it is closer to speech rhythm (speech vowel quantity) and perhaps closer to speech vowel quality as well. Consequently, I decided to code Genre as a factor to include all music with cantors in factor level 'Evensong', and all Christmas music as factor level 'Carols' (containing no cantor-style singing), and everything else, recordings of hymns and anthems, into a factor-level 'Misc.'. As there was next to no difference between factor levels 'Carols' and 'Misc.' they were collapsed for the analysis. However, there were some differences, as expected, between the remaining two levels 'Carols' and 'Evensong'.

There is a slight confound here, as Genre contains both aspects of the type of repertoire and also the number of singers and type of singer. As this is not a primary research question of this study, in this chapter Genre serves to control for variation that may come from both repertoire and number/type of singers. As I predict that the factor Genre may differ by duration because of the cantor-style singing included in the Genre factor-level 'Evensong', I also included the interaction Genre by Vowel Duration in the models reported in this chapter.

6.4 Results

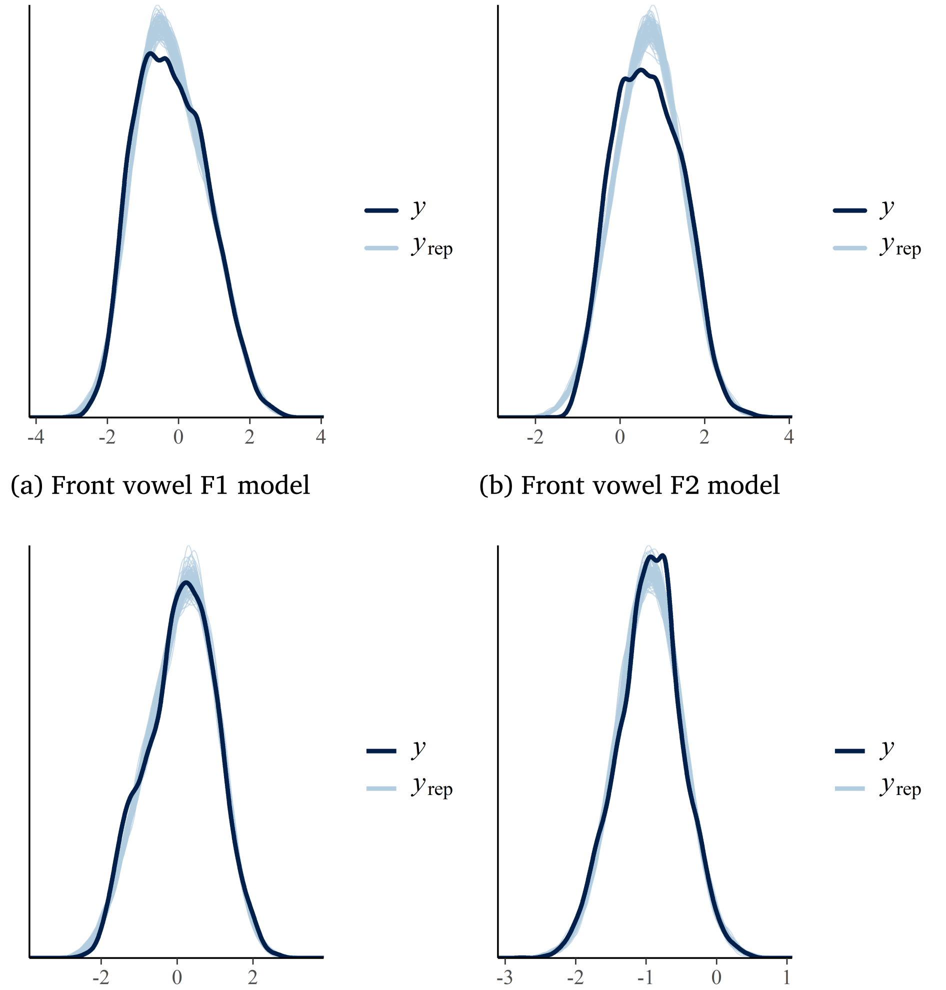
The raw data, code and models reported in this chapter can be found on the OSF at osf.io/psv5b. The general model structure for the vowel formant models is as found in table 6.2.

Table 6.2: Fixed effects, interactions, and varying effects structure for modelling

Predictor	Type	Levels/Units
Time/Director	Factor	BO (1945–1958), DW (1959–1974), PL (1976–1982), SC (1984–2019)
Vowel	Factor	Front: FLEECE, KIT, DRESS, TRAP; Back: BATH, STRUT, LOT, THOUGHT, FOOT, GOOSE; TRAP–BATH
Vowel Duration	Contin.	Log (ms)
Following Segment	Factor	See Appendix D
Genre	Factor	Carols, ChurchMusic, Misc.
Vowel:Time/Director Vowel:Duration Time/Director:Duration Genre:Duration	Interaction Interaction Interaction Interaction	
(1|Word) (1|Song) (1|Album) (1|Song:Word) (1|Album:Song)	Varying effect Varying effect Varying effect Nesting effect Nesting effect	

6.4.1 Model convergence criteria

Following extensive trialling in Chapter 5, I decided to continue with weakly informative priors. All models were checked for convergence following the procedure outlined in Vasishth et al. (2018). Model chains were visually inspected for each model to ensure they mixed well. Figure 6.1 contains posterior predictive checks for the King's vowel formant models. The dark lines show the real data, and the light lines show simulated data. All models generate simulated data which



(a) Front vowel F1 model

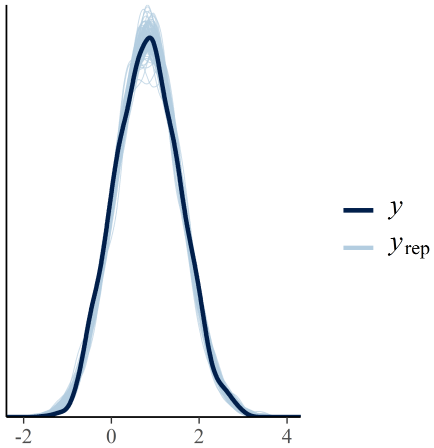
(b) Front vowel F2 model

(c) Back vowel F1 model

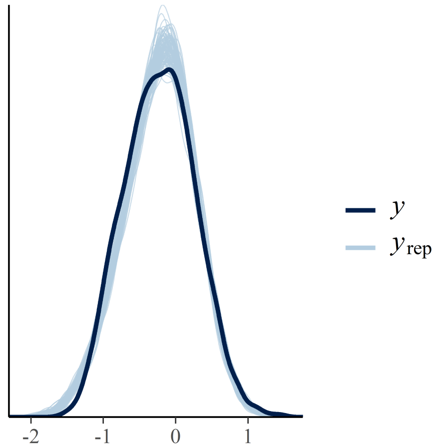
(d) Back vowel F2 model

Figure 6.1: King's: Front and back vowel F1/F2 model posterior predictive checks

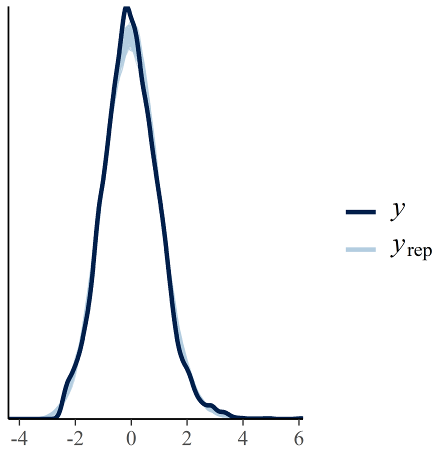
fits the real data reasonably well, though less good for front vowels (particularly F2). There is a good overlap between the light and dark lines on each plot, so we can be reasonably confident in the model output. Figure 6.2 contains posterior predictive checks for the King's corpus TRAP–BATH and Vowel Duration models. Again, I am satisfied with each. As with the Glasgow models, Rhat was 1 for all coefficients, and the minimum effective sample size was greater than 400 (greater than 100 $\times$ the number of chains). I was satisfied that the models have converged successfully and that the results of the analyses are amenable to interpretation.



(a) TRAP–BATH F1 model



(b) TRAP–BATH F2 model



(c) Duration model

Figure 6.2: King's: TRAP–BATH and duration model posterior predictive checks

6.4.2 King's: Front vowel system

Table 6.3 presents the number of tokens of each vowel (N), and raw formant and duration data for the front vowels grouped by Vowel and Time/Director. Then I present the results for the King's front vowel F1 model.

For this model and all subsequent models of acoustic vowel quality (F1/F2), I will first report the main effects of Vowel and Time/Director followed by the interaction of the two. The interaction of Vowel by Time/Director is the effect of interest as it will inform us whether the acoustic vowel quality has changed over time. I will then report post hoc pairwise comparisons of the interaction to show where there are differences and where not. This will be followed by any further main effects that are supported with sufficient evidence (where 95% credible intervals do not contain zero) from the posterior summary and any remaining interactions.

Table 6.3: King's: Front vowel raw formants and duration data by Time/Director

			F1 (Hz)		F2 (Hz)		Duration (ms)	
Vowel	Time/Director	N	Mean	SD	Mean	SD	Mean	SD
FLEECE	BO 1945–1958	285	493	86	1713	277	450	320
FLEECE	DW 1959–1974	495	472	92	1687	221	600	560
FLEECE	PL 1976–1982	304	499	84	1666	229	530	410
FLEECE	SC 1984–2019	836	500	92	1751	228	740	780
KIT	BO 1945–1958	655	529	85	1572	199	360	480
KIT	DW 1959–1974	1186	491	85	1616	210	470	520
KIT	PL 1976–1982	706	519	88	1604	200	470	740
KIT	SC 1984–2019	1939	532	99	1652	212	510	530
DRESS	BO 1945–1958	229	660	84	1465	150	500	630
DRESS	DW 1959–1974	351	602	73	1501	152	620	560
DRESS	PL 1976–1982	231	637	70	1476	123	600	780
DRESS	SC 1984–2019	682	692	76	1477	136	750	570
TRAP	BO 1945–1958	277	670	94	1398	119	310	220
TRAP	DW 1959–1974	487	655	85	1391	137	410	370
TRAP	PL 1976–1982	304	671	88	1342	111	380	230
TRAP	SC 1984–2019	896	731	86	1340	105	460	450

King's: Front vowel predictions

In contrast to Chapter 5, we now have more concrete predictions about change in the choir sound. Based on the Glasgow results, we might expect to find that:

- KIT, DRESS and TRAP lower over time
- TRAP retracts over time
- as vowel duration increases FLEECE and KIT raise while TRAP and DRESS lower
- as vowel duration increases DRESS and TRAP retract
- GOOSE may be cardinal-like in quality

In addition, based on Day (2018)'s auditory analysis, and my own observations from listening while aligning the King's data, I anticipate that Boris Ord (1945–1958) had a lower front vowel acoustic quality which raised under David Willcocks (1959–1975) and Philip Ledger (1976–1982), and lowered under Stephen Cleobury (1984–2019). If this is the case, the pattern of change should look like a rise followed by a fall.

King's: Front vowel F1 posterior summary

I now present the results of the King's front vowel F1 model. This means we are now in the dimension of vowel height. The greater F1 is, the lower the tongue/jaw and the more open (low) the acoustic vowel quality. The lower F1 is, the higher the tongue and the closer (more raised) the acoustic vowel quality. Therefore, this model asks how our independent variables (Time/Director, Vowel, Vowel Duration) affect tongue height. Table 6.4 shows the posterior summary for the King's front vowel F1 (tongue height) model.

As seen in Table 6.4, There is a main effect of Time/Director with front vowel quality under David Willcocks (1959–1974) raised compared to the grand mean (median -0.30, CI $[-0.43; -0.17]$), whereas the front vowel quality produced under Time/Director Stephen Cleobury (1984–2019) is lower than the grand mean (median 0.15, CI $[0.04; 0.26]$). This means that the front vowels were produced with a higher tongue/jaw configuration under David Willcocks and have lowered over time.

There is also an interaction of Vowel by Time/Director. Post hoc comparisons

Table 6.4: King's: Front vowel F1 model posterior summary

	Estimate	95% CI	
Intercept	0.03	−0.09	0.15
vowelKIT	**−0.61**	**−0.66**	**−0.57**
vowelDRESS	**0.44**	**0.38**	**0.50**
vowelTRAP	**1.03**	**0.97**	**1.10**
directorDW1959–1974	**−0.30**	**−0.43**	**−0.17**
directorPL1976–1982	−0.06	−0.21	0.10
directorSC1984–2019	**0.15**	**0.04**	**0.26**
VowelDuration (log)	**−0.04**	**−0.07**	**−0.01**
genreEvensong	−0.15	−0.34	0.04
vowelKIT:directorDW1959–1974	**0.04**	**0.00**	**0.07**
vowelDRESS:directorDW1959–1974	**−0.12**	**−0.17**	**−0.07**
vowelTRAP:directorDW1959–1974	−0.01	−0.06	0.04
vowelKIT:directorPL1976–1982	0.03	−0.01	0.07
vowelDRESS:directorPL1976–1982	−0.02	−0.08	0.03
vowelTRAP:directorPL1976–1982	−0.04	−0.10	0.01
vowelKIT:directorSC1984–2019	**−0.10**	**−0.13**	**−0.07**
vowelDRESS:directorSC1984–2019	**0.14**	**0.10**	**0.18**
vowelTRAP:directorSC1984–2019	**0.07**	**0.04**	**0.11**
vowelKIT:vdur_log	**−0.08**	**−0.11**	**−0.05**
vowelDRESS:vdur_log	**0.07**	**0.02**	**0.11**
vowelTRAP:vdur_log	**0.12**	**0.08**	**0.16**
directorDW1959–1974:vdur_log	−0.01	−0.04	0.03
directorPL1976–1982:vdur_log	0.01	−0.02	0.05
directorSC1984–2019:vdur_log	**−0.05**	**−0.07**	**−0.02**
vdur_log:genreEvensong	**0.09**	**0.04**	**0.14**

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

(found in Appendix Table E.1), show that David Willcocks (1959–1974) was more raised than Boris Ord (1945–1958) for FLEECE (median -0.3458, CI $[-0.6005; -0.1014]$) and KIT (median -0.4617, CI $[-0.7136; -0.2355]$). Stephen Cleobury (1984–2019) is lower than David Willcocks for FLEECE (median 0.2747, CI $[0.0880; 0.4612]$) and KIT (median 0.3534, CI $[0.1698; 0.5240]$. There are no differences between Boris Ord and Stephen Cleobury for FLEECE and KIT vowel height.

The DRESS vowel is much higher for David Willcocks compared to all other Time/Director pairs. And, the DRESS vowel in Stephen Cleobury's recordings is lower than under Philip Ledger (median 0.4284, CI $[0.1888; 0.6535]$) too, meaning that there was a trajectory of lowering after Willcocks. The TRAP vowel is also much higher under Willcocks compared to Boris Ord (median -0.4613, CI $[-0.7212; -0.2178]$), and then it is much lower under Stephen Cleobury compared to David Willcocks (median 0.5759, CI $[0.3908; 0.7636]$) and Philip Ledger (median 0.3830, CI $[0.1653; 0.6222]$). However, there is no difference in TRAP vowel height between Stephen Cleobury and Boris Ord. This interaction of vowel by time/director is visualised in figure 6.3.

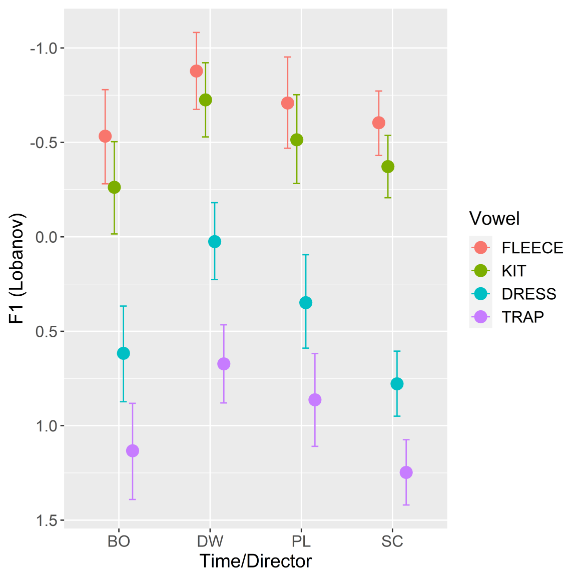


Figure 6.3: King's: Front vowel F1 model, Vowel by Time/Director interaction. 'BO' = Boris Ord (1945–1958); 'DW' = David Willcocks (1959–1974); 'PL' = Philip Ledger (1976–1982); 'SC' = Stephen Cleobury (1984–2019).

Returning to the posterior summary (Table 6.4), there is a main effect of Vowel Duration (median -0.04, CI $[-0.07; -0.01]$), such that the longer a vowel, the more raised it becomes. However, we need to interpret this carefully as there is an interaction of Vowel by Vowel Duration. The interaction is such that as Vowel Duration increases, FLEECE (median -0.11, CI $[-0.15; -0.07]$) and KIT (median -0.08, CI $[-0.11; -0.05]$) raise, and DRESS (median 0.07, CI $[0.02; 0.11]$), and TRAP lower, as visualised in Figure 6.4. This reflects the same pattern found in the

Glasgow choirs reported in Chapter 5.

There is an interaction of Time/Director by Vowel Duration. For Stephen Cleobury (1984–2019), the longer the front vowels, the more raised they become (median -0.05, CI $[-0.07; -0.02]$). In addition, there is an interaction of Vowel Duration by Genre. As duration increases, the Genre 'Evensong' lowers more than Genre 'Carols' (median 0.09, CI $[0.04; 0.14]$). This may be an effect of the cantor singing, controlled for by the 'Evensong' Genre, which is closer to speech rhythm and, perhaps, closer to speech vowel quality.

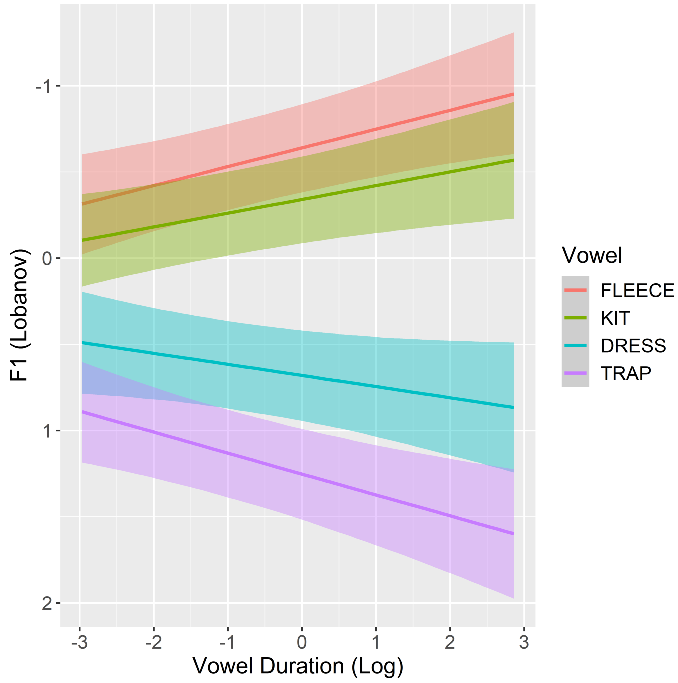


Figure 6.4: King's: Front vowel F1 model: Vowel by Vowel Duration interaction

King's: Front vowel F2 posterior summary

Table 6.5 shows the posterior summary for the King's front vowel F2 model (frontness–backness).

There is no main effect of Time/Director in the front vowels F2 dimension. The reason for the absence of a main effect of Time/Director in the front vowel F2 model is the interaction of Vowel by Time/Director which is shown in figure 6.5. DRESS is fronter under Stephen Cleobury (1984–2019) while TRAP is more retracted. This is confirmed by post hoc comparisons (Appendix Table E.2), as TRAP realisation is backer under the direction of Stephen Cleobury than under Boris Ord (median -0.2620, CI $[-0.4901; -0.0233]$) and David Willcocks (median -0.2348, CI $[-0.4263; -0.0468]$). As FLEECE and DRESS front while TRAP retracts, the effects cancel each other out and this is why there is no main effect of Time/Director for front vowel F2 (frontness–backness dimension). The King's data,

Table 6.5: King's: Front vowel F2 model posterior summary

	Estimate	95% CI	
Intercept	**0.54**	**0.42**	**0.66**
vowelKIT	**0.26**	**0.22**	**0.30**
vowelDRESS	**−0.23**	**−0.29**	**−0.18**
vowelTRAP	**−0.64**	**−0.71**	**−0.58**
directorDW1959–1974	0.05	−0.08	0.19
directorPL1976–1982	−0.04	−0.20	0.12
directorSC1984–2019	0.07	−0.04	0.18
VowelDuration (log)	**−0.03**	**−0.06**	**−0.00**
genreEvensong	−0.15	−0.34	0.03
vowelKIT:directorDW1959–1974	0.00	−0.03	0.04
vowelDRESS:directorDW1959–1974	0.02	−0.03	0.06
vowelTRAP:directorDW1959–1974	**0.08**	**0.04**	**0.13**
vowelKIT:directorPL1976–1982	**0.04**	**0.01**	**0.08**
vowelDRESS:directorPL1976–1982	0.04	−0.01	0.10
vowelTRAP:directorPL1976–1982	−0.05	−0.10	0.01
vowelKIT:directorSC1984–2019	**0.10**	**0.07**	**0.13**
vowelDRESS:directorSC1984–2019	−0.04	−0.07	0.00
vowelTRAP:directorSC1984–2019	**−0.17**	**−0.21**	**−0.14**
vowelKIT:vdur_log	**0.08**	**0.05**	**0.10**
vowelDRESS:vdur_log	**−0.07**	**−0.11**	**−0.03**
vowelTRAP:vdur_log	**−0.06**	**−0.10**	**−0.03**
directorDW1959–1974:vdur_log	**0.03**	**0.00**	**0.07**
directorPL1976–1982:vdur_log	0.00	−0.03	0.04
directorSC1984–2019:vdur_log	**0.03**	**0.01**	**0.06**
log_vdur:genreEvensong	**−0.07**	**−0.12**	**−0.02**

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

models and priors point to the same pattern of TRAP retraction that was shown in the Glasgow data reported in Chapter 5.

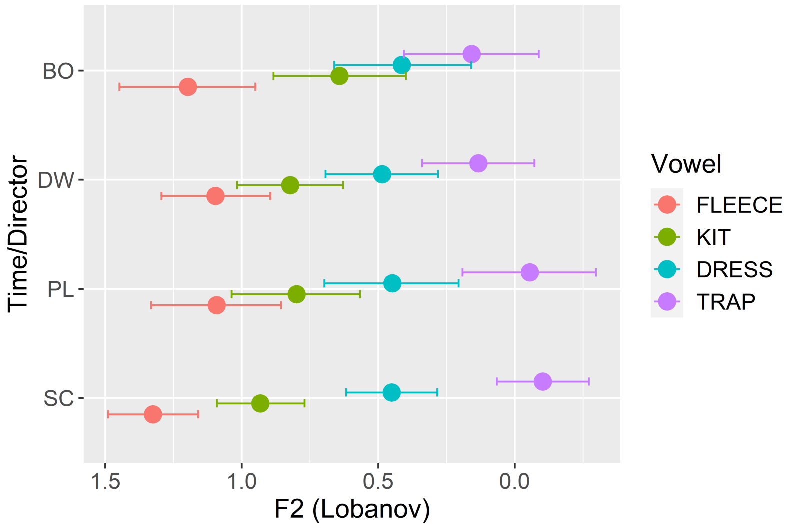


Figure 6.5: King's: Front vowel F2 model, Vowel by Time/Director interaction. 'BO' = Boris Ord (1945–1958); 'DW' = David Willcocks (1959–1974); 'PL' = Philip Ledger (1976–1982); 'SC' = Stephen Cleobury (1984–2019).

As Vowel Duration increases, high vowels front and low vowels retract. That is, FLEECE (median 0.06, CI $[0.02; 0.09]$) and DRESS (median 0.08, CI $[0.05; 0.10]$) front compared to the grand mean, while DRESS (median -0.07, CI $[-0.11; -0.03]$) and TRAP retract (as can be seen in figure 6.6) – again replicating the findings of Chapter 5.

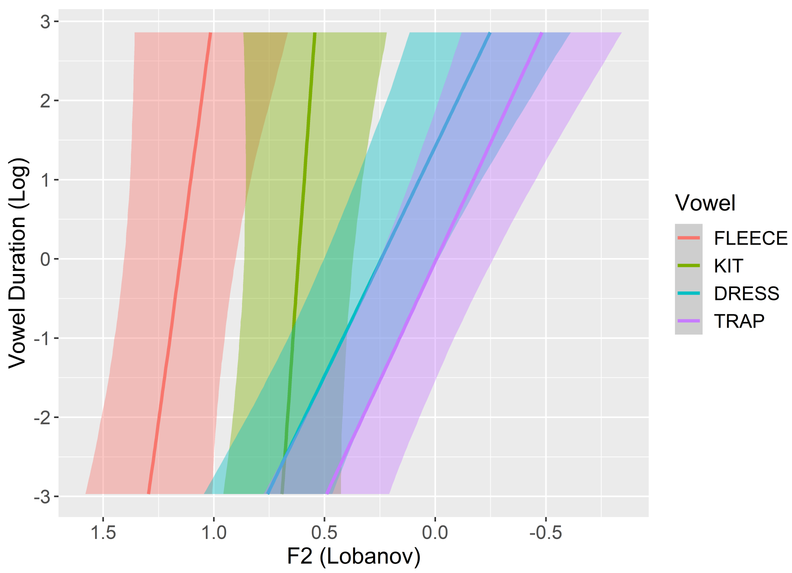


Figure 6.6: King's: Front vowel F2 model, Vowel by Vowel Duration interaction

King's: Front vowel summary

The analysis presented here has confirmed a lot of the findings from Glasgow data. The choir of King's College, Cambridge shows change over time with similarities to the Glasgow choirs. As predicted, DRESS and TRAP lowered over time; TRAP has retracted over time; as vowel duration increases, FLEECE and KIT raise while DRESS and TRAP lower; as vowel duration increases DRESS and TRAP retract. Boris Ord had lower vowel quality which raised under David Willcocks and Philip Ledger – so the pattern of change over time looks as anticipated: a rise, sustained and followed by a fall. In addition, we have found that FLEECE is fronter in the late time period under Stephen Cleobury than under Boris Ord and David Willcocks.

6.4.3 King's: Back vowel system

Table 6.6 presents the number of tokens (N), raw formant and duration data for the back vowels grouped by Time/Director. Subsequently, I present the results of the King's back vowel F1 model.

Table 6.6: [King's: Back vowel raw formants and duration data by Time/Director

			F1 (Hz)		F2 (Hz)		Duration (ms)	
Vowel	Time/Director	N	Mean	SD	Mean	SD	Mean	SD
BATH	BO 1945–1958	116	703	65	1176	75	1090	2140
BATH	DW 1959–1974	142	652	85	1140	105	987	1470
BATH	PL 1976–1982	88	670	73	1179	97	985	1580
BATH	SC 1984–2019	254	709	76	1181	97	1270	2110
STRUT	BO 1945–1958	194	672	94	1203	96	400	360
STRUT	DW 1959–1974	271	648	87	1183	101	520	410
STRUT	PL 1976–1982	156	648	88	1196	113	590	540
STRUT	SC 1984–2019	489	702	82	1208	99	710	920
LOT	BO 1945–1958	207	645	77	1132	103	360	400
LOT	DW 1959–1974	341	609	76	1088	107	500	360
LOT	PL 1976–1982	247	620	73	1102	85	470	360
LOT	SC 1984–2019	671	667	71	1129	93	580	530
THOUGHT	BO 1945–1958	182	579	84	1015	129	510	340
THOUGHT	DW 1959–1974	316	543	72	1055	141	580	400
THOUGHT	PL 1976–1982	200	566	75	1062	134	590	390
THOUGHT	SC 1984–2019	525	625	72	1094	119	795	1090
FOOT	BO 1945–1958	30	478	58	998	115	430	410
FOOT	DW 1959–1974	47	456	68	956	130	670	740
FOOT	PL 1976–1982	39	493	73	999	125	540	440
FOOT	SC 1984–2019	97	477	55	1014	105	590	560
GOOSE	BO 1945–1958	122	467	70	1019	164	300	260
GOOSE	DW 1959–1974	262	465	75	988	138	560	590
GOOSE	PL 1976–1982	135	491	78	1027	141	520	440
GOOSE	SC 1984–2019	433	478	83	1046	134	620	620

King's: Back vowel predictions

In Chapter 5, I found that Glasgow back vowels have lowered over time in choral singing. There was no evidence of change over time in the F2 dimension for back vowels, apart from for BATH which appeared to retract over time.

Table 6.7: King's: Back vowel F1 model posterior summary

	Estimate	95% CI	
Intercept	**0.12**	**0.00**	**0.24**
vowelBATH	**0.69**	**0.60**	**0.77**
vowelSTRUT	**0.66**	**0.58**	**0.74**
vowelLOT	**0.41**	**0.33**	**0.49**
vowelTHOUGHT	**−0.08**	**−0.15**	**−0.00**
vowelGOOSE	**−0.93**	**−1.02**	**−0.84**
directorDW1959–1974	**−0.25**	**−0.37**	**−0.13**
directorPL1976–1982	−0.05	−0.19	0.10
directorSC1984–2019	**0.13**	**0.03**	**0.23**
VowelDuration (log)	−0.01	−0.05	0.03
genreEvensong	**−0.22**	**−0.40**	**−0.05**
vowelBATH:directorDW1959–1974	−0.00	−0.09	0.07
vowelSTRUT:directorDW1959–1974	0.04	−0.02	0.10
vowelLOT:directorDW1959–1974	−0.03	−0.09	0.02
vowelTHOUGHT:directorDW1959–1974	**−0.06**	**−0.12**	**−0.00**
vowelGOOSE:directorDW1959–1974	**0.12**	**0.05**	**0.19**
vowelBATH:directorPL1976–1982	**−0.09**	**−0.18**	**−0.00**
vowelSTRUT:directorPL1976–1982	−0.07	−0.14	0.00
vowelLOT:directorPL1976–1982	**−0.08**	**−0.14**	**−0.01**
vowelTHOUGHT:directorPL1976–1982	**−0.08**	**−0.15**	**−0.02**
vowelGOOSE:directorPL1976–1982	**0.10**	**0.03**	**0.18**
vowelBATH:directorSC1984–2019	0.04	−0.03	0.10
vowelSTRUT:directorSC1984–2019	0.05	−0.00	0.10
vowelLOT:directorSC1984–2019	**0.08**	**0.04**	**0.13**
vowelTHOUGHT:directorSC1984–2019	**0.18**	**0.14**	**0.23**
vowelGOOSE:directorSC1984–2019	**−0.20**	**−0.25**	**−0.14**
vowelBATH:vdur_log	**−0.08**	**−0.14**	**−0.02**
vowelSTRUT:vdur_log	−0.04	−0.08	0.01
vowelLOT:vdur_log	**0.06**	**0.01**	**0.10**
vowelTHOUGHT:vdur_log	−0.01	−0.06	0.04
vowelGOOSE:vdur_log	0.03	−0.02	0.09
directorDW1959–1974:vdur_log	−0.01	−0.05	0.03
directorPL1976–1982:vdur_log	0.02	−0.03	0.06
directorSC1984–2019:vdur_log	−0.00	−0.04	0.03
vdur_log:genreEvensong	0.05	−0.00	0.11

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

The back vowel F1 model asks how vowel height has changed over time for back vowels. As can be found in table 6.7, there is a main effect of Time/Director, such that back vowels produced under David Willcocks (1959–1974) are higher than the grand mean (median -0.25, CI $[-0.37; -0.13]$) whereas back vowels produced under Stephen Cleobury (1984–2019) are lower than the grand mean (median 0.13, CI $[0.03; 0.23]$).

In terms of the Vowel by Time/Director interaction, post hoc comparisons (Appendix Table E.7) show that BATH, STRUT, LOT and THOUGHT are raised in recordings made under David Willcocks (1959–1974) and Philip Ledger (1976–1982) compared to Boris Ord (1945–1958) and Stephen Cleobury (1984–2019). There are no differences between Ord and Cleobury for vowel height of BATH, STRUT, LOT and THOUGHT. FOOT in recordings of David Willcocks is higher than all other Time/Director pairs. No differences between the other time periods for FOOT. This indicates that Willcocks raised the entire vowel space, and this was not restricted to front vowels. The interaction of Vowel by Time/Director is visualised in figure 6.7.

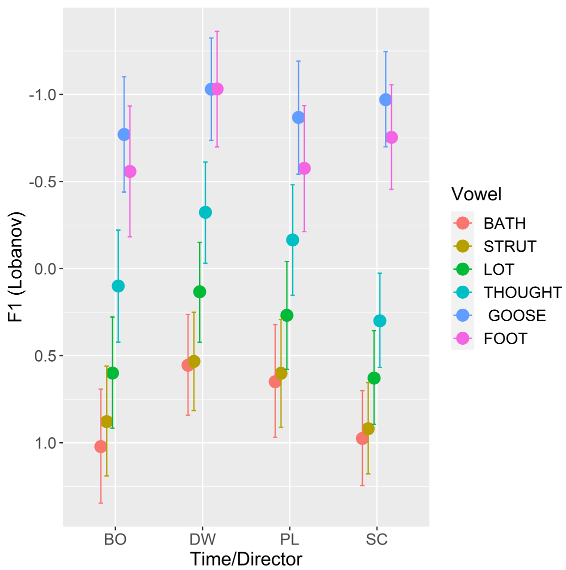


Figure 6.7: King's: Back vowel F1 model, Vowel by Time/Director interaction. 'BO' = Boris Ord (1945–1958); 'DW' = David Willcocks (1959–1974); 'PL' = Philip Ledger (1976–1982); 'SC' = Stephen Cleobury (1984–2019).

In terms of vowel pairs, post hoc comparisons (Appendix Table E.4) show that BATH and STRUT do not differ in vowel height for any time point. LOT is higher and distinct from THOUGHT in all time periods. FOOT and GOOSE are not different under Boris Ord and David Willcocks. However, FOOT is lower than GOOSE under Philip Ledger (1976–1982) (median 0.2929, CI $[0.0575; 0.5210]$) and under Stephen Cleobury (1982–2019) (median 0.2178, CI $[0.0362; 0.3895]$).

Returning to the back vowel F1 posterior summary (Table 6.7), there is no evidence of a main effect of Vowel Duration. There is an effect of Genre with the level 'Evensong' making back vowels higher than for the Genre 'Carols' (median -0.22, CI $[-0.40; -0.05]$). This may be attributed to the shorter duration of vowels in cantor singing in Evensong means the vowel space is closer to speech-like vowel height. There is an interaction of Vowel by Vowel Duration such that the longer the duration, the more BATH raises (median -0.08, CI $[-0.14; -0.02]$), and the more THOUGHT lowers (median 0.06, CI $[0.01; 0.10]$) perhaps indicating that the vowels converge in quality as duration increases.

King's: Back vowel F2 posterior summary

As seen in Table 6.8, for the back vowel F2 (backness) model, there is a main effect of Time/Director with David Willcocks (1959–1974) being more retracted (median -0.11 CI $[-0.17; -0.03]$) and Stephen Cleobury being more fronted (median 0.09 CI $[0.05; 0.14]$) with respect of the grand mean.

Post hoc pairwise comparisons for the back vowel F2 model are found in Appendix Table E.5. In terms of the interaction of Vowel by Time/Director, BATH is fronter under Stephen Cleobury (1984–2019) than under David Willcocks (1959–74) (median 0.1408, CI $[0.0390; 0.2447]$). BATH produced under David Willcocks is more retracted than that of Boris Ord (1945–1958) (median -0.1657, CI $[-0.3038; -0.0386]$). No difference between Stephen Cleobury and Boris Ord. STRUT is fronter under Stephen Cleobury than David Willcocks (median 0.1395, CI $[0.0535; 0.2279]$). LOT is backer for David Willcocks (1959–1974) and Philip Ledger (1976–1982) compared to Boris Ord (1945–1958) and Stephen Cleobury (1984–2019). THOUGHT is fronter under Stephen Cleobury than at all previous time/directors.

FOOT is fronter under Boris Ord and Stephen Cleobury than under David Willcocks and Philip Ledger. However, FOOT under Ledger is fronter than under Willcocks. So, it appears that FOOT has fronted to the position that it was under Boris Ord. GOOSE is fronter for Stephen Cleobury than for David Willcocks and Philip Ledger, no difference with Boris Ord. So again, it appears that David Willcocks shifted the back vowels backwards in the vowel space, and broadly, under Stephen Cleobury, they have returned to a similar position they were in under Boris Ord. This interaction of Vowel by Time/Director is visualised in figure 6.8.

In terms of vowel pairs, post hoc comparisons (Appendix Table E.6) show that BATH and STRUT are not different in frontness–backness apart from under Stephen Cleobury (1984–2019) (median 0.1160, CI $[0.0354; 0.1956]$) and David Willcocks (1959–1974) (median 0.1169, CI $[0.0269; 0.2121]$) where STRUT is fronter than BATH. This means that for the other two Time/Director pairs, there is little evidence that BATH and STRUT differ in vowel quality. However, as this is quite a subtle difference in F2 between BATH and STRUT and it only came out under Willcocks and Cleobury, which have the largest number of tokens, perhaps there

Table 6.8: King's: Back vowel F2 model posterior summary

	Estimate	95% CI	
Intercept	**−1.01**	**−1.08**	**−0.95**
vowelBATH	**0.30**	**0.25**	**0.36**
vowelSTRUT	**0.31**	**0.26**	**0.36**
vowelLOT	**0.08**	**0.03**	**0.13**
vowelTHOUGHT	**−0.08**	**−0.13**	**−0.03**
vowelGOOSE	**−0.33**	**−0.39**	**−0.27**
directorDW1959–1974	**−0.11**	**−0.17**	**−0.05**
directorPL1976–1982	−0.02	−0.09	0.05
directorSC1984–2019	**0.09**	**0.05**	**0.14**
VowelDuration (log)	**−0.07**	**−0.10**	**−0.05**
genreEvensong	−0.07	−0.16	0.02
vowelBATH:directorDW1959–1974	0.00	−0.05	0.05
vowelSTRUT:directorDW1959–1974	0.03	−0.01	0.07
vowelLOT:directorDW1959–1974	0.03	−0.01	0.06
vowelTHOUGHT:directorDW1959–1974	**0.05**	**0.01**	**0.09**
vowelGOOSE:directorDW1959–1974	−0.01	−0.05	0.03
vowelBATH:directorPL1976–1982	0.02	−0.04	0.08
vowelSTRUT:directorPL1976–1982	0.02	−0.03	0.07
vowelLOT:directorPL1976–1982	**−0.05**	**−0.09**	**−0.01**
vowelTHOUGHT:directorPL1976–1982	−0.01	−0.05	0.03
vowelGOOSE:directorPL1976–1982	0.00	−0.05	0.05
vowelBATH:directorSC1984–2019	**−0.05**	**−0.09**	**−0.00**
vowelSTRUT:directorSC1984–2019	−0.02	−0.05	0.01
vowelLOT:directorSC1984–2019	−0.01	−0.04	0.02
vowelTHOUGHT:directorSC1984–2019	**0.03**	**0.00**	**0.07**
vowelGOOSE:directorSC1984–2019	0.02	−0.02	0.05
vowelBATH:vdur_log	0.01	−0.03	0.05
vowelSTRUT:vdur_log	**−0.09**	**−0.12**	**−0.06**
vowelLOT:vdur_log	**0.05**	**0.02**	**0.08**
vowelTHOUGHT:vdur_log	**0.03**	**0.00**	**0.07**
vowelGOOSE:vdur_log	−0.02	−0.06	0.01
directorDW1959–1974:vdur_log	−0.01	−0.03	0.02
directorPL1976–1982:vdur_log	−0.01	−0.04	0.02
directorSC1984–2019:vdur_log	0.01	−0.01	0.04
vdur_log:genreEvensong	0.03	−0.00	0.07

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

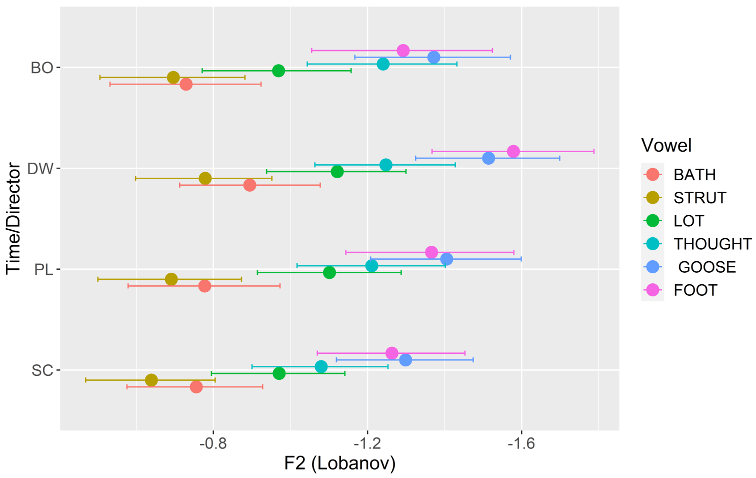


Figure 6.8: King's: Back vowel F2 model, Vowel by Time/Director interaction. 'BO' = Boris Ord (1945–1958); 'DW' = David Willcocks (1959–1974); 'PL' = Philip Ledger (1976–1982); 'SC' = Stephen Cleobury (1984–2019).

would also be slight differences if there was more data. LOT and THOUGHT are distinct in F2 as expected with THOUGHT being further back in the vowel space. FOOT and GOOSE are not distinct in F2 in any time period.

Returning to the back vowel F2 model posterior summary (Table 6.8), there is evidence of a main effect of Vowel Duration such that as duration increases, F2 decreases, meaning that the vowels move further back in the vowel space (median -0.07, CI $[-0.10; -0.05]$). There is also an interaction of Vowel by Vowel Duration whereby the longer STRUT is the backer it becomes (median -0.09, CI $[-0.12; -0.06]$), in contrast to LOT (median 0.05, CI $[0.02; 0.08]$) and THOUGHT (median 0.03, CI $[0.00; 0.07]$) which front as duration increases.

King's: Back vowel summary

Back vowel height is lower than the grand mean under Stephen Cleobury in the late time period. However, this is likely due to the fact that David Willcocks considerably raised the entire vowel space. Back vowels retract under David Willcocks and return to a fronter position under Stephen Cleobury – so this may provide evidence of an individual choir director's input on the choral accent.

6.4.4 King's: TRAP–BATH distinction

As I had to run separate models for the front and back vowel sets, as in the previous chapter, I still need to compare TRAP and BATH as there is a distinction in Southern Standard British English varieties.

Table 6.9: King's: TRAP–BATH F1 model posterior summary

	Estimate	95% CI	
Intercept	**0.73**	**0.56**	**0.92**
vowelTRAP	**0.37**	**0.23**	**0.50**
directorDW1959–1974	**−0.28**	**−0.47**	**−0.09**
directorPL1976–1982	−0.19	−0.42	0.03
directorSC1984–2019	**0.20**	**0.04**	**0.36**
VowelDuration (log)	**−0.17**	**−0.25**	**−0.08**
genreEvensong	−0.12	−0.36	0.13
vowelTRAP:directorDW1959–1974	−0.05	−0.17	0.06
vowelTRAP:directorPL1976–1982	0.02	−0.11	0.16
vowelTRAP:directorSC1984–2019	**0.10**	**0.00**	**0.19**
vowelTRAP:vdur_log	**0.21**	**0.13**	**0.29**
directorDW1959–1974:vdur_log	−0.02	−0.09	0.04
directorPL1976–1982:vdur_log	−0.02	−0.09	0.06
directorSC1984–2019:vdur_log	0.04	−0.01	0.10
vdur_log:genreEvensong	**0.17**	**0.09**	**0.26**

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

TRAP–BATH F1 model posterior summary can be found in Table 6.9. Overall there is a main effect of Vowel on TRAP–BATH height. TRAP is significantly lower than BATH (median 0.37, CI $[0.23; 0.5]$). There is also a main effect of Time/Director as David Willcocks is more raised than the grand mean (median -0.28, CI $[-0.47; -0.09]$), whereas vowel height under Stephen Cleobury is lower than the grand mean (median 0.20, CI $[0.04; 0.36]$).

There is an interaction of Vowel by Time/Director, as TRAP under Stephen Cleobury is lower than the overall mean for Stephen Cleobury (median 0.10, CI $[0.00; 0.19]$). Post hoc pairwise comparisons (Appendix Table E.7) show that, for BATH, David Willcocks and Philip Ledger are higher than Boris Ord and Stephen Cleobury, which pattern together. There is a similar pattern for TRAP with Stephen Cleobury being lower than David Willcocks (median 0.5604, CI $[0.3290; 0.7961]$) and Philip Ledger (median 0.4034, CI $[0.1255; 0.6894]$). However, Philip Ledger is not higher than Boris Ord.

Returning to the TRAP–BATH F1 model posterior summary (Table 6.9), there is a main effect of Vowel Duration. As duration increases, TRAP–BATH tend to raise (median -0.17, CI $[-0.25, -0.08]$). However, there is an interaction of Vowel by Vowel Duration, such that, as duration increases, TRAP lowers (median 0.21, CI $[0.13; 0.29]$), which seems to align with singing pedagogy. Finally, there is an interaction of Vowel Duration by Genre with vowels for the genre 'Evensong' lowering more than the vowels in the genre 'Carols' (median 0.17, CI $[0.09; 0.26]$).

Table 6.10: King's: TRAP–BATH F2 model posterior summary

	Estimate	95% CI	
Intercept	**−0.72**	**−0.81**	**−0.62**
vowelTRAP	**0.58**	**0.51**	**0.65**
directorDW1959–1974	−0.06	−0.17	0.04
directorPL1976–1982	−0.01	−0.14	0.11
directorSC1984–2019	0.01	−0.08	0.10
VowelDuration (log)	**−0.05**	**−0.10**	**−0.00**
genreEvensong	−0.07	−0.20	0.06
vowelTRAP:directorDW1959–1974	**0.21**	**0.15**	**0.28**
vowelTRAP:directorPL1976–1982	**−0.16**	**−0.24**	**−0.09**
vowelTRAP:directorSC1984–2019	**−0.14**	**−0.19**	**−0.08**
vowelTRAP:vdur_log	**−0.07**	**−0.12**	**−0.03**
directorDW1959–1974:vdur_log	**0.05**	**0.01**	**0.09**
directorPL1976–1982:vdur_log	**−0.06**	**−0.11**	**−0.02**
directorSC1984–2019:vdur_log	−0.01	−0.05	0.02
vdur_log:genreEvensong	−0.00	−0.05	0.05

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

As can be seen in table 6.10, there is a main effect of Vowel such that TRAP is very much fronter than BATH, as expected (median 0.58, CI $[0.51; 0.65]$). The model does not support a main effect of Time/Director. There is an interaction of Vowel by Time/Director as TRAP is backer under Philip Ledger (median -0.16, CI $[-0.24; -0.09]$) and Stephen Cleobury (median -0.14, CI $[-0.19; -0.08]$) in the later time periods than the overall mean for TRAP. For the TRAP–BATH F2 model, there is evidence of a main effect of Vowel Duration such that the longer the vowel, the more retracted it becomes (median -0.05, CI $[-0.10; -0.00]$).

Post hoc comparisons (Appendix Table E.8) show that TRAP is backer under Stephen Cleobury than under Boris Ord (median -0.2361, CI $[-0.3952; -0.0819]$) and David Willcocks (median -0.2126, CI $[-0.3388; -0.0867]$). Similarly, TRAP is backer under Philip Ledger than under Boris Ord (median -0.2436, CI $[-0.4355; -0.0517]$) and David Willcocks (median -0.2181, CI $[-0.3840; -0.0442]$). With the later two Time/Director pairs exhibiting a backer realisation of TRAP, there is some evidence of TRAP retraction over time. This is one of the key differences between recordings under Boris Ord and Stephen Cleobury, which shows that there has not been a wholesale return to the sound cultivated by Boris Ord.

6.4.5 King's: Duration model

Based on established knowledge about the phonology of English as well as the findings of Chapter 5, I would expect to find that: FLEECE is substantially longer than KIT; GOOSE is substantially longer than FOOT; BATH is longer than STRUT.

Table 6.11: King's: Duration model posterior summary

	Estimate	95% CI	
Intercept	**0.29**	**0.16**	**0.41**
vowelFLEECE	**0.12**	**0.06**	**0.19**
vowelKIT	**−0.25**	**−0.29**	**−0.21**
vowelDRESS	**0.08**	**0.03**	**0.14**
vowelTRAP	0.04	−0.04	0.12
vowelBATH	**0.39**	**0.31**	**0.47**
vowelSTRUT	0.03	−0.04	0.11
vowelLOT	**0.19**	**0.10**	**0.28**
vowelTHOUGHT	**0.25**	**0.17**	**0.34**
vowelFOOT	**−0.27**	**−0.41**	**−0.13**
vowelGOOSE	−0.03	−0.13	0.07
directorDW1959–1974	0.01	−0.12	0.13
directorPL1976–1982	−0.04	−0.18	0.10
directorSC1984–2019	0.03	−0.06	0.13
genreEvensong	0.02	−0.21	0.24

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

As seen in Table 6.11, surprisingly, the duration model output shows no main effect of Time/Director or Genre. This is perhaps encouraging, as it may indicate that the effect of Genre in the vowel formant models may not only be restricted to effects of cantor singing in the Genre 'Evensong'. The fact that there is no effect of Time/Director may suggest that the reform at King's in terms of tempo occurred before these recordings were made. Listening to the two recordings produced under Arthur H. Mann reveal a more languid flexibility, so perhaps this effect would emerge if there were more recordings from earlier in the century.

There is a large effect of Vowel as expected, patterning in linguistically explicable ways. There are vowels that are shorter than the grand mean, for example, DRESS (median -0.25, CI [$-0.29; -0.21$]), FOOT (median -0.27, CI [$-0.41; -0.13$]) and COMMA (not shown). There are vowels that are considerably longer than the grand mean including BATH (median 0.39, CI [$0.31; 0.47$]), LOT (median 0.19, CI

$[0.10; 0.28]$), THOUGHT (median 0.25, CI $[0.17; 0.34]$) and FLEECE (median 0.12, CI $[0.06; 0.19]$).

Post hoc comparisons (Appendix Table E.9) show that FLEECE is considerably longer than KIT (median 0.38, CI $[0.3; 0.45]$); TRAP is substantially shorter than BATH (median -0.35, CI $[-0.47; -0.23]$); BATH is longer than STRUT (median 0.36, CI $[0.25; 0.47]$); FOOT is shorter than GOOSE (median -0.24, CI $[-0.42; -0.06]$); and there was no difference between LOT and THOUGHT.

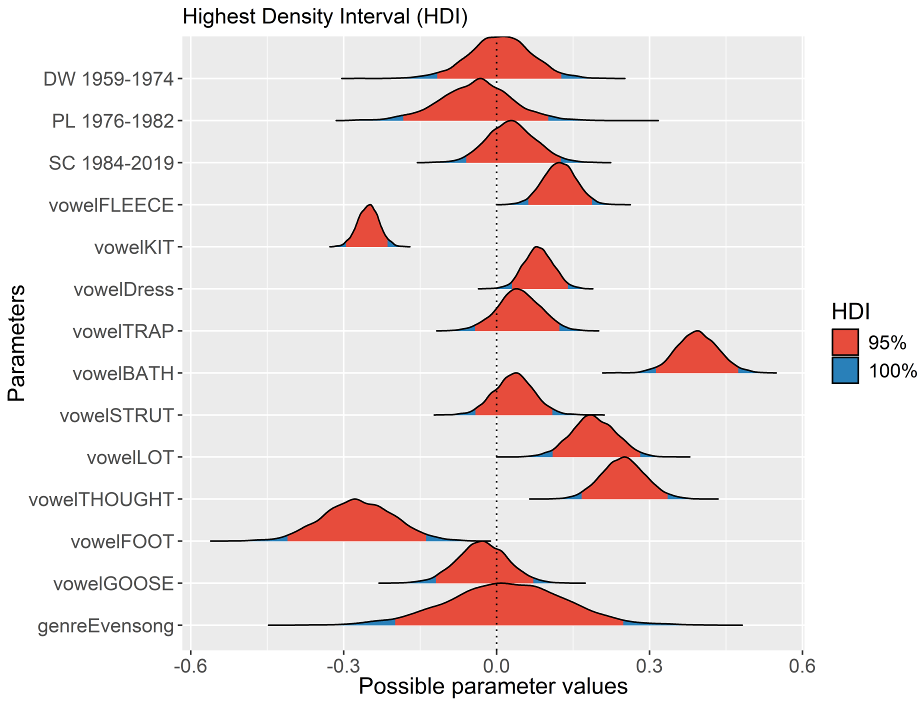


Figure 6.9: Plot of Duration model estimates for fixed effects

As seen in Figure 6.9, the main patterns of the Glasgow model are repeated here. While there is no effect of Time/Director, KIT and FOOT are significantly shorter than the grand mean, and FLEECE, BATH, LOT, and THOUGHT are longer than the grand mean. There is no evidence to support an effect of genre for the King's corpus. Similar to the findings of Chapter 5, vowel duration in choral singing in English preserves the phonological contrasts of spoken English. It is still somewhat surprising to phoneticians given the very long raw durations (seen in Tables 6.3 and 6.6) and I will return to this in the discussion.

6.5 Discussion

In this chapter, I present an acoustic analysis of vowel quality of the recordings of the Choir of King's College, Cambridge, from 1945–2019. The analysis broadly revealed that vowel height has shifted over time (by Time/Director). The following discussion will be structured with respect to the research questions. Firstly, is there evidence of variation and change over time in vowel quality? Is the phonology similar to a prestigious variety of Southern British English? Similarities to patterns observed in Chapter 5 will be noted throughout. A separate section will be dedicated to any evidence of the effect of the choir director on the choir's sound.

6.5.1 Evidence for variation and change over time at King's

As in Chapter 5, the analyses presented in this chapter provide ample evidence that vowel quality has changed over time. In the previous chapter, I found that the front vowels of choral singing in Glasgow have lowered and retracted over time. In this chapter, the analysis revealed that David Willcocks (1959–1974) substantially raised DRESS and TRAP in the vowel space. DRESS and TRAP began to lower under Philip Ledger (1976–1982); however, they lowered steeply under Stephen Cleobury (1984–2019), returning to a similar height to that recorded under Boris Ord (1945–1958). Regarding F2 (frontness–backness), TRAP is more retracted in the late period under Stephen Cleobury than under Boris Ord and David Willcocks, mirroring the finding of TRAP retraction from Chapter 5.

For the Glasgow back vowels, BATH and LOT retracted over time and BATH, TRAP, LOT, and THOUGHT lowered over time. In the present chapter, David Willcocks substantially raised back vowel height overall, particularly noticeably for FOOT and GOOSE. Under Willcocks the back vowels migrated further back in the vowel space, particularly for THOUGHT, LOT and BATH–STRUT. There was a similar pattern with the back vowels subsequently lowering in the later Time/Director pairs. Back vowels lowered under the direction of Stephen Cleobury. FOOT is lower under Philip Ledger and Stephen Cleobury than it was under David Willcocks and distinct from GOOSE in vowel height. However, it is possible that there may have been a difference between FOOT–GOOSE height in the earlier recordings that would come out if there were more tokens. It is only in the two Time/Director pairs with the most data (David Willcocks and Stephen Cleobury) that there is enough evidence to support a subtle difference in F2 between BATH and STRUT. Perhaps this difference would emerge for the other two Time/Director pairs if there was more data. At least for recordings made under the direction of Stephen Cleobury (1984–2019), it seems like there may be similar back vowel quality to the Glasgow recordings made under Marilyn J. Smith (1987–2016).

6.5.2 Is the vowel phonology similar to a prestigious variety of Southern British English?

Overall, the recordings of the Choir of King's College, Cambridge, reveal a vowel phonology similar to a prestige variety of Southern British English (RP, SSBE).

TRAP is fronter and lower than BATH overall which is consistent with phonetic descriptions of SSBE or RP. The difference in vowel height was not found in the Glasgow data. The same pattern of change over time is found with the TRAP–BATH model, with Willcocks raising height substantially and the subsequent lowering over Ledger and Cleobury's tenure. TRAP is also shorter than BATH as is to be expected from speech data.

LOT–THOUGHT differ in height and backness for every Time/Director pair. THOUGHT is always higher and backer than LOT. However, LOT–THOUGHT do not differ in duration, which is surprising as LOT tends to be shorter than THOUGHT in speech (Wells, 1982b). In the Glasgow data, I found that LOT–THOUGHT were distinct in height but not backness. Similarly, there was no difference in duration, so perhaps this is an effect of singing or music.

FOOT–GOOSE do not differ in vowel height under Boris Ord or David Willcocks. However, there appears to have been a slight lowering as FOOT is lower than GOOSE under Philip Ledger and Stephen Cleobury. This is what we would expect, for FOOT–GOOSE to be similar to speech, as FOOT is less peripheral in the vowel space in SSBE speech. There is no difference in backness between FOOT–GOOSE at any time point. FOOT is substantially shorter than GOOSE overall, so this difference in duration will also play a role in distinguishing the two vowel identities. In summary, there is evidence of change over time as FOOT–GOOSE has become distinguished in vowel height in the later period. Duration is also likely a salient cue to vowel identity as in speech. In the Glasgow data, there was no evidence supporting FOOT–GOOSE contrast height or backness for any Time/Director, though this could be due to the relative paucity of FOOT–GOOSE tokens.

Regarding Vowel Duration, a similar pattern of short–long vowels in spoken English (for example, House, 1961) is largely preserved in choral singing. FLEECE, DRESS, BATH, and THOUGHT are longer than the grand mean of duration for vowels. KIT, FOOT and COMMA are shorter than the grand mean of duration for vowels. FLEECE is longer than KIT, BATH is longer than TRAP, GOOSE is longer than FOOT: no difference between LOT and THOUGHT. In speech, we would expect LOT to be shorter than THOUGHT, and STRUT to be shorter than BATH – however, these differences are not borne out in the recordings of choral singing. Wells writes that 'The RP vowel [LOT] is relatively short, and restricted to checked syllables' (Wells, 1982b, p. 130), whereas, 'the THOUGHT vowel is relatively long [in RP]' (Wells, 1982b, p. 145). This is not the case in these recordings of choral singing. To some extent, this is to be expected, as the composer and choir director play a role in specifying the duration. However, there is no evidence of a 'free-for-all' regarding vowel duration. That is, both Glasgow and King's data show that some vowels are systematically comparatively short, for example, COMMA, followed by the short vowels KIT and FOOT. The overall shape of vowel duration distribution is similar to speech, however, there are small differences that may be introduced by the musical form. There is a high degree of uncertainty about the constraints on vowel duration in choral singing, which make it an interesting area for further research. For example, why are some vowel pairs distinct in duration (FLEECE–KIT, FOOT–GOOSE), but others not (LOT–THOUGHT)? Perhaps duration as a cue to LOT–THOUGHT identity would be redundant given that LOT and THOUGHT are statistically distinct in both height and backness in the King's data.

There was an effect of Genre for back vowels, with vowels in 'Evensong' being produced more raised than vowels for 'Carols'. This is possibly related to cantor singing having a habitually more raised jaw, tongue, and laryngeal setting as it is closer to speech in vowel quality and vowel duration. Potter wrote that 'a great deal of early recitative is very close to heightened speech' (Potter, 1998, p. 37) indicating that there was a similar tongue and laryngeal configuration to speech, compared to current operatic styles. Similarly, cantor singing is more speech-like in duration and this will also affect larynx position and have knock-on effects on vowel quality, possibly explaining the effect of Genre that we found.

6.5.3 Impact of choir director

In the Literature Review (Chapter 3, Section 3.6.2–3.6.3), we saw that there is tension between the view that the sound of King's has stayed relatively static (Sagrans, 2016) and those who felt it evolved over time (Day, 2018). The results from this chapter show that whether the sound has changed or not is, in fact, a complicated question. What appears to have happened is that front vowel lowering, particularly of DRESS and TRAP evidenced in speech data for Southern Standard British English (see Cruttenden, 2014), was already complete in the singing recorded under Boris Ord (1945–1958). Then, under the direction of David Willcocks (1959–1974), the sung vowel quality returned to the more conservative Received Pronunciation that David Willcocks was familiar with from his time as a chorister at Westminster Abbey, as suggested by Day (2018, p. 261), and this resulted in fundamentally raising the front vowel height. Under Philip Ledger (1976–1982), the front vowels stayed mostly stable but began to lower, with the lowering trajectory completed under Stephen Cleobury (1984–2019).

As Day wrote of the recordings made under David Willcocks: So *alleluia* became 'e-lleluia' (2018, p. 261). In phonetic terms, [alɛlu:jə] became [ɛlelu:jə]. The TRAP vowel is particularly culturally salient in British English and the conservative-RP raised TRAP was a noticeable feature of the accent (Wells, 1982b, p. 281).

However, the raising was not only restricted to TRAP. Under Willcocks DRESS /ɛ/ also raised from [ɛ] to [e]. These are the most noticeable differences as the allophones have entirely changed. However, there is evidence of raising across the whole vowel space with back vowels also raising, particularly with LOT–THOUGHT, and GOOSE.

Based on the analyses presented in this chapter, it seems unlikely that Cleobury succeeded in imparting an Italianate vowel quality. DRESS and TRAP are much lower and more retracted under Cleobury's direction than under David Willcocks. In future research, it would be interesting to examine vowel formant trajectories rather than means. Doing so would enable the researcher to examine whether the monophthong vowels are indeed monophthongs. For example, FLEECE and GOOSE, while canonically realised as monophthongs in conservative-RP, are commonly realised as diphthongs in SSBE (Lindsey, 2019, pp. 23–24). From my own auditory impressions of the data, the realisation of the diphthongs FACE and GOAT are particularly salient to the character of the sung accent. My impression is that there may be a less pronounced glide for GOAT under Stephen Cleobury than there was in earlier recordings. However, this needs to be tested in further research. It is possible that the fronter realisation of FLEECE under Stephen Cleobury could be attributed to encouraging the choir to sing with a 'bright forward tone', but it is unclear whether this is related to singing with Italian vowel sounds. The question of Italianate quality aside, this analysis supports the view that the vowel quality of the Choir of King's College, Cambridge evolved over time. The front vowels produced in recordings directed by Stephen Cleobury (1984–2019), KIT, DRESS and TRAP, and the back vowels BATH, STRUT, LOT, and THOUGHT, are significantly lower than those produced by the choir when directed by David Willcocks (1959–1975). There are no differences between Stephen Cleobury and Boris Ord (1945–1958). It appears, therefore, that the vowel quality of King's has changed over the century, but it has migrated back towards a similar vowel quality to that produced under Boris Ord.

It is possible that the impact of the choir director, then, is the establishment or implementation of the referee for the choral accent. If we believe, as Day (2018) suggests, that David Willcocks brought with him the Received Pronunciation that he heard at Westminster Abbey in the 1930s, then it seems Willcocks changed the referee from an SSBE-like accent to a conservative-RP accent. Philip Ledger mostly seems to have kept the same referee as Willcocks, perhaps due to how influential Willcocks was, but also due to his relatively short tenure. Then, under Stephen Cleobury, the referee shifted back to that of SSBE, consequently reverting the changes that Willcocks implemented. That is, for the most part, the whole vowel space lowered, the high back vowels fronted, and the low vowels retracted. This pattern has quite a lot in common with the anti-clockwise vowel shift of RP (see Figure 3.1). However, there may have been an impact also of the singing technique, as the low back vowels did not participate in raising; in fact, they continuously lowered over time.

6.6 Conclusion

This chapter analysed the acoustic vowel quality of monophthong vowels from recordings of the Choir of King's College, Cambridge, over time. The results have largely confirmed the findings of Chapter 5. This chapter has also provided insight into the impact that a choir director may have on the accent of a choir's singing. It appears that the choir director in cathedral or collegiate choirs has a high degree of agency in selecting and implementing the referee for the choir's accent. In this chapter, the analyses support a change in the referee from SSBE to conservative RP, followed by a reversion to SSBE, as in the more complex model proposed in Table 3.2. As the data from Chapters 5 and 6 seems to provide a similar vowel space and pattern of change, despite the differences in the makeup of the choirs, in Chapter 7 I will directly compare the Glasgow and King's datasets to investigate differences of vowel quality and duration and to see if a potential RP–SSBE and M/K–SSE shift can be differentiated in the two corpora.

Chapter 7

An emerging choral standard? Evidence from direct comparison of data from Glasgow and Cambridge[1]

In Chapters 5 and 6, I presented separate analyses of recordings of the Glasgow Orpheus and Glasgow Phoenix choirs and the Choir of King's College, Cambridge. In both corpora, I found evidence of variation and change driven by the factor Time/Director. That is, the sound of the choirs changed over time. In Glasgow, both front and back vowels seem to have lowered over time. A different pattern was found in the analysis of recordings of the Choir of King's College, Cambridge which revealed a rise followed by a fall. The reasons for conducting separate analyses previously were outlined at the start of Chapter 6. As the vowel phonology appears quite similar from the separate analyses, in the present chapter, I directly compare the data extracted from the Glasgow and King's corpora. The reason for conducting this further joint analysis is to investigate whether there is evidence of a standard way of producing English vowels in choral singing that is shared across these different spoken dialect areas.

In order to answer the research questions 1, 2 and 3a–c (laid out in Section 1.3), I will use post hoc comparisons to investigate the similarity of the sounds produced in the Glasgow and King's corpora at different time periods. For example, as Chapters 5 and 6 support lowering in both the Glasgow and King's data, we might expect to find that the vowel height produced under Marilyn J. Smith (Glasgow, 1987–2016) and Stephen Cleobury (King's, 1984–2019) are similar. This prediction, and others like it, will need to be tested using post hoc comparisons, as the models alone, with the contrast coding schemes employed, cannot tell us this

[1] An earlier version of some of the sections of this chapter will appear in Marshall et al. (2024).

information.

Also, I will also investigate the vowel contrasts FLEECE–KIT (as a control), TRAP–BATH, BATH–STRUT, LOT–THOUGHT, FOOT–STRUT, and GOOSE–FOOT. Do all of the Time/Directors distinguish these vowels in the three dimensions of vowel height (F1), vowel backness (F2), and vowel duration? As mentioned in the introduction to Chapter 5, we would not expect a contrast between the lexical sets TRAP–BATH, LOT–THOUGHT, or FOOT–GOOSE for the Glasgow choirs, which correspond to three merged Scottish vowels CAT, COT, and BOOT (Stuart-Smith, 2003).

7.1 Adapted method

The method is identical to the acoustic one laid out in Chapter 4 along with the adaptations mentioned in Chapters 5 and 6, with the addition of three points, as shown below.

7.1.1 Normalisation

Vowels were not renormalised for the joint analysis presented here. Keeping the vowels normalised by corpus is analogous to commonly-used vowel normalisation procedure when comparing across speakers in a multi-speaker analysis.

7.1.2 Time/Director

As in Chapters 5 and 6, Time/Director is sum coded such that each level is compared to the grand mean. The factor levels are the same as they were in the previous analyses; however, as the datasets were combined there is now one variable Time/Director, with seven levels, as summarised in Table 7.1.

7.1.3 Genre

In contrast to Time/Director, where the factor levels remained the same as in the previous analyses, the factor Genre had to be recoded when the datasets were combined for this analysis. The levels of Genre emerged from the data and, as such, there are some differences in Genre by Corpus. The resulting levels of Genre are shown in Table 7.2. Unfortunately, the distribution of the data is somewhat lopsided, for example, the level ‘Carols’ represents only recordings of the Festival of Nine Lessons and Carols produced by the Choir of King’s College, Cambridge, and does not contain any Glasgow tokens. The level ‘Church Music’ contains recordings of hymns and psalms from Glasgow and King’s, with additional Evensong repertoire for King’s, including other liturgical music. Any traces of

Table 7.1: Combined: Time/Director factor levels by Corpus

Corpus	Dates active	Director	Coding
King's	1929–1958	Boris Ord	BO 1945–1958
	1957–1974	David Willcocks	DW 1959–1974
	1974–1982	Philip Ledger	PL 1976–1982
	1982–2019	Stephen Cleobury	SC 1984–2019
	2019–present	Daniel Hyde	
Glasgow	1901–1951	Hugh S. Roberton	HSR 1925–1951
	1955–1983	Peter Mooney	PM 1959–1975
	1983–1990	Peter S. Shand	MJS 1987–2016
	1991–2016	Marilyn J. Smith	
	2018–Present	Cameron Murdoch	

popular music from both corpora, which may have an effect on vowel quality or quantity, are grouped under 'Misc.'. In this analysis, Genre is included to act as a control for the possible effects of the style of music on vowel quality and quantity. I will not interpret the results of the main effect, but Genre aims to constrain any sources of variation that are introduced by genre-related factors.

Table 7.2: Combined: Genre Recoding

Genre	**Corpus**	**Coding**
Carols	King's	Carols
Evensong	King's	Church Music
Church Music	Glasgow	
Misc.	King's	Misc.
Scottish Vernacular	Glasgow	
Other Popular	Glasgow	

7.2 Results

The raw data, code and models reported in this chapter can be found on the OSF at osf.io/3vjxm.

7.2.1 Comparison of Lobanov-normalised formant data across corpora

Before I dive into the modelling, I present boxplots of the Lobanov-normalised vowel formants across corpora averaged over time (Figures 7.1 and 7.2).

As seen in Figure 7.1, the Glasgow FLEECE, TRAP, BATH, and STRUT vowels are higher than King's. King's has a higher THOUGHT overall.

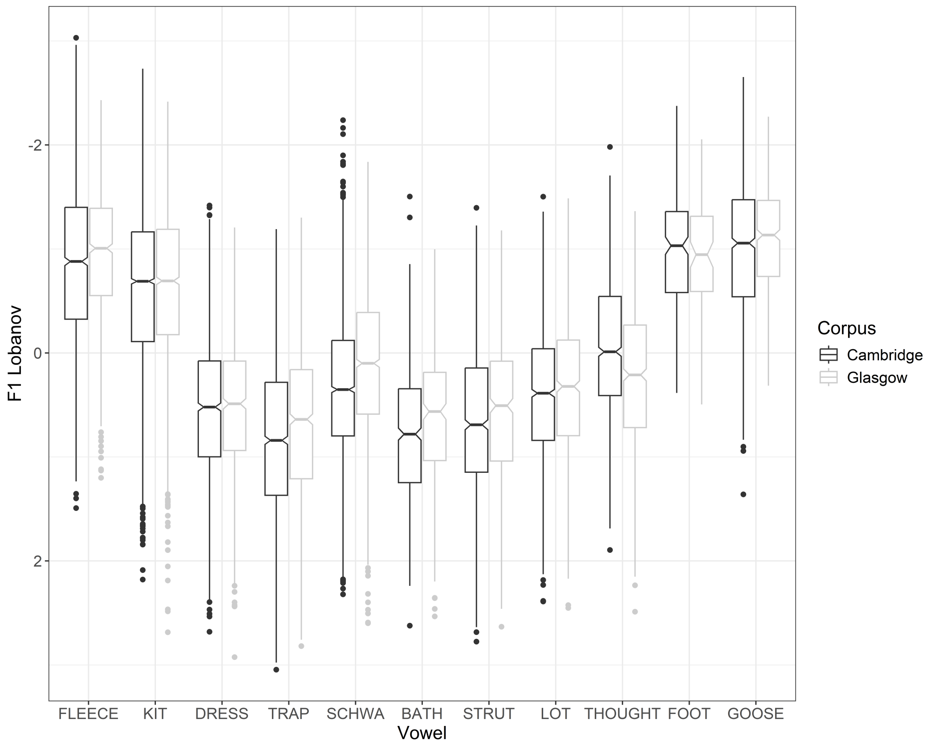


Figure 7.1: Boxplot of F1 (Lobanov) by Corpus (averaged over time).

Figure 7.2 shows that FLEECE and KIT are slightly fronter for Glasgow than King's, whereas Glasgow DRESS and GOOSE are more retracted than King's.

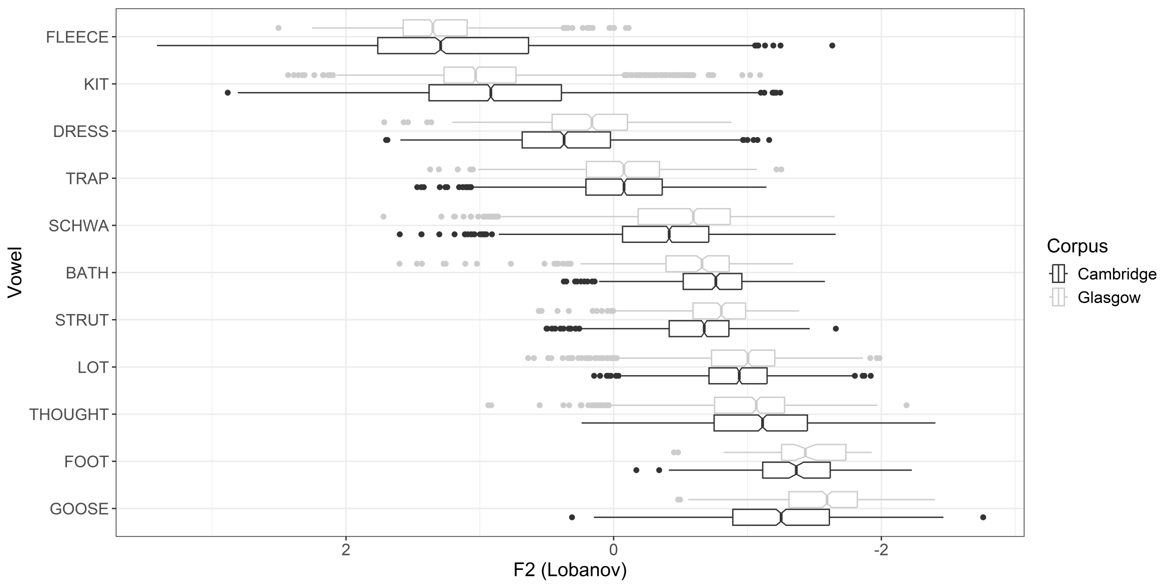


Figure 7.2: Boxplot of F2 (Lobanov) by Corpus (averaged over time).

7.2.2 Priors

Following extensive trialling in Chapter 5, I proceed with weakly informative priors.

7.2.3 Modelling

The terms included in the modelling are summarised in Table 7.3

Table 7.3: Fixed effects, interactions, and varying effects structure for modelling

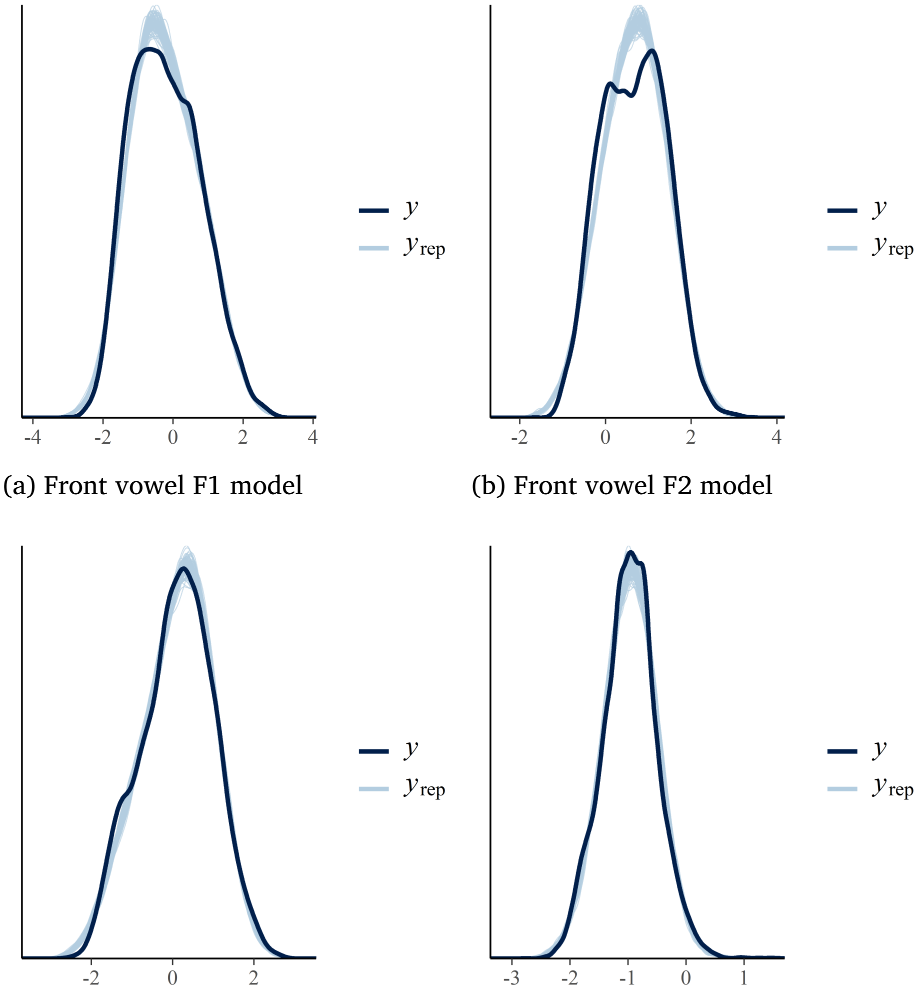
Predictor	Type	Levels/Units
Time/Director	Factor	HSR (1925–1951), PM (1959–1975), MJS (1987–2016), BO (1945–1958), DW (1959–1974), PL (1976–1982), SC (1984–2019)
Vowel	Factor	Front: FLEECE, KIT, DRESS, TRAP; Back: BATH, STRUT, LOT, THOUGHT, FOOT, GOOSE; TRAP–BATH
Vowel Duration	Contin.	Log (ms)
Following Segment	Factor	See Appendix D
Genre	Factor	Carols, Church Music, Misc.
Vowel:Time/Director Vowel:Duration Time/Director:Duration Genre:Duration	Interaction Interaction Interaction Interaction	
(1|Word) (1|Song) (1|Album) (1|Song:Word) (1|Album:Song)	Varying effect Varying effect Varying effect Nesting effect Nesting effect	

The model formula for Vowel Formant (F1 or F2) and Vowel Duration models were:

```
Vowel Formant or Vowel Duration ~ Vowel + Time/Director +
Duration + FollowingSegment + Genre + Vowel:Time/Director +
Vowel:Duration + Time/Director:Duration + Genre:Duration +
(1|Album) + (1|Song) + (1|Word) + (1|Album:Song) + (1|Song:Word)
```

7.2.4 Model convergence criteria

Figure 7.3 contains posterior predictive checks for the Combined vowel formant models. As before, the dark lines show the real data and the light lines show



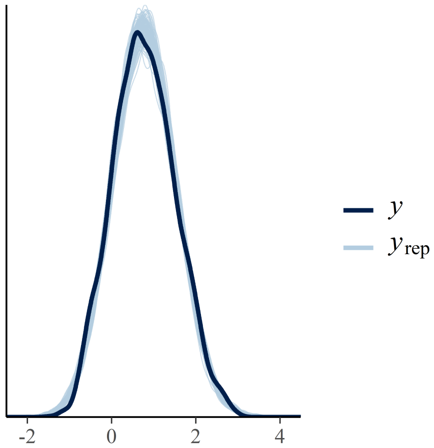
(a) Front vowel F1 model (b) Front vowel F2 model

(c) Back vowel F1 model (d) Back vowel F2 model

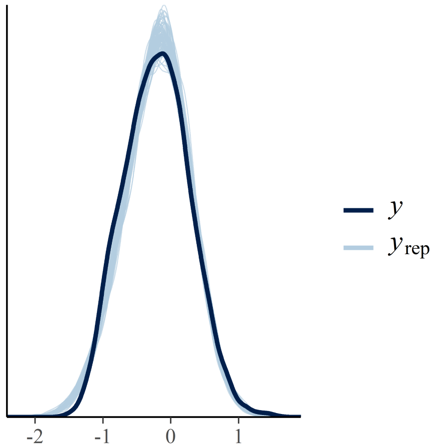
Figure 7.3: Combined: Front and back vowel model posterior predictive checks

simulated data. Where there is a high degree of overlap between the dark line and the light lines the model is performing well. We can be reasonably confident in the model output, with perhaps a slight more scepticism for the Front Vowel F2 model. Figure 7.4 contains posterior predictive checks for the Combined TRAP–BATH and Duration models. Again, I am satisfied with each.

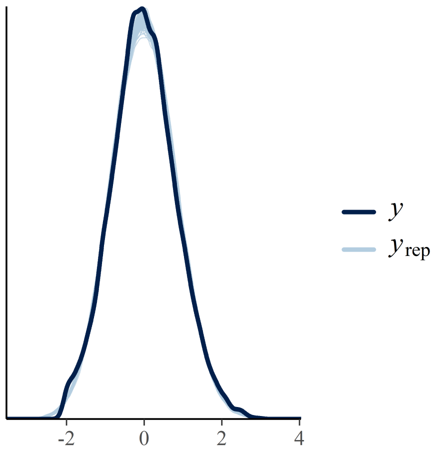
As with the previous models, chains were visually inspected for convergence, Rhat was 1 for all coefficients and the minimum effective sample size for all terms was greater than 100 $\times$ the number of chains. I was satisfied that the models have converged successfully and that the posterior summaries are amenable to interpretation.



(a) TRAP–BATH F1 model



(b) TRAP–BATH F2 model



(c) Duration model

Figure 7.4: Combined: TRAP–BATH and Duration model posterior predictive checks

7.2.5 Combined: Front vowel system

Direct comparison of front vowel quality in early time period across corpora

Figure 7.5 shows that front vowel height was broadly similar in the early time periods of each corpora. However, it appears that recordings made under Boris Ord had a higher F1 (lower tongue) than both Hugh S. Roberton and David Willcocks. If we expect to find evidence of the shift from RP to SSBE in the King's recordings, it appears this shift may have already occurred in the recordings of Boris Ord from 1945–1958.

Similarly, Figure 7.6 shows that there was a quite significant difference in F2 in the early time period, with recordings made under Hugh S. Roberton having a much fronter and/or less rounded realisation for all front vowels, but particularly for FLEECE and KIT compared to early recordings of King's under Boris Ord and David Willcocks.

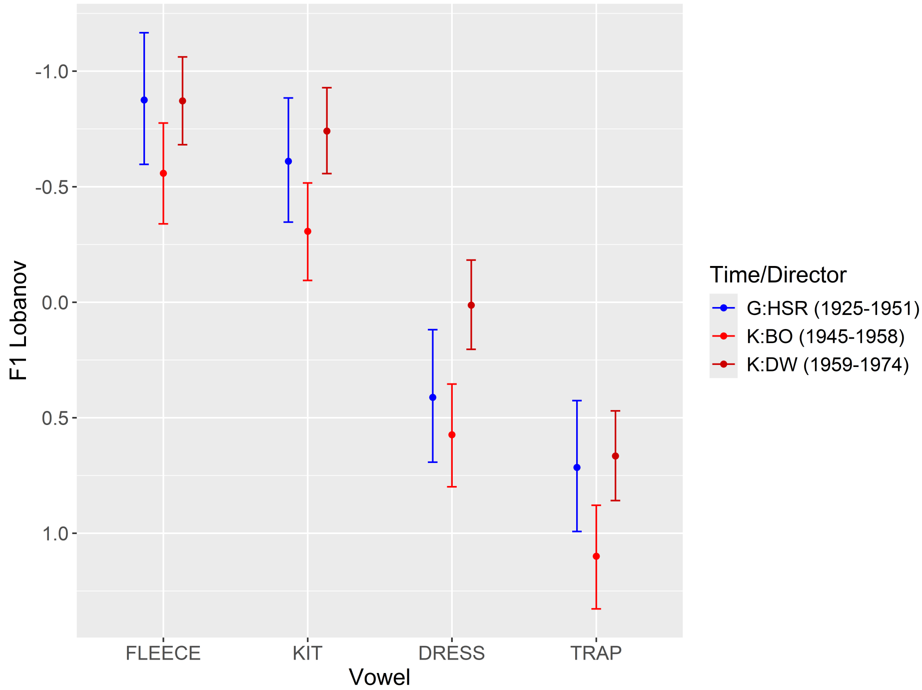


Figure 7.5: Front vowel F1 model estimates for Glasgow and Cambridge corpora in early time periods

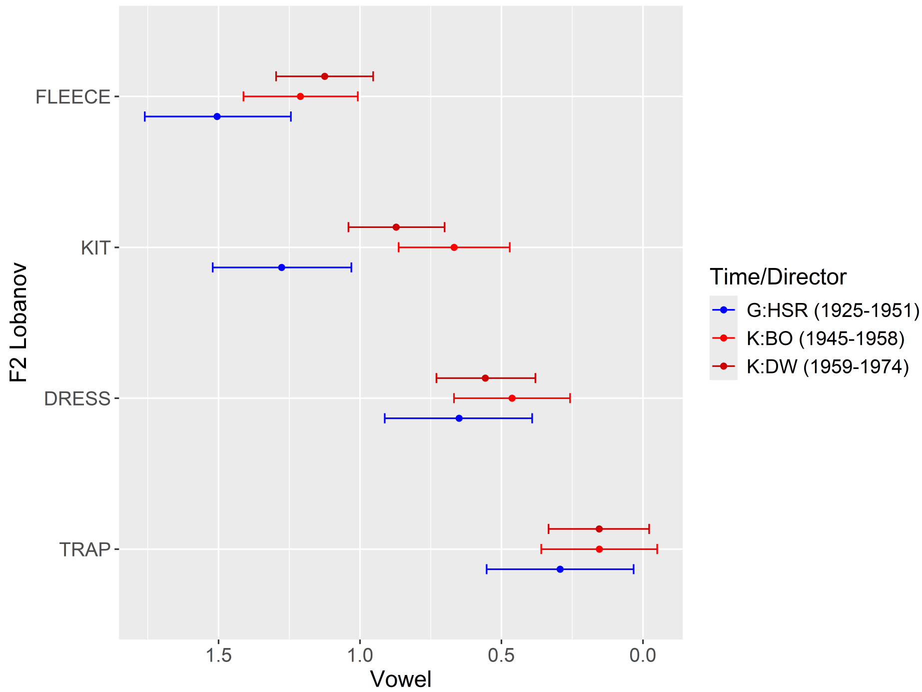


Figure 7.6: Front vowel F2 model estimates for Glasgow and Cambridge corpora in early time periods

Based on the modelling reported in Chapters 5 and 6, I expect to find strong evidence for the main effect of Vowel and Time/Director on F1. There may also be evidence of an interaction of Vowel by Time/Director for F1, supporting lowering over time for KIT, DRESS, and TRAP, while FLEECE stays the same. I expect to find evidence of an interaction of Vowel by Vowel Duration for F1, the longer Duration is, the more raised FLEECE and KIT are, in contrast to DRESS and TRAP which lower as duration increases. A specific question that this model and post hoc comparisons may help to address is: As DRESS and TRAP lowered over time separately in both the Glasgow and King's corpora, have the respective realisations of each corpus become more similar overall? Are there differences in TRAP height between the different time periods across both datasets? That is, do post hoc comparisons show differences between Marilyn J. Smith (Glasgow, 1987–2019) and Stephen Cleobury (King's, 1984–2019) for TRAP height? Were there differences previously, for example, between Hugh S. Roberton (Glasgow, 1925–1951) and David Willcocks (King's, 1959–1974)?

Table 7.4: Combined: Front vowel F1 model posterior summary

	Estimate	95% CI	
Intercept	−0.02	−0.09	0.05
vowelKIT	**−0.62**	**−0.66**	**−0.59**
vowelDRESS	**0.50**	**0.45**	**0.54**
vowelTRAP	**0.98**	**0.93**	**1.03**
directorPM1959–1975	0.00	−0.12	0.13
directorMJS1987–2016	**0.21**	**0.06**	**0.36**
directorBO1945–1958	**0.17**	**0.01**	**0.34**
directorDW1959–1974	**−0.31**	**−0.44**	**−0.18**
directorPL1976–1982	−0.09	−0.26	0.07
directorSC1984–2019	**0.15**	**0.05**	**0.25**
Vowel_Duration (log)	−0.00	−0.02	0.01
genreChurch	−0.07	−0.15	0.01
genreMisc.	−0.02	−0.09	0.05
vowelKIT:directorPM1959–1975	−0.00	−0.04	0.04
vowelDRESS:directorPM1959–1975	0.03	−0.02	0.09
vowelTRAP:directorPM1959–1975	**−0.12**	**−0.17**	**−0.07**
vowelKIT:directorMJS1987–2016	−0.05	−0.11	0.01
vowelDRESS:directorMJS1987–2016	**0.17**	**0.09**	**0.25**
vowelTRAP:directorMJS1987–2016	0.07	−0.00	0.14
vowelKIT:directorBO1945–1958	0.04	−0.01	0.09
vowelDRESS:directorBO1945–1958	−0.06	−0.13	0.00
vowelTRAP:directorBO1945–1958	0.01	−0.05	0.08
vowelKIT:directorDW1959–1974	**0.04**	**0.00**	**0.08**
vowelDRESS:directorDW1959–1974	**−0.19**	**−0.24**	**−0.13**
vowelTRAP:directorDW1959–1974	0.02	−0.04	0.07
vowelKIT:directorPL1976–1982	0.03	−0.02	0.07
vowelDRESS:directorPL1976–1982	**−0.09**	**−0.16**	**−0.03**
vowelTRAP:directorPL1976–1982	−0.01	−0.07	0.05
vowelKIT:directorSC1984–2019	**−0.09**	**−0.12**	**−0.06**
vowelDRESS:directorSC1984–2019	**0.07**	**0.03**	**0.12**
vowelTRAP:directorSC1984–2019	**0.11**	**0.06**	**0.15**
vowelKIT:vdur_log	**−0.09**	**−0.11**	**−0.07**
vowelDRESS:vdur_log	**0.07**	**0.04**	**0.10**
vowelTRAP:vdur_log	**0.12**	**0.09**	**0.14**
directorPM1959–1975:vdur_log	−0.01	−0.04	0.02

	Estimate	95% CI	
directorMJS1987–2016:vdur_log	**−0.05**	**−0.09**	**−0.01**
directorBO1945–1958:vdur_log	**0.05**	**0.01**	**0.10**
directorDW1959–1974:vdur_log	0.00	−0.04	0.04
directorPL1976–1982:vdur_log	0.03	−0.02	0.07
directorSC1984–2019:vdur_log	**−0.04**	**−0.07**	**−0.01**
vdur_log:genreChurch	**0.03**	**0.01**	**0.05**
vdur_log:genreMisc.	0.00	−0.02	0.03

Bold type indicates 0 outside 95% credible interval.

I will now report the results of the combined front vowel height (F1) model as shown in Table 7.4. As expected from the previous analyses, there is strong evidence of a main effect of Vowel for front vowel height with KIT higher than the grand mean (median -0.62, CI [-0.66; -0.59], and DRESS (median 0.50, CI [0.45; 0.54]) and TRAP (median 0.98, CI [0.93; 1.03]) lower than the grand mean. Most importantly for this model, there is a robust main effect of Time/Director such that Stephen Cleobury (Kings, 1984-2019) (median 0.15, CI [0.05; 0.25]), and Marilyn J. Smith (Glasgow, 1987–2019) (median 0.21, CI [0.06; 0.36]) pattern together with Boris Ord (Kings, 1945-1958) (median 0.17, CI [0.01; 0.34]), with an acoustic vowel quality likely produced with a lower tongue or jaw configuration. In contrast, David Willcocks (Kings, 1959–1974) produces a more raised acoustic vowel quality (median -0.31, CI [-0.44; -0.18]) compared to the grand mean. Front vowels are lower in the late time periods of both Glasgow and King's.

There is evidence of an interaction of Vowel by Time/Director. Peter Mooney (1959–1975) does not differ from the grand mean; however, the TRAP vowel produced under PM is significantly raised compared to the grand mean (median -0.12, CI [-0.17; -0.07]). While there is a main effect of Marilyn J. Smith (1987–2016) lowering overall, DRESS is even lower for MJS compared to the grand mean (median 0.17, CI [0.09; 0.25]). In contrast, while the main effect of David Willcocks reveals raising, the effect for DRESS is even greater (median -0.19, CI [-0.24; -0.13]). Furthermore, while the main effect of Stephen Cleobury reveals lowering, there is an even stronger effect for DRESS (median 0.07, CI [0.03; 0.12]) and TRAP (median 0.11, CI [0.06; 0.14]) This is the same effect as for MJS – indicating a shared overall pattern of lowering and a shared pattern of interaction in the late time periods of Glasgow and King's.

As can be seen in figure 7.7, Hugh S. Roberton (Glasgow, 1925–1951) and David Willcocks (King's, 1959–1974) largely pattern together in front vowel height; post hoc comparisons show that there are no differences between them for FLEECE, KIT and TRAP. There is however a difference for DRESS, with recordings made under Willcocks exhibiting a much higher realisation than under Roberton (median

-0.39, CI [-0.68; -0.13]) closer to [e] than [ɛ]. Peter Mooney (Glasgow, 1959–1975) and Philip Ledger (King's, 1976–1982) both follow Roberton and Willcocks respectively and show a modest lowering for all front vowels from the peak of acoustic front vowel height under both choirs' previous directors.

Boris Ord (King's, 1945–1958), Stephen Cleobury (King's, 1984–2019) and Marilyn J. Smith (Glasgow, 1987–2019) pattern together in front vowel height for FLEECE, KIT, and TRAP and post hoc tests reveal no differences between them (Appendix Table F.1). There is a difference between Boris Ord and Marilyn J. Smith for DRESS with Ord producing a more raised realisation (median -0.37, CI [-0.63; -0.09]). Broadly, in terms of front vowel height, the later Time/Director pairs (Stephen Cleobury, and Marilyn J. Smith) for King's and Glasgow produce a similar acoustic vowel quality to that produced under Boris Ord.

Returning to the posterior summary in Table 7.4, the model does not support a main effect of Vowel Duration or Genre for front vowel height. As expected, there is evidence of an interaction of Vowel by Vowel Duration, such that as Vowel Duration increases, KIT raises (median -0.09, CI [-0.11; -0.07] while DRESS (median 0.07, CI [0.04; 0.10]) and TRAP (median 0.12, CI [0.09; 0.14]) lower. Interestingly, there is evidence of an interaction of Time/Director by Vowel Duration for front vowel height. For both of the later Time/Director pairs there is an effect such that the greater Vowel Duration is, the more raised the vowels become: Marilyn J. Smith (Glasgow, 1987–2016) (median -0.05, CI [-0.09; -0.01]) and Stephen Cleobury (King's, 1984–2019) (median -0.04, CI [-0.07; -0.01]). This is in contrast to Boris Ord, for whom the longer vowel duration is, the lower front vowel height becomes (median 0.05, CI [0.01; 0.10]).

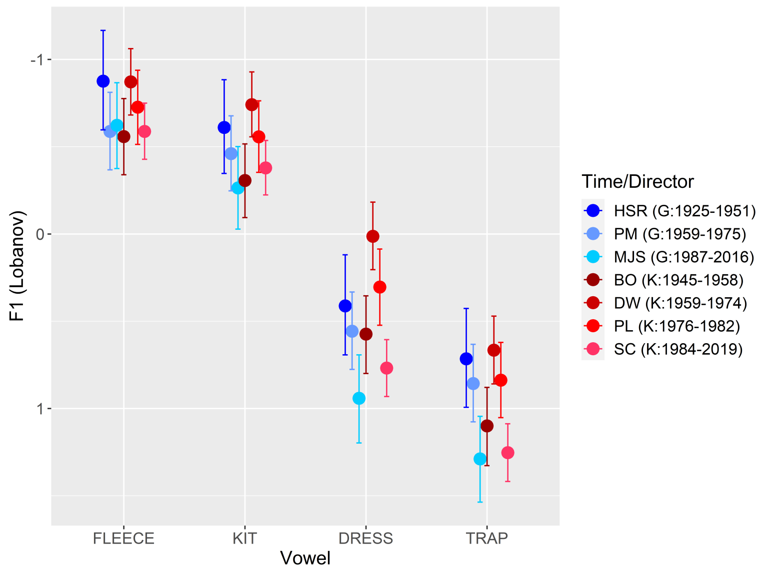


Figure 7.7: Combined: Front vowel F1 model, Vowel by Time/Director interaction (bars show 95% credible intervals; G = Glasgow corpus, K = King's corpus; N = 14,404)

Combined: Front vowel F2 model

I now report the results for the combined front vowel F2 (backness) model. Based on the modelling of Chapters 5 and 6 I expect to find no evidence of a main effect of Time/Director on front vowel F2. However, I expect to find evidence of an interaction of Vowel by Time/Director driven by the TRAP vowel for which there was weak evidence of retraction. I also predict to find evidence of an interaction of vowel by vowel duration for F2, such that the longer vowel duration the fronter FLEECE and KIT are, and the backer TRAP and DRESS are.

Table 7.5: Combined: Front vowel F2 model posterior summary

	Estimate	95% CI	
Intercept	**0.58**	**0.52**	**0.64**
vowelKIT	**0.33**	**0.30**	**0.36**
vowelDRESS	**−0.29**	**−0.33**	**−0.25**
vowelTRAP	**−0.70**	**−0.75**	**−0.66**
directorPM1959–1975	0.04	−0.08	0.15
directorMJS1987–2019	0.08	−0.05	0.21
directorBO1945–1958	**−0.18**	**−0.33**	**−0.02**
directorDW1959–1974	−0.03	−0.15	0.09
directorPL1976–1982	−0.14	−0.30	0.02
directorSC1984–2019	−0.01	−0.10	0.09
VowelDuration_log	**−0.02**	**−0.04**	**−0.01**
genreChurch	**−0.08**	**−0.15**	**−0.02**
genreMisc.	0.01	−0.06	0.07
vowelKIT:directorPM1959–1975	**0.10**	**0.06**	**0.13**
vowelDRESS:directorPM1959M–1975	**−0.12**	**−0.16**	**−0.07**
vowelTRAP:directorPM1959–1975	0.02	−0.02	0.06

	Estimate	95% CI	
vowelKIT:directorMJS1987–2016	**0.09**	**0.04**	**0.13**
vowelDRESS:directorMJS1987–2016	**−0.18**	**−0.24**	**−0.11**
vowelTRAP:directorMJS1987–2016	**−0.12**	**−0.18**	**−0.06**
vowelKIT:directorBO1945–1958	**−0.21**	**−0.26**	**−0.17**
vowelDRESS:directorBO1945–1958	**0.06**	**0.01**	**0.12**
vowelTRAP:directorBO1945–1958	**0.16**	**0.10**	**0.22**
vowelKIT:directorDW1959–1974	**−0.06**	**−0.10**	**−0.03**
vowelDRESS:directorDW1959–1974	**0.10**	**0.06**	**0.15**
vowelTRAP:directorDW1959–1974	**0.11**	**0.06**	**0.15**
vowelKIT:directorPL1976–1982	−0.02	−0.06	0.02
vowelDRESS:directorPL1976–1982	**0.13**	**0.08**	**0.19**
vowelTRAP:directorPL1976–1982	−0.02	−0.07	0.03
vowelKIT:directorSC1984–2019	**0.03**	**0.00**	**0.06**
vowelDRESS:directorSC1984–2019	**0.05**	**0.01**	**0.09**
vowelTRAP:directorSC1984–2019	**−0.14**	**−0.18**	**−0.11**
vowelKIT:vdur_log	**0.09**	**0.07**	**0.10**
vowelDRESS:vdur_log	**−0.08**	**−0.10**	**−0.05**
vowelTRAP:vdur_log	**−0.08**	**−0.10**	**−0.06**
directorPM1959–1975:vdur_log	**0.04**	**0.01**	**0.06**
directorMJS1987–2016:vdur_log	**0.08**	**0.05**	**0.12**
directorBO1945–1958:vdur_log	**−0.11**	**−0.15**	**−0.07**
directorDW1959–1974:vdur_log	−0.00	−0.03	0.03
directorPL1976–1982:vdur_log	−0.03	−0.07	0.01
directorSC1984–2019:vdur_log	0.00	−0.02	0.03
vdur_log:genreChurch	**−0.03**	**−0.05**	**−0.02**
vdur_log:genreMisc.	0.01	−0.01	0.03

Bold type indicates 0 outside 95% credible interval.

The posterior summary for the combined front vowel F2 model can be found in Table 7.5. As expected, there is a strong main effect of Vowel, with KIT being fronter than the grand mean (median 0.33, CI [0.30; 0.36]) and DRESS (median -0.29, CI [-0.33; -0.25]) and TRAP [median -0.70, CI -0.75; -0.66] backer than the grand mean. There is a main effect of Time/Director with Boris Ord being more retracted than the grand mean (median -0.18, CI [-0.33; -0.02]). The model reveals a main effect of Vowel Duration, such that the longer front vowels are, the more they retract (median -0.02, CI [-0.04; -0.01]). There is also a main effect of Genre for F2 with the factor level 'ChurchMusic' more retracted than the grand mean for Genre (median -0.08, CI [-0.15; -0.02]). While I am cautious in interpreting this result due to the way Genre has been coded, it seems to make sense to me that 'ChurchMusic' might elicit a backer vowel quality. This would be something interesting for future research to pursue.

There is also an interaction of Vowel by Time/Director. KIT is fronter than the grand mean for Peter Mooney (median 0.10, CI [0.06; 0.13]), Marilyn J. Smith (median 0.09, CI $[0.04; 0.13]$), and Stephen Cleobury (median 0.03, CI $[0.00; 0.06]$). Whereas, KIT is more retracted for Boris Ord (median -0.21, CI $[-0.26; -0.17]$), and David Willcocks (median -0.06, CI $[-0.10; -0.03]$).

DRESS is more retracted for Peter Mooney (median -0.12, CI $[-0.16; -0.07]$), and Marilyn J. Smith (median -0.18, CI $[-0.24; -0.11]$). In contrast, DRESS is fronter than the grand mean for Boris Ord (median 0.06, CI $[0.01; 0.12]$), David Willcocks (median 0.10, CI $[0.06; 0.15]$), Philip Ledger (median 0.13, CI $[0.08; 0.19]$), and Stephen Cleobury (median 0.05, CI $[0.01; 0.09]$). This suggests that perhaps there is a difference in the habitual frontness of the DRESS vowel conditioned by Corpus.

Finally, TRAP is more retracted than the grand mean for Marilyn J. Smith (median -0.12, CI $[-0.18; -0.06]$) and Stephen Cleobury (median -0.14, CI $[-0.18; -0.11]$). Meanwhile TRAP is fronter for Boris Ord (median 0.16, CI $[0.10; 0.22]$) and David Willcocks (median 0.11, CI $[0.06; 0.15]$). So, on average it appears that Glasgow KIT is fronter than King's, but King's DRESS is fronter overall. The interaction is visualised in Figure 7.8.

As seen in Appendix Table F.2, post hoc comparisons reveal that FLEECE and KIT have fronted under Stephen Cleobury (King's, 1984–2019) and there are no differences between Stephen Cleobury and the three Glasgow Time/Director pairs. KIT has likewise fronted for Stephen Cleobury, whereas there are no differences with Peter Mooney (Glasgow, 1959–1975) and Marilyn J. Smith (Glasgow, 1987–2019) apart from being different to Hugh S. Roberton (Glasgow, 1925–1951) (median -0.29, CI $[-0.51; -0.06]$). For DRESS, Stephen Cleobury is more retracted than Marilyn J. Smith (median 0.21, CI $[0.02; 0.41]$), but not different to Peter Mooney or Hugh S. Roberton. For TRAP, Stephen Cleobury is more retracted than Hugh S. Roberton (median -0.37, CI $[-0.59; -0.12]$) and Peter Mooney (median -0.18, CI $[-0.35; -0.01]$), but there is no difference to Marilyn J. Smith. In short FLEECE, KIT and TRAP have become more similar between the Glasgow and King's recordings over time in F2. DRESS appears to have behaved differently.

Returning to the combined front vowel F2 posterior summary (Table 7.5), in contrast to the F1 model there are main effects of Vowel Duration and Genre. The longer Vowel Duration is, the backer a front vowel becomes overall (median -0.02, CI $[-0.04; -0.01]$). The Genre 'Church Music' is more retracted than the grand mean for Genre (median -0.08, CI $[-0.15; -0.02]$).

As predicted, there is an interaction of Vowel by Vowel Duration, such that as Vowel Duration increases, KIT fronts (median 0.09, CI $[0.07; 0.10]$) while DRESS (median -0.08, CI $-0.10; -0.05]$) and TRAP (median -0.08, CI $[-0.10; -0.06]$)

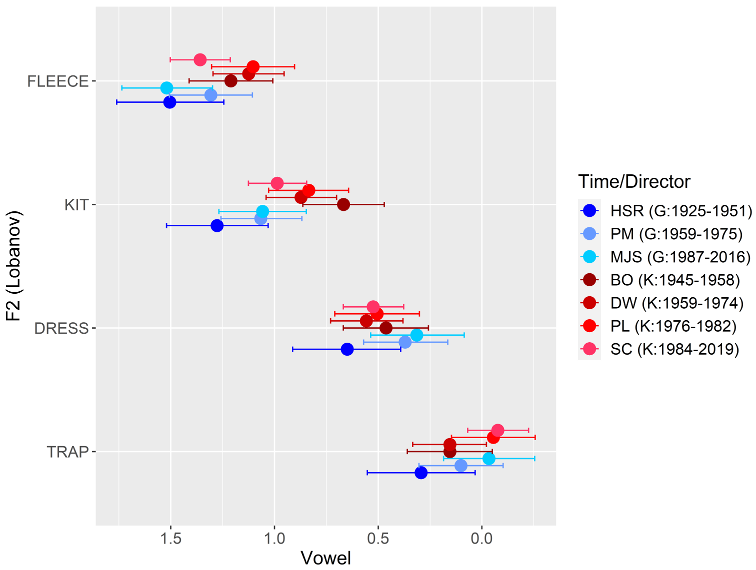


Figure 7.8: Combined: Front vowel F2 model, Vowel by Time/Director interaction (bars show 95% credible intervals; G = Glasgow corpus, K = King's corpus; N = 14,404)

retract. There was also an interaction of Genre by Vowel Duration. With the same caveat as before, it appears that as Vowel Duration increases, vowels in the genre 'Church Music' retract slightly (median -0.03, CI [-0.05; -0.02]).

7.2.6 Combined: Back vowel system

Direct comparison of front vowel quality in early time period across corpora

Figure 7.9 shows that back vowel height was broadly similar between recordings of King's under Boris Ord and Glasgow under Hugh S. Roberton. However, David Willcocks has a higher realisation for BATH, STRUT, LOT, THOUGHT and FOOT.

Figure 7.10 shows that there was a quite significant difference in F2 in the early time period with recordings made under Hugh S. Roberton having a much fronter realisation compared to early recordings of King's under Ord and Willcocks for BATH and THOUGHT, but backer for GOOSE.

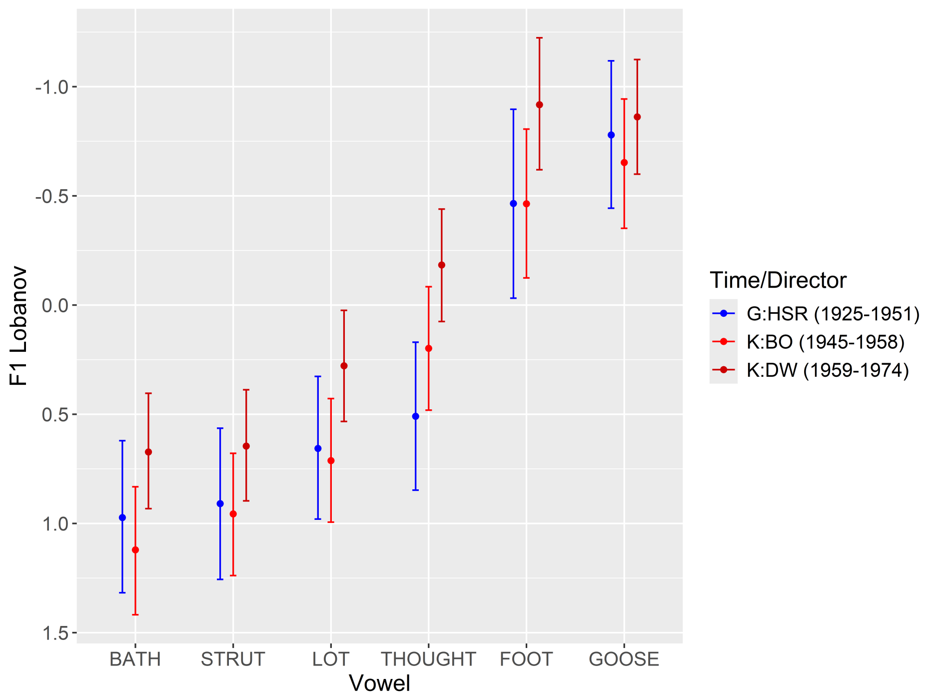


Figure 7.9: Back vowel F1 model estimates for Glasgow and Cambridge corpora in early time periods

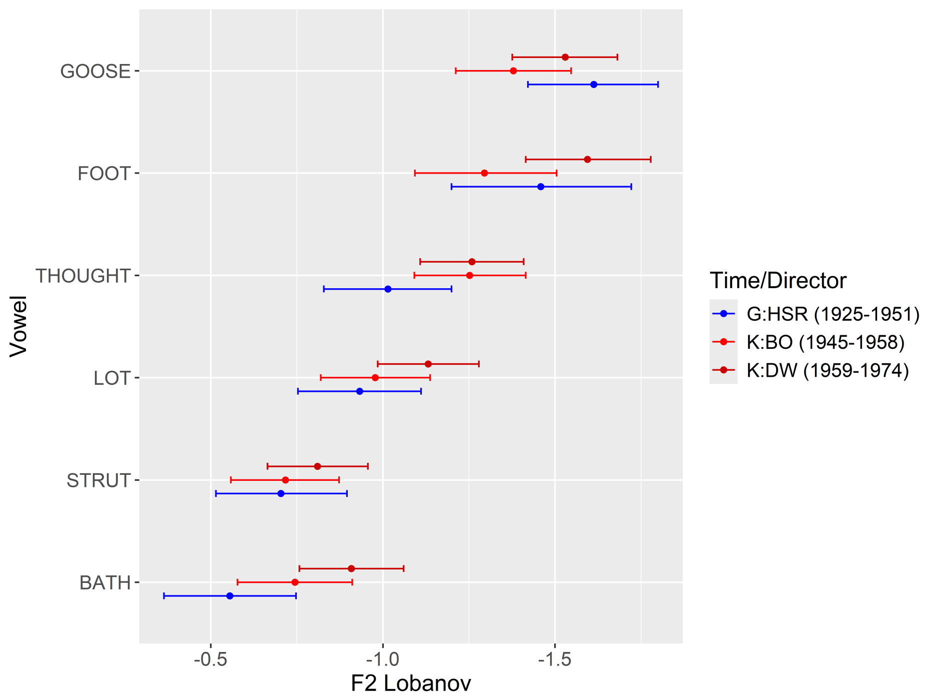


Figure 7.10: Back vowel F2 model estimates for Glasgow and Cambridge corpora in early time periods

Table 7.6: Combined: Back vowel F1 model posterior summary

	Estimate	95% CI	
Intercept	0.07	−0.01	0.14
vowelSTRUT	**0.61**	**0.54**	**0.67**
vowelLOT	**0.40**	**0.34**	**0.46**
vowelTHOUGHT	**0.06**	**0.01**	**0.12**
vowelFOOT	**−0.77**	**−0.89**	**−0.66**
vowelGOOSE	**−1.00**	**−1.07**	**−0.94**
directorPM1959–1975	−0.02	−0.15	0.11
directorMJS1987–2016	**0.19**	**0.03**	**0.35**
directorBO1945–1958	0.10	−0.07	0.27
directorDW1959–1974	**−0.28**	**−0.42**	**−0.15**
directorPL1976–1982	−0.10	−0.28	0.07
directorSC1984–2019	**0.10**	**0.00**	**0.21**
Vowel_Duration (log)	−0.00	−0.03	0.02
genreChurch	**−0.11**	**−0.19**	**−0.04**
genreMisc.	0.02	−0.06	0.10
vowelSTRUT:directorPM1959–1975	**−0.12**	**−0.19**	**−0.05**
vowelLOT:directorPM1959–1975	−0.01	−0.07	0.05
vowelTHOUGHT:directorPM1959–1975	**0.23**	**0.17**	**0.30**
vowelFOOT:directorPM1959–1975	0.00	−0.13	0.14
vowelGOOSE:directorPM1959–1975	−0.04	−0.11	0.03
vowelSTRUT:directorMJS1987–2016	−0.02	−0.12	0.08
vowelLOT:directorMJS1987–2016	**0.10**	**0.01**	**0.19**
vowelTHOUGHT:directorMJS1987–2016	**0.23**	**0.14**	**0.32**
vowelFOOT:directorMJS1987–2016	−0.07	−0.29	0.16
vowelGOOSE:directorMJS1987–2016	**−0.21**	**−0.32**	**−0.11**
vowelSTRUT:directorBO1945–1958	0.02	−0.07	0.10
vowelLOT:directorBO1945–1958	0.01	−0.07	0.09
vowelTHOUGHT:directorBO1945–1958	**−0.20**	**−0.28**	**−0.12**
vowelFOOT:directorBO1945–1958	0.02	−0.14	0.18
vowelGOOSE:directorBO1945–1958	0.04	−0.05	0.14
vowelSTRUT:directorDW1959–1974	**0.08**	**0.01**	**0.15**
vowelLOT:directorDW1959–1974	−0.05	−0.11	0.01
vowelTHOUGHT:directorDW1959–1974	**−0.21**	**−0.27**	**−0.14**
vowelFOOT:directorDW1959–1974	−0.06	−0.19	0.08
vowelGOOSE:directorDW1959–1974	**0.21**	**0.14**	**0.28**
vowelSTRUT:directorPL1976–1982	−0.03	−0.11	0.05
vowelLOT:directorPL1976–1982	**−0.09**	**−0.16**	**−0.02**
vowelTHOUGHT:directorPL1976–1982	**−0.23**	**−0.30**	**−0.15**
vowelFOOT:directorPL1976–1982	**0.22**	**0.08**	**0.37**
vowelGOOSE:directorPL1976–1982	**0.19**	**0.10**	**0.27**
vowelSTRUT:directorSC1984–2019	**0.09**	**0.03**	**0.15**
vowelLOT:directorSC1984–2019	**0.07**	**0.02**	**0.13**
vowelTHOUGHT:directorSC1984–2019	0.04	−0.01	0.10
vowelFOOT:directorSC1984–2019	**−0.16**	**−0.27**	**−0.05**
vowelGOOSE:directorSC1984–2019	**−0.11**	**−0.18**	**−0.05**
vowelSTRUT:vdur_log	−0.03	−0.06	0.01

	Estimate	95% CI	
vowelLOT:vdur_log	0.02	−0.02	0.05
vowelTHOUGHT:vdur_log	−0.03	−0.06	0.01
vowelFOOT:vdur_log	0.04	−0.04	0.11
vowelGOOSE:vdur_log	0.01	−0.04	0.05
directorPM1959–1975:vdur_log	−0.01	−0.05	0.02
directorMJS1987–2016:vdur_log	**−0.07**	**−0.11**	**−0.02**
directorBO1945–1958:vdur_log	0.04	−0.01	0.09
directorDW1959–1974:vdur_log	0.02	−0.02	0.07
directorPL1976–1982:vdur_log	**0.06**	**0.01**	**0.11**
directorSC1984–2019:vdur_log	0.02	−0.01	0.06
vdur_log:genreChurch	−0.01	−0.03	0.02
vdur_log:genreMisc.	**0.04**	**0.01**	**0.07**

Bold type indicates 0 outside 95% credible interval.

I now turn to the combined back vowel analysis, beginning with the back vowel height (F1) model as seen in Table 7.6. The model supports a main effect of Vowel with STRUT (median 0.61, CI [0.54; 0.67]), LOT (median 0.40, CI [0.34; 0.46]), and THOUGHT (median 0.06, CI [0.01; 0.12]) lower than the grand mean. FOOT (median -0.77, CI [-0.89; -0.66]) and GOOSE [median -1.00, CI [-1.07; -0.94]) are higher than the grand mean. There is also evidence of a main effect of Time/Director, with David Willcocks (King's, 1959–1974) (median -0.28, CI [-0.42; -0.15]) being higher than the grand mean, and Marilyn J. Smith (Glasgow, 1987–2019) (median 0.19, CI [0.03; 0.35]) and Stephen Cleobury (King's, 1984–2019) (median 0.10, CI [0.00; 0.21]) being lower than the grand mean. There is also a main effect of Genre with the level 'Church Music' being more raised than the grand mean (median -0.11, CI [-0.19; -0.04]).

The model supports an interaction of Vowel by Time/Director. For the vowel THOUGHT, Peter Mooney (median 0.23, CI [0.17; 0.30]), and Marilyn J. Smith (median 0.23, CI [0.14; 0.32]) are lower than the grand mean. However, THOUGHT is more raised for Boris Ord (median -0.20, CI [-0.28; -0.12]), David Willcocks (median -0.21, CI [-0.27; -0.14]), and Philip Ledger (median -0.23, CI [-0.30; -0.15]). This difference in THOUGHT height may represent a difference between Glasgow and King's corpora. LOT is lower than the grand mean for Marilyn J. Smith (median 0.10, CI [0.01; 0.19]) and Stephen Cleobury (median 0.07, CI [0.02; 0.13]), but more raised for Philip Ledger (median -0.09, CI [-0.16; -0.02]). GOOSE is lower than the grand mean for David Willcocks (median 0.21, CI [0.14; 0.28]) and Philip Ledger (median 0.19, CI [0.10; 0.27]), but higher than the grand mean for Marilyn J. Smith (median -0.21, CI [-0.32; -0.11]) and Stephen Cleobury (median -0.11, CI [-0.18; -0.05]).

The interaction of Vowel by Time/Director is visualised in Figure 7.11. Marilyn J. Smith (Glasgow, 1987–2019), Stephen Cleobury (King's, 1984–2019), and Boris Ord (King's, 1945–1958) seem to pattern together in terms of back vowel height for BATH, STRUT, FOOT and GOOSE. David Willcocks (King's, 1959–1974) and Philip Ledger (King's, 1976–1982) broadly pattern together for back vowel height – with the exception of FOOT. The vowel with the widest spread of realisations between Time/Directors is THOUGHT. Post hoc comparisons for back vowel height can be found in Appendix Table F.3. It appears that something similar to front vowels is going on at King's meaning that the vowel space raised extremely under David Willcocks and Philip Ledger, and returned to the vowel height of Boris Ord under Stephen Cleobury. This is the case for BATH, STRUT and LOT. Something different is happening with THOUGHT as it is lower under Stephen Cleobury than it was under Ord, and, if we cast our minds back to Chapter 6, while the 95% credible interval for the post hoc comparison does include zero (median 0.2, CI [-0.03; 0.41]), 90% of that interval is on the positive side of zero, providing weak evidence that THOUGHT produced under Stephen Cleobury is heading in the direction of lowering. Stephen Cleobury is higher than Marilyn J. Smith for THOUGHT [median -0.3369, CI [-0.5547; -0.1215]) but not different to Hugh S. Roberton or Peter Mooney.

There was no evidence of a main effect of Vowel Duration on back vowel height – and there was no evidence of an interaction of Vowel by Vowel Duration for back vowel height. There is evidence of an interaction of Genre by Vowel Duration but I am not going to interpret this as it was largely a control. There is evidence of an interaction of Vowel Duration by Time/Director with Marilyn J. Smith (Glasgow, 1987–2019) (median -0.07, CI [-0.11; -0.02]) raising back vowel quality as duration increases, with the opposite occurring for Philip Ledger (King's, 1976–1982) (median 0.06, CI [0.01; 0.11]), that is, the back vowels lowering as vowel duration increases.

Table 7.7: Combined: Back vowel F2 model posterior summary

	Estimate	95% CI	
Intercept	**−1.04**	**−1.08**	**−1.00**
vowelSTRUT	**0.31**	**0.27**	**0.35**
vowelLOT	**0.09**	**0.05**	**0.13**
vowelTHOUGHT	−0.03	−0.07	0.01
vowelFOOT	**−0.31**	**−0.38**	**−0.24**
vowelGOOSE	**−0.41**	**−0.45**	**−0.36**
directorPM1959–1975	−0.04	−0.10	0.02
directorMJS1987–2019	−0.03	−0.11	0.04
directorBO1945–1958	0.05	−0.03	0.13
directorDW1959–1974	**−0.10**	**−0.16**	**−0.03**
directorPL1976–1982	0.01	−0.07	0.09

	Estimate	95% CI	
directorSC1984–2019	**0.11**	**0.06**	**0.16**
Vowel_Duration (log)	**−0.08**	**−0.10**	**−0.07**
genreChurch	−0.03	−0.07	0.01
genreMisc.	**0.04**	**0.00**	**0.08**
vowelSTRUT:directorPM1959–1975	**−0.09**	**−0.13**	**−0.04**
vowelLOT:directorPM1959–1975	**0.05**	**0.01**	**0.09**
vowelTHOUGHT:directorPM1959–1975	**0.13**	**0.09**	**0.18**
vowelFOOT:directorPM1959–1975	−0.05	−0.14	0.04
vowelGOOSE:directorPM1959–1975	**−0.16**	**−0.21**	**−0.11**
vowelSTRUT:directorMJS1987–2016	−0.00	−0.07	0.06
vowelLOT:directorMJS1987–2016	0.01	−0.05	0.07
vowelTHOUGHT:directorMJS1987–2016	**0.09**	**0.03**	**0.15**
vowelFOOT:directorMJS1987–2016	−0.07	−0.21	0.08
vowelGOOSE:directorMJS1987–2016	−0.03	−0.10	0.04
vowelSTRUT:directorBO1945–1958	0.00	−0.05	0.06
vowelLOT:directorBO1945–1958	0.01	−0.04	0.06
vowelTHOUGHT:directorBO1945–1958	**−0.16**	**−0.21**	**−0.10**
vowelFOOT:directorBO1945–1958	0.11	−0.00	0.21
vowelGOOSE:directorBO1945–1958	**0.08**	**0.02**	**0.15**
vowelSTRUT:directorDW1959–1974	**0.05**	**0.01**	**0.10**
vowelLOT:directorDW1959–1974	0.00	−0.04	0.04
vowelTHOUGHT:directorDW1959–1974	−0.02	−0.06	0.02
vowelFOOT:directorDW1959–1974	−0.05	−0.14	0.04
vowelGOOSE:directorDW1959–1974	**0.08**	**0.03**	0.12
vowelSTRUT:directorPL1976–1982	0.04	−0.01	0.09
vowelLOT:directorPL1976–1982	**−0.08**	**−0.12**	**−0.03**
vowelTHOUGHT:directorPL1976–1982	**−0.08**	**−0.13**	**−0.03**
vowelFOOT:directorPL1976–1982	0.06	−0.03	0.16
vowelGOOSE:directorPL1976–1982	**0.09**	**0.04**	**0.15**
vowelSTRUT:directorSC1984–2019	−0.00	−0.04	0.03
vowelLOT:directorSC1984–2019	**−0.03**	**−0.07**	**−0.00**
vowelTHOUGHT:directorSC1984–2019	−0.03	−0.07	0.00
vowelFOOT:directorSC1984–2019	0.07	−0.00	0.14
vowelGOOSE:directorSC1984–2019	**0.10**	**0.06**	**0.14**
vowelSTRUT:vdur_log	**−0.05**	**−0.07**	**−0.02**
vowelLOT:vdur_log	**0.03**	**0.00**	**0.05**
vowelTHOUGHT:vdur_log	0.00	−0.02	0.03
vowelFOOT:vdur_log	0.04	−0.01	0.09
vowelGOOSE:vdur_log	−0.01	−0.04	0.02
directorPM1959–1975:vdur_log	−0.00	−0.03	0.02
directorMJS1987–2019:vdur_log	−0.01	−0.04	0.02
directorBO1945–1958:vdur_log	0.02	−0.01	0.06
directorDW1959–1974:vdur_log	0.02	−0.01	0.05
directorPL1976–1982:vdur_log	0.01	−0.02	0.05
directorSC1984–2016:vdur_log	**0.04**	**0.01**	**0.06**
vdur_log:genreChurch	**0.02**	**0.00**	**0.03**
vdur_log:genreMisc.	0.01	−0.01	0.03

Bold type indicates 0 outside 95% credible interval.

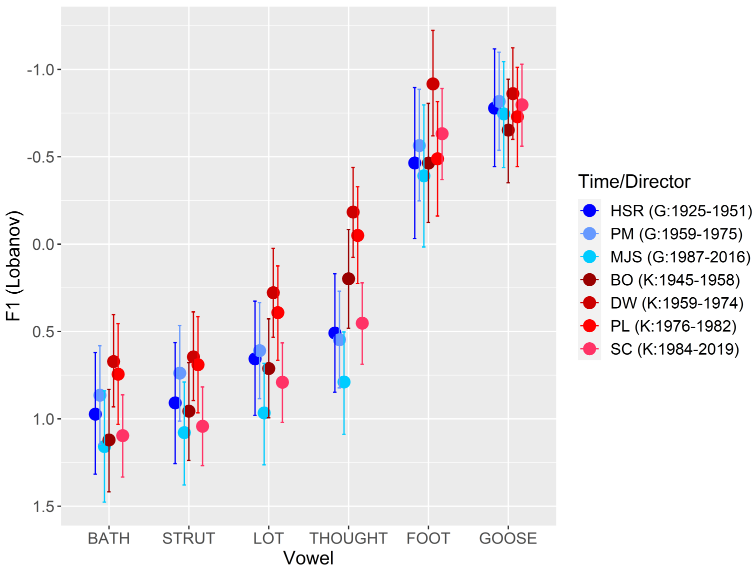


Figure 7.11: Combined: Back vowel F1 model, Vowel by Time/Director interaction (bars show 95% credible intervals; G = Glasgow corpus, K = King's corpus; N = 8,349)

As seen in Table 7.7, the back vowel F2 model supports a main effect of Vowel with STRUT (median 0.31, CI $[0.27; 0.35]$) and LOT (median 0.09, CI $[0.05; 0.13]$) forward of the grand mean, and FOOT (median -0.31, CI $[-0.38; -0.24]$) and GOOSE (median -0.41, CI $[-0.45; -0.36]$) more backed, as expected. There is evidence of a main effect of Time/Director with David Willcocks (King's, 1959–1974) backer than the grand mean (median -0.10, CI $[-0.16; -0.03]$) and Stephen Cleobury fronter than the grand mean (median 0.11, CI $[0.06; 0.16]$). The model also supports a main effect of Vowel Duration, such that the longer the vowel, the more retracted it becomes (median -0.08, CI $[-0.10; -0.07]$).

The model supports an interaction of Vowel by Time/Director. LOT is fronter than the grand mean for Peter Mooney (median 0.05, CI $[0.01; 0.09]$), but backer than the grand mean for Philip Ledger (median -0.08, CI $[-0.12; -0.03]$) and Stephen Cleobury (median -0.03, CI $[-0.07; -0.00]$). THOUGHT is fronter than the grand mean for Peter Mooney (median 0.13, CI $[0.09; 0.18]$), and Marilyn J. Smith (median 0.09, CI $[0.03; 0.15]$), but backer than the grand mean for Boris Ord (median -0.16, CI $[-0.21; -0.10]$) and Philip Ledger (median -0.08, CI $[-0.13; -0.03]$). GOOSE is backer than the grand mean for Peter Mooney (median -0.16, CI $[-0.21; -0.11]$) but fronter than the grand mean for all King's Time/Directors: Boris Ord (median 0.08, CI $[0.02; 0.15]$), David Willcocks (median 0.08, CI $[0.03; 0.12]$), Philip Ledger (median 0.09, CI $[0.04; 0.15]$), and Stephen Cleobury (median 0.10, CI $[0.04; 0.14]$). Therefore, GOOSE is significantly fronter in the King's corpus than in the Glasgow corpus.

The interaction of Vowel by Time/Director is visualised in Figure 7.12. Post hoc

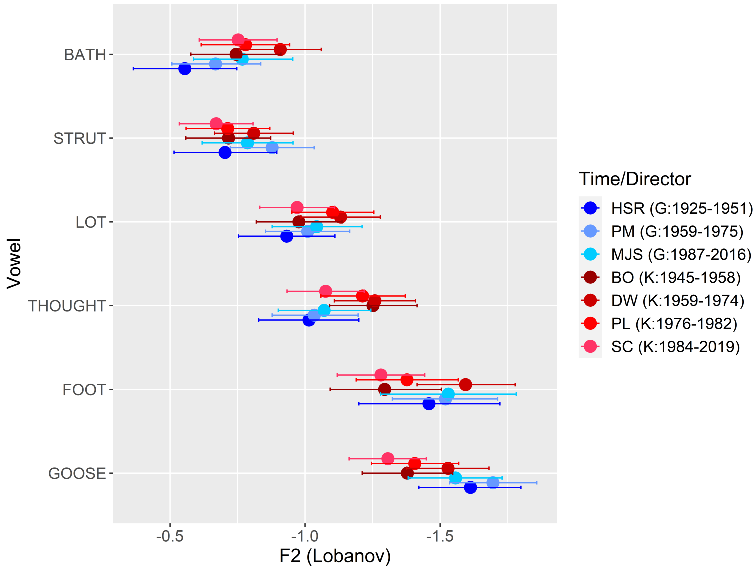


Figure 7.12: Combined: Back vowel F2 model, Vowel by Time/Director interaction (bars show 95% credible intervals; G = Glasgow corpus, K = King's corpus; N = 8,349)

comparisons can be found in Appendix Table F.4. Working from top to bottom, all King's Time/Directors produced a more retracted BATH than Hugh S. Roberton (1925–1951). There are no differences between the later Time/Directors apart from between David Willcocks and Peter Mooney (median -0.2398, CI [-0.3615; -0.1133]), due to the particularly cardinal-like realisation elicited under David Willcocks. In summary, BATH retracted over time in the Glasgow choir recordings, so BATH in Glasgow has become more similar in quality to the BATH produced at King's, with the exception of under David Willcocks, which had an extremely backed realisation of BATH.

Peter Mooney (1959–1975) appears to have elicited a particularly backed realisation of STRUT which is different to Boris Ord (median 0.1618, CI [0.0388; 0.2897]), Philip Ledger (median 0.1639, CI [0.0380; 0.2902]), and Stephen Cleobury (median 0.2072, CI [0.1093; 0.3074]). But there is no difference supported between King's Time/Directors and Hugh S. Roberton or Marilyn J. Smith.

For LOT, David Willcocks produced a significantly backer realisation than Hugh S. Roberton (median -0.2004, CI [-0.3380; -0.0701]) and Peter Mooney (median -0.1230, CI [-0.2258; -0.0253]). LOT for Philip Ledger was also backer than Hugh S. Roberton (median -0.1693, CI [-0.3196;-0.0253]).

THOUGHT was significantly more retracted for Boris Ord, David Willcocks, and Philip Ledger than all Glasgow Time/Directors. For LOT and THOUGHT there are no differences between Stephen Cleobury (King's, 1984–2019) and Marilyn J. Smith (1987–2019). THOUGHT is particularly interesting as it is one of the few examples of back vowels fronting over time in the King's corpus as Cleobury is not different to any of the Glasgow Time/Director pairs.

FOOT and GOOSE present a different pattern to the other back vowels. There is generally speaking a clear separation between the Glasgow and King's recordings with Glasgow producing a backer realisation of both FOOT and GOOSE, with the exception of David Willcocks who also cultivated a much backer realisation, particularly for FOOT. Boris Ord and Stephen Cleobury are significantly fronter than all Glasgow Time/Directors. Philip Ledger is significantly fronter than Hugh S. Roberton and Peter Mooney, but not Marilyn J. Smith, due to GOOSE fronting slightly under Marilyn J. Smith. GOOSE is fronter for David Willcocks compared to Peter Mooney (median 0.1658, CI [0.0515; 0.2705]), but not compared to Hugh S. Roberton or Marilyn J. Smith.

The wholesale difference in GOOSE backness between the Glasgow and King's corpora may relate to the social salience of GOOSE in Glasgow. It is conceivable that middle-class choral singers are setting themselves apart from the stigmatised fronted realisations of /u/ [y] of the local varieties as a form of hypercorrection. Alternatively, this kind of highly retracted /u/ may relate to the impact of classical singing training. The King's data appears to follow the pattern of RP change over time tending towards GOOSE fronting /u/ = [ʉ].

The model also supports an interaction of Vowel by Vowel Duration with STRUT retracting as duration increases (median -0.05, CI [-0.07; -0.02]) and LOT fronting as Duration increases (median 0.03, CI [0.00; 0.05]). It is possible that STRUT backing may be to distinguish from BATH, and LOT fronting may be to distinguish from THOUGHT on long vowels.

7.2.7 Combined: TRAP–BATH models

In chapters 5 and 6, I reported robust differences between the lexical sets TRAP and BATH which select /a/ and /ɑ/ respectively. This defied the prediction based on spoken dialect, where in Scottish English, both sets take /a/. The following section will compare the nature of the contrast across the two corpora. I now report the results of the combined TRAP–BATH height model.

As seen in Table 7.9, the model supports a main effect of Vowel with TRAP lower in height than the grand mean (median 0.24, CI [0.14; 0.35]). There is also evidence of a main effect of Time/Director with David Willcocks (King's, 1959–1974) being higher than the grand mean (median -0.29, CI [-0.49; -0.10]) and Stephen Cleobury (King's, 1984–2019) being lower than the grand mean

Table 7.8: Combined: TRAP–BATH raw formant and duration data by Time/Director

			F1 (Hz)		F2 (Hz)		Duration (ms)	
Vowel	Time/Director	N	Mean	SD	Mean	SD	Mean	SD
TRAP	HSR (1925–1951)	160	627	102	1488	172	770	940
TRAP	PM (1959–1975)	637	650	98	1450	136	660	580
TRAP	MJS (1987–2016)	262	708	109	1383	151	640	650
TRAP	BO (1945–1958)	277	689	94	1398	119	310	220
TRAP	DW (1959–1974)	487	654	85	1390	137	410	370
TRAP	PL (1976–1982)	304	671	88	1342	111	380	230
TRAP	SC (1984–2019)	896	730	86	1339	105	460	450
BATH	HSR (1925–1951)	63	672	77	1336	251	950	850
BATH	PM (1959–1975)	166	639	90	1258	136	1060	1000
BATH	MJS (1987–2016)	78	661	94	1208	101	760	530
BATH	BO (1945–1958)	116	703	65	1176	75	1090	2140
BATH	DW (1959–1974)	142	652	85	1139	105	990	470
BATH	PL (1976–1982)	88	670	73	1178	97	980	1580
BATH	SC (1984–2019)	254	709	76	1180	96	1270	2110

(median 0.13, CI [0.02; 0.23]).

There is an interaction of Vowel by Time/Director driven by Stephen Cleobury's TRAP being considerably lower than the grand mean (median 0.13, CI [0.02; 0.23]). Post hoc comparisons can be found in Appendix Table F.5. Stephen Cleobury, Marilyn J. Smith and Boris Ord do not differ in height for TRAP or BATH. However, David Willcocks is higher than Marilyn J. Smith for BATH (median -0.5262, CI [-0.9091; -0.2430]) and TRAP (median -0.6864, CI [-0.9819; -0.4033]).

For the TRAP–BATH model, there is no evidence of a main effect of Vowel Duration or Genre. There is evidence for an interaction of Vowel by Vowel Duration with TRAP lowering as duration increases (median 0.12, CI [0.06; 0.17]). There is an interaction of vowel duration by Time/Director with Marilyn J. Smith raising as vowel duration increases compared to the grand mean (median -0.08, CI [-0.15; -0.01]). There is also an interaction of Vowel Duration by Genre with 'ChurchMusic' (median 0.05, CI [0.01; 0.09] and 'Misc.' (median 0.07, CI [0.02; 0.11]) lowering vowel quality as Vowel Duration increases compared to the grand mean. Overall, TRAP and BATH appear to have lowered over time with no differences between Marilyn J. Smith, and Stephen Cleobury. This interaction is visualised in Figure 7.13.

I will now turn our attention to the F2 dimension. The main difference in acoustic quality in TRAP–BATH in SSBE is a difference in F2, with BATH being more

Table 7.9: Combined: TRAP–BATH F1 model posterior summary

	Estimate	95% CI	
Intercept	**0.73**	**0.61**	**0.86**
vowelTRAP	**0.24**	**0.14**	**0.35**
directorPM1959–1975	−0.09	−0.28	0.10
directorMJS1987–2016	0.21	−0.03	0.45
directorBO1945–1958	0.23	−0.01	0.46
directorDW1959–1974	**−0.29**	**−0.49**	**−0.10**
directorPL1976–1982	−0.23	−0.48	0.02
directorSC1984–2019	**0.18**	**0.02**	**0.34**
Vowel_Duration (log)	−0.01	−0.06	0.04
genreChurch	−0.09	−0.19	0.01
genreMisc.	−0.01	−0.11	0.09
vowelTRAP:directorPM1959–1975	−0.01	−0.13	0.10
vowelTRAP:directorMJS1987–2016	0.08	−0.08	0.24
vowelTRAP:directorBO1945–1958	−0.04	−0.20	0.11
vowelTRAP:directorDW1959–1974	−0.04	−0.17	0.09
vowelTRAP:directorPL1976–1982	0.05	−0.11	0.20
vowelTRAP:directorSC1984–2019	**0.13**	**0.02**	**0.23**
vowelTRAP:vdur_log	**0.12**	**0.06**	**0.17**
directorPM1959–1975:vdur_log	−0.05	−0.10	0.01
directorMJS1987–2016:vdur_log	**−0.08**	**−0.15**	**−0.01**
directorBO1945–1958:vdur_log	0.03	−0.05	0.11
directorDW1959–1974:vdur_log	−0.01	−0.08	0.06
directorPL1976–1982:vdur_log	0.02	−0.07	0.11
directorSC1984–2019:vdur_log	0.04	−0.01	0.10
vdur_log:genreChurch	**0.05**	**0.01**	**0.09**
vdur_log:genreMisc.	**0.07**	**0.02**	**0.11**

Bold type indicates 0 outside 95% credible interval.

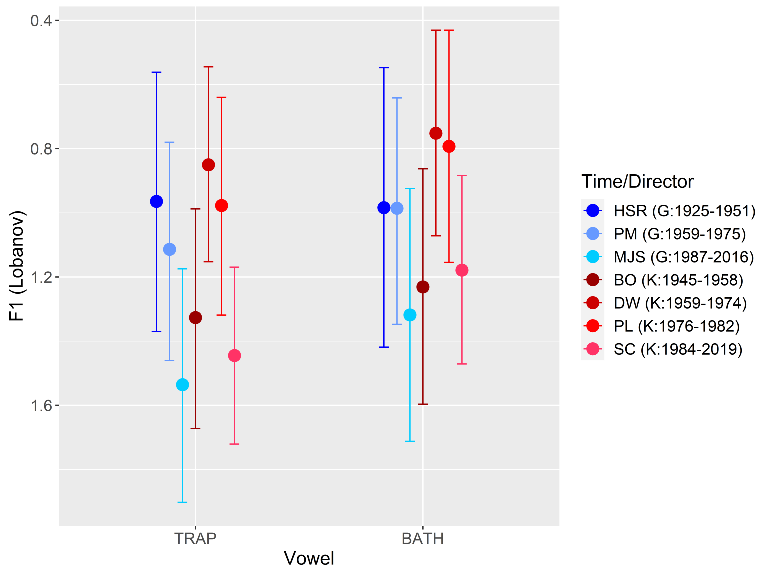


Figure 7.13: Combined: TRAP/BATH F1 model, Vowel by Time/Director interaction (bars show 95% credible intervals; G = Glasgow corpus, K = King's corpus; N = 3,928)

retracted /ɑ/ and TRAP being fronter. If there is a statistical difference to be found between TRAP–BATH for the Scottish corpus we would expect to find it in the F2 dimension. If the Scottish choral accent is based on a SSE phonology we would expect to find next to no difference between TRAP–BATH in F2, as they should have a singular phoneme or target CAT. If the phonology is based on SSBE, then we would expect to find a distinction in F2 between TRAP–BATH in both the Glasgow and King's corpora.

As seen in Table 7.10, the combined TRAP–BATH F2 model supports a main effect of Vowel with TRAP substantially fronter than the grand mean (median 0.49, CI $[0.43; 0.55]$). There is also a main effect of Time/Director with David Willcocks (King's, 1959–1974) more retracted than the grand mean (median -0.12, CI $[-0.23; -0.02]$).

The model also evidences an interaction of Vowel by Time/Director, such that TRAP is significantly fronter for Boris Ord (median 0.14, CI $[0.05; 0.23]$) and particularly for David Willcocks (median 0.27, CI $[0.20; 0.34]$), whereas TRAP is significantly retracted for Marilyn J. Smith (median -0.13, CI $[-0.23; -0.04]$), Philip Ledger (median -0.11, CI $[-0.20; -0.02]$) and Stephen Cleobury (median -0.09, CI $[-0.15; -0.03]$). This interaction is visualised in Figure 7.14.

As mentioned in Chapters 5 and 6, there is evidence of TRAP retracting over time in both Glasgow and King's datasets, with no difference between Marilyn J. Smith and Stephen Cleobury in the most recent recordings. BATH retracted in Glasgow and is now showing similar backness to King's, again, no difference between the

Table 7.10: Combined: TRAP–BATH F2 model posterior summary

	Estimate	95% CI	
Intercept	**−0.69**	**−0.76**	**−0.62**
vowelTRAP	**0.49**	**0.43**	**0.55**
directorPM1959–1975	0.09	−0.02	0.19
directorMJS1987–2019	0.01	−0.11	0.14
directorBO1945–1958	−0.00	−0.13	0.13
directorDW1959–1974	**−0.12**	**−0.23**	**−0.02**
directorPL1976–1982	−0.07	−0.20	0.07
directorSC1984–2019	−0.04	−0.12	0.05
Vowel_Duration (log)	**−0.09**	**−0.12**	**−0.05**
genreChurch	−0.04	−0.10	0.01
genreMisc.	0.02	−0.04	0.07
vowelTRAP:directorPM1959–1975	−0.06	−0.13	0.01
vowelTRAP:directorMJS1987–2019	**−0.13**	**−0.23**	**−0.04**
vowelTRAP:directorBO1945–1958	**0.14**	**0.05**	**0.23**
vowelTRAP:directorDW1959–1974	**0.27**	**0.20**	**0.34**
vowelTRAP:directorPL1976–1982	**−0.11**	**−0.20**	**−0.02**
vowelTRAP:directorSC1984–2019	**−0.09**	**−0.15**	**−0.03**
vowelTRAP:vdur_log	−0.02	−0.05	0.02
directorPM1959–1975:vdur_log	0.01	−0.02	0.04
directorMJS1987–2019:vdur_log	0.01	−0.03	0.05
directorBO1945–1958:vdur_log	0.04	−0.00	0.09
directorDW1959–1974:vdur_log	**0.06**	**0.02**	**0.10**
directorPL1976–1982:vdur_log	−0.04	−0.09	0.01
directorSC1984–2019:vdur_log	−0.00	−0.03	0.03
vdur_log:genreChurch	−0.01	−0.03	0.02
vdur_log:genreMisc.	0.02	−0.00	0.05

Bold type indicates 0 outside 95% credible interval.

later two Time/Director pairs. There is a difference between TRAP and BATH in F2 domain for all Time/Directors (no overlap in credible intervals for TRAP–BATH for any Time/Director in Figure 7.14).

The model supports a main effect of Vowel Duration (median -0.09, CI $[-0.12; -0.05]$). There is evidence of an interaction of Vowel Duration by Time/Director, as for David Willcocks, an increase in duration leads to fronting of acoustic vowel quality (median 0.06, CI $[0.02; 0.10]$).

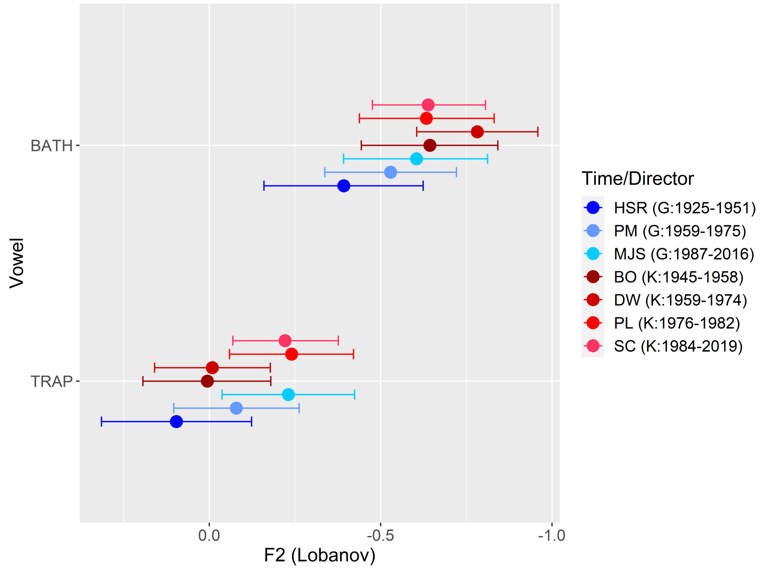


Figure 7.14: Combined: TRAP–BATH F2 model, Vowel by Time/Director interaction (bars show 95% credible intervals; G = Glasgow corpus, K = King's corpus; N = 3,928)

7.2.8 Combined: Duration model

In the final part of this results section we turn to a combined durational model. This model seeks to ask where there are systematic differences in vowel quantity which may contribute to the percept of a particular vowel in choral singing. In this model, I present all of the vowel qualities together (27,000 vowel tokens, after trimming), so that I can directly compare all contrasts. The reason for doing so is that it will give us an idea if there is a broad durational pattern of change over time, that fits the pattern described by Leech-Wilkinson (2009b). This is very much a blunt instrument when trying to get at tempo, but, it will give us some indication of the impacts of Vowel and Time/Director pairs on duration. In addition, post hoc tests will allow us to directly compare Time/Director pairs which will mean we can get some way towards seeing if there is evidence of change over time – that is, general shortening of vowel duration would correlate with an increase in tempo.

As I am modelling vowel durations across the whole vowel space and the effect of the following segment was found to be opposing for front vowels and back vowels in earlier analyses, I decided to remove the factor Following Segment. My justification is that I aimed to produce a simple model. The alternative would be to include a vowel by following segment interaction, however the size of this interaction would be a minimum of 18 segments × 11 vowels = 198 terms! In addition, not all consonants can follow all vowels. Even though I had a decent amount of data, I felt that there was not enough to justify this interaction, not to mention the amount of time that it would have taken to fit. A main effect of following segment across all vowels was wrong so I decided to exclude it instead.

The final duration model structure is:

`Vowel Duration ∼ Vowel + Time/Director + Vowel:Time/Director + (1|Word) + (1|Song) + (1|Album) + (1|Album:Song) + (1|Song:Word)`

Based on the findings of Chapters 5 and 6, I expect to find that FLEECE is longer than KIT. In speech, we would expect LOT–THOUGHT to differ in duration. However, this was not the case for previous models. TRAP–BATH and FOOT–GOOSE should differ in duration. If there is evidence of change over time in vowel duration (as a proxy for tempo) then we would expect that Marilyn J. Smith (Glasgow, 1987–2019) and Stephen Cleobury (King's, 1984–2019) should both be shorter than the grand mean and not different to one another. We might expect the earlier recordings, for example, those made under Hugh S. Roberton (1925–1951), or Boris Ord (King's, 1945–1958), to be longer than the grand mean.

Table 7.11: Combined: Duration model posterior summary

	Estimate	95% CI	
Intercept	**−0.27**	**−0.33**	**−0.20**
vowelFLEECE	**0.70**	**0.65**	**0.75**
vowelKIT	**0.24**	**0.20**	**0.28**
vowelDRESS	**0.54**	**0.50**	**0.59**
vowelTRAP	**0.49**	**0.43**	**0.56**
vowelBATH	**0.67**	**0.61**	**0.74**
vowelSTRUT	**0.46**	**0.40**	**0.53**
vowelLOT	**0.65**	**0.58**	**0.71**
vowelTHOUGHT	**0.78**	**0.71**	**0.84**
vowelFOOT	**0.19**	**0.08**	**0.30**
vowelGOOSE	**0.51**	**0.44**	**0.58**
directorPM1959–1975	**0.10**	**0.00**	**0.20**
directorMJS1987–2016	0.07	−0.05	0.19
directorBO1945–1958	−0.08	−0.20	0.04
directorDW1959–1974	0.00	−0.09	0.10
directorPL1976–1982	−0.08	−0.19	0.04
directorSC1984–2016	−0.07	−0.15	0.01
vowelFLEECE:directorPM1959–1975	**0.18**	**0.10**	**0.25**
vowelKIT:directorPM1959–1975	0.05	−0.00	0.11

	Estimate	95% CI	
vowelDRESS:directorPM1959–1975	0.04	−0.03	0.11
vowelTRAP:directorPM1959–1975	0.07	−0.00	0.15
vowelBATH:directorPM1959–1975	0.01	−0.10	0.12
vowelSTRUT:directorPM1959–1975	0.08	−0.01	0.17
vowelLOT:directorPM1959–1975	0.06	−0.02	0.14
vowelTHOUGHT:directorPM1959–1975	**0.08**	**0.01**	**0.16**
vowelFOOT:directorPM1959–1975	0.01	−0.17	0.18
vowelGOOSE:directorPM1959–1975	0.08	−0.01	0.17
vowelFLEECE:directorMJS1987–2016	**0.11**	**0.01**	**0.20**
vowelKIT:directorMJS1987–2016	**−0.10**	**−0.17**	**−0.02**
vowelDRESS:directorMJS1987–2016	**−0.11**	**−0.21**	**−0.00**
vowelTRAP:directorMJS1987–2016	**−0.11**	**−0.21**	**−0.01**
vowelBATH:directorMJS1987–2016	−0.11	−0.25	0.03
vowelSTRUT:directorMJS1987–2016	0.11	−0.01	0.23
vowelLOT:directorMJS1987–2016	**0.10**	**0.00**	**0.20**
vowelTHOUGHT:directorMJS1987–2016	0.03	−0.08	0.13
vowelFOOT:directorMJS1987–2016	−0.01	−0.28	0.27
vowelGOOSE:directorMJS1987–2016	0.10	−0.02	0.22
vowelFLEECE:directorBO1945–1958	**−0.10**	**−0.18**	**−0.01**
vowelKIT:directorBO1945–1958	0.03	−0.04	0.10
vowelDRESS:directorBO1945–1958	−0.05	−0.14	0.04
vowelTRAP:directorBO1945–1958	0.03	−0.06	0.12
vowelBATH:directorBO1945–1958	0.02	−0.09	0.13
vowelSTRUT:directorBO1945–1958	**−0.11**	**−0.21**	**−0.01**
vowelLOT:directorBO1945–1958	−0.07	−0.17	0.03
vowelTHOUGHT:directorBO1945–1958	−0.04	−0.14	0.06
vowelFOOT:directorBO1945–1958	0.06	−0.14	0.26
vowelGOOSE:directorBO1945–1958	−0.10	−0.22	0.02
vowelFLEECE:directorDW1959–1974	**−0.18**	**−0.25**	**−0.10**
vowelKIT:directorDW1959–1974	**−0.07**	**−0.13**	**−0.01**
vowelDRESS:directorDW1959–1974	**−0.18**	**−0.26**	**−0.11**
vowelTRAP:directorDW1959–1974	−0.08	−0.15	0.00
vowelBATH:directorDW1959–1974	−0.10	−0.21	0.00
vowelSTRUT:directorDW1959–1974	**−0.12**	**−0.21**	**−0.03**
vowelLOT:directorDW1959–1974	**−0.16**	**−0.24**	**−0.08**
vowelTHOUGHT:directorDW1959–1974	**−0.21**	**−0.29**	**−0.12**
vowelFOOT:directorDW1959–1974	0.03	−0.15	0.20
vowelGOOSE:directorDW1959–1974	−0.09	−0.18	0.01
vowelFLEECE:directorPL1976–1982	**−0.20**	**−0.28**	**−0.12**
vowelKIT:directorPL1976–1982	−0.01	−0.08	0.05
vowelDRESS:directorPL1976–1982	−0.06	−0.14	0.03
vowelTRAP:directorPL1976–1982	−0.01	−0.10	0.07
vowelBATH:directorPL1976–1982	−0.04	−0.17	0.08
vowelSTRUT:directorPL1976–1982	−0.06	−0.17	0.04
vowelLOT:directorPL1976–1982	−0.07	−0.16	0.02
vowelTHOUGHT:directorPL1976–1982	−0.08	−0.18	0.02
vowelFOOT:directorPL1976–1982	0.03	−0.15	0.22
vowelGOOSE:directorPL1976–1982	−0.02	−0.13	0.09

	Estimate	95% CI	
vowelFLEECE:directorSC1984–2019	**−0.07**	**−0.13**	**−0.01**
vowelKIT:directorSC1984–2019	−0.02	−0.07	0.03
vowelDRESS:directorSC1984–2019	−0.01	−0.07	0.05
vowelTRAP:directorSC1984–2019	−0.05	−0.11	0.01
vowelBATH:directorSC1984–2019	0.06	−0.03	0.15
vowelSTRUT:directorSC1984–2019	−0.02	−0.09	0.06
vowelLOT:directorSC1984–2019	−0.03	−0.10	0.03
vowelTHOUGHT:directorSC1984–2019	−0.04	−0.11	0.03
vowelFOOT:directorSC1984–2019	0.01	−0.13	0.16
vowelGOOSE:directorSC1984–2019	−0.03	−0.11	0.04

Bold type indicates 0 outside 95% credible interval.

As shown in Table 7.11, there is a robust main effect of Vowel as anticipated. All vowels are longer than the grand mean, as the factor Vowel in this model also includes COMMA (schwa), which is very well represented in the data and shorter than the other vowels. The model also supports a main effect of Time/Director with Peter Mooney being longer than the grand mean (median 0.10, CI [0.00; 0.20]). However, this not the main effect of Time/Director that was predicted. The model does not support duration shortening over time in the recordings presented.

There is also an interaction of Vowel by Time/Director. FLEECE is longer than the grand mean for Peter Mooney (median 0.18, CI [0.10; 0.25]) and Marilyn J. Smith (median 0.11, CI [0.01; 0.20]), but shorter than the grand mean for Boris Ord (median -0.10, CI [-0.18; -0.01]), David Willcocks (median -0.18, CI [-0.25; -0.10]), Philip Ledger (median -0.20, CI [-0.28; -0.12]), and Stephen Cleobury (median -0.07, CI [-0.13; -0.01]). This means that overall FLEECE appears to be systematically longer for the Glasgow corpus than the King's corpus.

For Marilyn J. Smith, the front vowels are shorter than the grand mean: KIT (median -0.10, CI [-0.17; -0.02]), DRESS (median -0.11, CI [-0.21; -0.00]) and TRAP (median -0.11, CI [-0.21; -0.01]). David Willcocks seems to have a general shortening effect, with many vowels shorter than the grand mean: KIT (median -0.07, CI [-0.13; -0.01]), DRESS (median -0.18, CI [-0.26; -0.11]), STRUT (median -0.12, CI [-0.21; -0.03]), LOT (median -0.16, CI [-0.24; -0.08]), and THOUGHT (median -0.21, CI [-0.29; -0.12]).

Post hoc comparisons of vowel contrasts FLEECE–KIT, TRAP–BATH, BATH–STRUT, LOT–THOUGHT, FOOT–STRUT and FOOT–GOOSE are shown for each Time/Director in Table 7.13. FLEECE is longer than KIT for every Time/Director. BATH is longer than STRUT for all King's Time/Directors, but there is no difference between them for any Glasgow Time/Director.

TRAP–BATH are not different in duration for any Glasgow Time/Director pairs, however, TRAP is shorter than BATH for Boris Ord (median -0.1682, CI [-0.3146; -0.0218]), David Willcocks (median -0.1520, CI [-0.2863; -0.0202]), and Stephen Cleobury (median -0.2900, CI [-0.3950; -0.1715]). LOT is shorter than THOUGHT for Hugh S. Roberton (median -0.2232, CI [-0.4136; -0.0435]) and Peter Mooney (median -0.1576, CI [-0.2733; -0.0423]), but there is no difference for Marilyn J. Smith. LOT/THOUGHT is distinct in duration for Boris Ord (median -0.1609, CI [-0.3048; -0.0172]) and Stephen Cleobury (median -0.1186, CI [-0.2206; -0.0103]). FOOT is significantly shorter than GOOSE for all Glasgow Time/Directors. However, FOOT–GOOSE are not different in duration for Boris Ord, or David Willcocks, but later the pair become distinct in duration under Philip Ledger (median -0.2610, CI [-0.4885; -0.0416]) and Stephen Cleobury (median -0.2686, CI [-0.4406; -0.1014]).

The duration model estimates are visualised in Figure 7.15. FLEECE–KIT and FOOT–GOOSE clearly differ in quantity across corpora. There is also a main effect of corpus, with the Glasgow time/director pairs having a greater vowel duration than the King's time/director pairs overall. The credible interval for FOOT is substantially wider than the other vowels. This reflects the relative uncertainty about FOOT due to the number of tokens – the least well-represented in the combined corpus, as expected due to the phonotactic distribution of vowels in English. Despite this uncertainty, FOOT is clearly shorter than GOOSE. KIT is very much shorter than FLEECE. The differences between TRAP–BATH and LOT–THOUGHT are less clear.

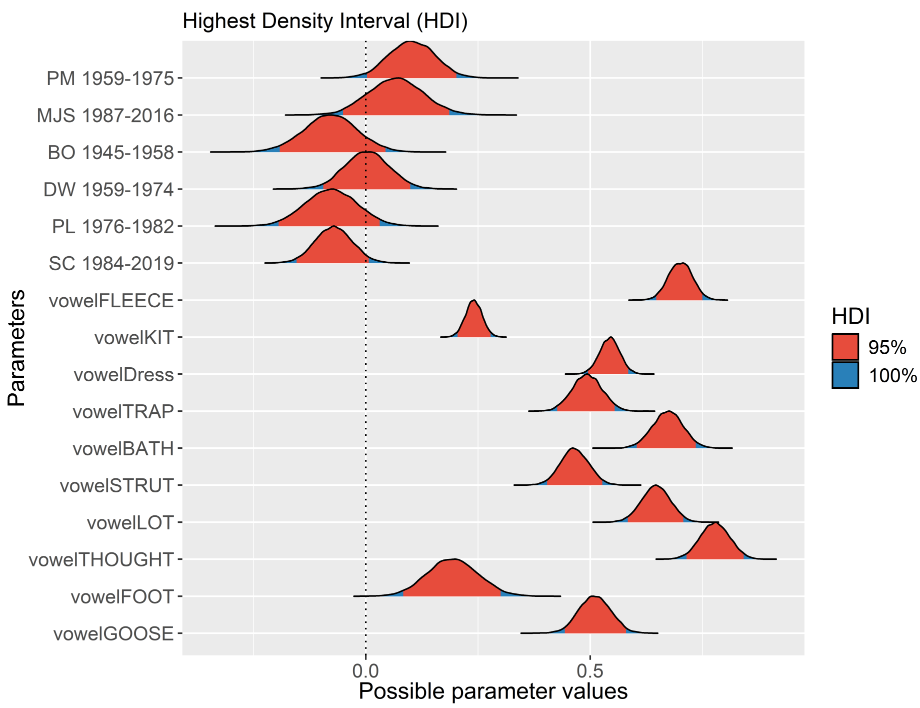


Figure 7.15: Combined Duration model estimates Highest Density Intervals

7.2.9 Summary of findings

In the combined front vowel F1 analysis, the data largely preserve the patterns found in the individual analyses. That is, Glasgow shows lowering over time, whereas King's shows a sharp rise followed by lowering over time. There is also no difference in height between the later Time/Directors of the Glasgow Corpus (Marilyn J. Smith, 1987–2016) or the King's Corpus (Stephen Cleobury, 1984–2019) for FLEECE, KIT, or TRAP. There is no difference between these two Time/Directors and the earlier King's recordings made under Boris Ord (1945–1958). This may suggest that these two later Time/Directors have orientated towards a similar referee as Ord.

In terms of front vowel F2, the pattern is slightly different. FLEECE fronts at King's over time becoming more similar to the FLEECE produced at Glasgow. KIT retracted in Glasgow while fronting at King's, meaning that KIT has become more similar in acoustic vowel quality over time. DRESS retracted over time in Glasgow, while there was no change at King's. TRAP retracted significantly over time in both Glasgow and King's with the change occurring in lockstep, such that there is no difference between Hugh S. Roberton (Glasgow, 1925–1951) and Boris Ord (1945–1958) or David Willcocks (1959–1974), and now retracted, there is no difference between Marilyn J. Smith (1987–2016) and Philip Ledger (1976–1982), or Stephen Cleobury (1984–2019).

For back vowel F1, there was a similar pattern to the front vowels. There was lowering over time in the Glasgow corpus for BATH, STRUT, LOT and THOUGHT. Also, there was a sharp rise followed by a fall in the King's corpus. The result is that Marilyn J. Smith (Glasgow, 1987–2016) patterns together with Stephen Cleobury (King's, 1984–2019) and Boris Ord (King's, 1945–1958) for BATH, STRUT, LOT, FOOT and GOOSE.

Returning to back vowel F2, BATH retracted over time in Glasgow to rest at a similar position to King's with no differences between Marilyn J. Smith and Boris Ord, Philip Ledger or Stephen Cleobury. THOUGHT fronted over time at King's to a similar quality produced in the Glasgow corpus, with no difference between Stephen Cleobury and the Glasgow Time/Directors. The Glasgow corpus shows a much backer realisation of FOOT and GOOSE than the King's corpus, apart from David Willcocks (1959–1974) who elicited a backer realisation of both vowels. The backed realisation of GOOSE may provide evidence of a 'hyper-RP' M/K target in the Glasgow singing rather than the RP target of King's.

The TRAP–BATH analysis also showed that there was a difference between TRAP and BATH in either F1 or F2 for all time periods in both corpora – which is not what we would expect if the vowel phonology of both choirs was based on the regional variety of the singers. Thus this study provides the first evidence for variation and change in choral singing, and for a common choral reference style or accent, at least for vowel quality.

The Vowel Duration analysis showed that vowel duration systematically varies by Vowel as expected from speech data. However, I am not able to quantify how different they are structurally, for example, whether the ratio of duration for short vowels to long vowels is preserved between speech and singing, or indeed, whether audiences are able to use the relative differences in vowel duration as cues to vowel identity.

7.2.10 Combining vowel quality (F1, F2) and vowel quantity (duration)

In this subsection, I will try to draw together the threads of vowel quality and vowel quantity broken down by corpus and Time/Director, starting with the Glasgow corpus. First, I want to return to Table 5.1, included again for ease.

Table 7.12: SSE and SSBE vowel system comparison

<table>
<tr><th>Keyword</th><th>SSE (Scottish)</th><th>SSBE (English)</th></tr>
<tr><td>FLEECE</td><td>i</td><td>i</td></tr>
<tr><td>KIT</td><td>ɪ</td><td>ɪ</td></tr>
<tr><td>DRESS</td><td>ɛ</td><td>ɛ</td></tr>
<tr><td>TRAP</td><td rowspan="2">a</td><td>a</td></tr>
<tr><td>BATH</td><td>ɑ</td></tr>
<tr><td>LOT</td><td rowspan="2">ɔ</td><td>ɒ</td></tr>
<tr><td>THOUGHT</td><td>ɔ</td></tr>
<tr><td>FOOT</td><td rowspan="2">u</td><td>ʊ</td></tr>
<tr><td>GOOSE</td><td>u</td></tr>
<tr><td>STRUT</td><td>ʌ</td><td>ʌ</td></tr>
</table>

As seen in Table 7.12, if the vowel inventory of choral singing is related to regional vowel phonology, we would expect there to be no differences between the vowel pairs TRAP–BATH, LOT–THOUGHT and FOOT–GOOSE in Glasgow choir singing, as Scottish varieties of English do not distinguish them. However, if we find these vowel pairs are distinct, this would support the hypothesis that choral singing in English is based on SSBE pronunciation. Table 7.13 shows post hoc comparisons for vowel pairs.

Table 7.13: Combined: Vowel contrast F1, F2, and Duration post hoc comparisons by Time/Director. Note these post hoc comparisons come from the various models reported in the chapter. Post hoc comparisons are averaged over the effect of the Following Segment and Genre for vowel formants, but not for Duration. **Bold type** indicates 0 outside 95% credible interval.

Contrast	F1 Est.	95% CI		F2 Est.	95% CI		Dur Est.	95% CI	
director = HSR (Glasgow, 1925–1951)									
FLEECE – KIT	**−0.2661**	**−0.4057**	**−0.1285**	**0.2287**	**0.1079**	**0.3447**	**0.6013**	**0.4744**	**0.7380**
BATH – TRAP	0.0197	−0.1878	0.2345	**−0.4875**	**−0.6089**	**−0.3643**	0.1955	−0.0052	0.4072
STRUT – BATH	−0.0633	−0.2860	0.1614	**−0.1489**	**−0.2937**	**−0.0018**	−0.2420	−0.4695	0.0053
THOUGHT – LOT	−0.1471	−0.3243	0.0382	−0.0824	−0.1983	0.0353	**0.2232**	**0.0435**	**0.4136**
FOOT – STRUT	**−1.3748**	**−1.7252**	**−1.0320**	**−0.7546**	**−0.9956**	**−0.5302**	**−0.5328**	**−0.8983**	**−0.1481**
GOOSE – FOOT	−0.3127	−0.6540	0.0409	−0.1535	−0.3899	0.0688	**0.5126**	**0.1302**	**0.8740**
director = PM (Glasgow, 1959–1975)									
FLEECE – KIT	**−0.1268**	**−0.2127**	**−0.0333**	**0.2408**	**0.1649**	**0.3186**	**0.5852**	**0.4996**	**0.6657**
BATH – TRAP	−0.1257	−0.2736	0.0138	**−0.4501**	**−0.5333**	**−0.3658**	0.1195	−0.0215	0.2614
STRUT – BATH	−0.1260	−0.2672	0.0048	**−0.2095**	**−0.2957**	**−0.1189**	−0.1401	−0.2884	0.0049
THOUGHT – LOT	−0.0616	−0.1729	0.0473	−0.0253	−0.0981	0.0419	**0.1576**	**0.0423**	**0.2733**
FOOT – STRUT	**−1.3045**	**−1.4959**	**−1.1063**	**−0.6419**	**−0.7763**	**−0.5136**	**−0.3430**	**−0.5584**	**−0.1503**
GOOSE – FOOT	**−0.2513**	**−0.4459**	**−0.0548**	**−0.1754**	**−0.3116**	**−0.0485**	**0.3874**	**0.1841**	**0.5984**
director = MJS (Glasgow, 1987–2016)									
FLEECE – KIT	**−0.3580**	**−0.4775**	**−0.2326**	**0.4611**	**0.3604**	**0.5693**	**0.6612**	**0.5527**	**0.7719**
BATH – TRAP	**−0.2200**	**−0.4173**	**−0.0169**	**−0.3735**	**−0.4876**	**−0.2583**	0.1850	−0.0018	0.3622
STRUT – BATH	−0.0758	−0.2712	0.1121	−0.0188	−0.1480	0.1015	0.0089	−0.1883	0.2013
THOUGHT – LOT	**−0.1766**	**−0.3136**	**−0.0404**	−0.0272	−0.1171	0.0632	0.0523	−0.0832	0.1952
FOOT – STRUT	**−1.4732**	**−1.8014**	**−1.1527**	**−0.7448**	**−0.9525**	**−0.5301**	**−0.3934**	**−0.7028**	**−0.0423**
GOOSE – FOOT	**−0.3544**	**−0.6868**	**−0.0394**	−0.0248	−0.2359	0.1920	**0.4293**	**0.1096**	**0.7567**
director = BO (King's, 1945–1958)									
FLEECE – KIT	**−0.2515**	**−0.3542**	**−0.1517**	**0.5428**	**0.4561**	**0.6336**	**0.3377**	**0.2485**	**0.4283**
BATH – TRAP	−0.0948	−0.2796	0.0920	**−0.6491**	**−0.7561**	**−0.5440**	**0.1682**	**0.0218**	**0.3146**

Contrast	F1 Est.	95% CI		F2 Est.	95% CI		Dur Est.	95% CI	
director = BO (King's, 1945–1958) contin.									
STRUT – BATH	**−0.1659**	**−0.3324**	**−0.0080**	0.0282	−0.0737	0.1351	**−0.3380**	**−0.4867**	**−0.1909**
THOUGHT – LOT	**−0.5140**	**−0.6556**	**−0.3706**	**−0.2748**	**−0.3661**	**−0.1860**	**0.1609**	**0.0172**	**0.3048**
FOOT – STRUT	**−1.4190**	**−1.6457**	**−1.1738**	**−0.5787**	**−0.7314**	**−0.4192**	−0.0976	−0.3333	0.1349
GOOSE – FOOT	−0.1894	−0.4301	0.0592	−0.0841	−0.2460	0.0790	0.1546	−0.0943	0.3991
director = DW (King's, 1959–1974)									
FLEECE – KIT	**−0.1301**	**−0.2139**	**−0.0475**	**0.2529**	**0.1781**	**0.3259**	**0.3554**	**0.2768**	**0.4318**
BATH – TRAP	−0.0989	−0.2487	0.0487	**−0.7739**	**−0.8605**	**−0.6867**	**0.1520**	**0.0202**	**0.2863**
STRUT – BATH	−0.0263	−0.1646	0.1082	**0.0984**	**0.0071**	**0.1865**	**−0.2269**	**−0.3645**	**−0.0868**
THOUGHT – LOT	**−0.4606**	**−0.5778**	**−0.3434**	**−0.1268**	**−0.2033**	**−0.0521**	0.0826	−0.0412	0.2011
FOOT – STRUT	**−1.5633**	**−1.7665**	**−1.3674**	**−0.7850**	**−0.9116**	**−0.6561**	−0.1241	−0.3192	0.0814
GOOSE – FOOT	0.0549	−0.1448	0.2548	0.0647	−0.0631	0.1966	0.2057	−0.0010	0.4100
director = PL (King's, 1976–1982)									
FLEECE – KIT	**−0.1696**	**−0.2654**	**−0.0716**	**0.2679**	**0.1844**	**0.3529**	**0.2708**	**0.1813**	**0.3562**
BATH – TRAP	−0.1860	−0.3708	0.0004	**−0.3945**	**−0.5051**	**−0.2854**	0.1476	−0.0089	0.3024
STRUT – BATH	−0.0549	−0.2200	0.1145	0.0656	−0.0460	0.1713	**−0.2295**	**−0.3927**	**−0.0703**
THOUGHT – LOT	**−0.4418**	**−0.5733**	**−0.3138**	**−0.1117**	**−0.2017**	**−0.0308**	0.1237	−0.0056	0.2649
FOOT – STRUT	**−1.1769**	**−1.3966**	**−0.9605**	**−0.6633**	**−0.8049**	**−0.5275**	−0.1747	−0.3973	0.0355
GOOSE – FOOT	**−0.2407**	**−0.4622**	**−0.0085**	−0.0299	−0.1768	0.1158	**0.2610**	**0.0416**	**0.4885**
director = SC (King's, 1984–2019)									
FLEECE – KIT	**−0.2091**	**−0.2790**	**−0.1353**	**0.3717**	**0.3078**	**0.4349**	**0.4117**	**0.3458**	**0.4739**
BATH – TRAP	**−0.2673**	**−0.4019**	**−0.1340**	**−0.4172**	**−0.4932**	**−0.3423**	**0.2900**	**0.1715**	**0.3950**
STRUT – BATH	−0.0539	−0.1675	0.0616	**0.0808**	**0.0044**	**0.1538**	**−0.2833**	**−0.3987**	**−0.1732**
THOUGHT – LOT	**−0.3376**	**−0.4423**	**−0.2361**	**−0.1059**	**−0.1730**	**−0.0376**	**0.1186**	**0.0103**	**0.2206**
FOOT – STRUT	**−1.6758**	**−1.8328**	**−1.5127**	**−0.6095**	**−0.7113**	**−0.5053**	**−0.2417**	**−0.4059**	**−0.0887**
GOOSE – FOOT	−0.1645	−0.3295	0.0005	−0.0267	−0.1310	0.0840	**0.2682**	**0.1014**	**0.4406**

At first glance Table 7.13 appears somewhat off-putting, but I will try and digest some of the patterns I would like to identify. The table shows post hoc comparisons for the vowel contrasts FLEECE–KIT, BATH–TRAP, LOT–THOUGHT, FOOT–GOOSE which are particularly salient. I also include the vowel contrasts FOOT–STRUT and STRUT–BATH for interest. I have included the table at this point so that it is clear which vowel contrasts are distinct and in what dimensions.

In order to orient ourselves, and as a sanity check, first I present the contrast FLEECE–KIT. FLEECE is significantly higher, fronter, and longer than KIT for all Time/Director pairs irrespective of Corpus or spoken dialect area, as we would expect for the spoken vowel contrast. Similarly, FOOT is significantly higher and backer than STRUT for all Time/Directors irrespective of Corpus. However, FOOT is significantly shorter than STRUT for all Glasgow Time/Director pairs plus Stephen Cleobury (1984–2019) in the King's corpus.

BATH is significantly backer than TRAP for all Time/Directors. BATH is significantly higher than TRAP for the later Time/Directors in each corpus (Marilyn J. Smith, Glasgow; Stephen Cleobury, King's), due to TRAP lowering over time. BATH is significantly longer than TRAP for Boris Ord, David Willcocks, and Stephen Cleobury, but not for any Glasgow Time/Director pairs.

STRUT is higher than BATH for Hugh S. Roberton, Peter Mooney, and Boris Ord. There is no difference between STRUT and BATH for Marilyn J. Smith. STRUT is shorter than BATH for all King's Time/Director pairs, and lower than BATH for David Willcocks and Stephen Cleobury.

THOUGHT is longer than LOT for Hugh S. Roberton, Peter Mooney, Boris Ord and Stephen Cleobury. THOUGHT is higher than LOT for Marilyn J. Smith, and all King's Time/Directors. THOUGHT is backer than LOT for all King's Time/Director pairs.

GOOSE is longer than FOOT for Hugh S. Roberton, Peter Mooney, Marilyn J. Smith, Philip Ledger and Stephen Cleobury. GOOSE is higher than FOOT for Peter Mooney, Marilyn J. Smith, and Philip Ledger. GOOSE is backer than FOOT for Peter Mooney only.

Combining these findings, it would appear that the vowel phonology of the two corpora are as shown in Table 7.14. In the Glasgow data, there is an appreciable TRAP–BATH split which we would not expect based on local varieties. For the most part, there is little difference in vowel quality between LOT–THOUGHT in the Glasgow data, supporting the LOT–THOUGHT merger of SSE.

FOOT and GOOSE are statistically distinct in the Glasgow corpus due to the particularly backed realisation of GOOSE. However, the King's corpus does not provide evidence of separate phonemes.

Table 7.14: Combined: Comparison of Glasgow and King's sung vowel systems

<table>
<tr><th>Keyword</th><th>Glasgow</th><th>King's</th></tr>
<tr><td>FLEECE</td><td>i</td><td>i</td></tr>
<tr><td>KIT</td><td>ɪ</td><td>ɪ</td></tr>
<tr><td>DRESS</td><td>ɛ</td><td>e or ɛ</td></tr>
<tr><td>TRAP</td><td>a</td><td>a</td></tr>
<tr><td>BATH</td><td>ɑ</td><td>ɑ</td></tr>
<tr><td>LOT</td><td rowspan="2">ɔ</td><td>ɒ</td></tr>
<tr><td>THOUGHT</td><td>ɔ</td></tr>
<tr><td>FOOT</td><td>ʊ</td><td rowspan="2">u</td></tr>
<tr><td>GOOSE</td><td>u</td></tr>
<tr><td>STRUT</td><td>ʌ</td><td>ʌ or ɑ</td></tr>
</table>

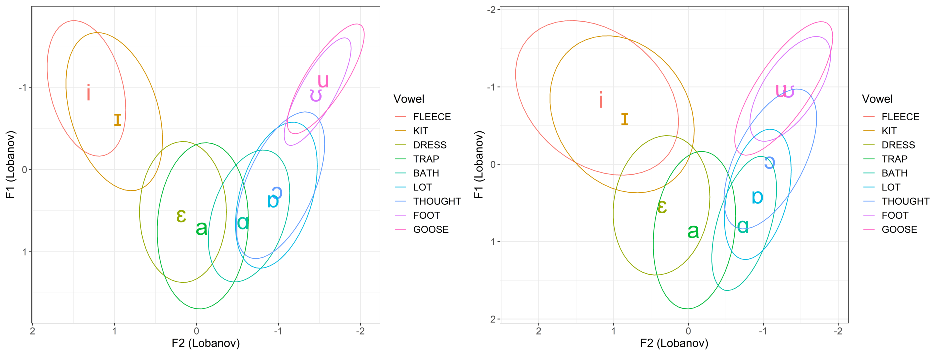
7.3 Discussion

Chapters 5 and 6 investigated change and variation over time in a corpus of recordings of the Glasgow Orpheus and Glasgow Phoenix choirs, and the Choir of King's College, Cambridge respectively. There were slightly different patterns, but overall there appeared to be a general pattern of lowering over time in both the front and back vowels in both corpora. As I was satisfied that it would be possible to compare the corpora directly, this chapter investigates differences between the singing in the Glasgow corpus and King's corpus. In this section, I will open up a wider discussion about the vowel phonology of British choral singing.

7.3.1 British classical choirs show a common front vowel system

This section addresses research questions 1a and 1b. In this study, I investigated the front vowels FLEECE, KIT, DRESS, TRAP, the back vowels BATH, STRUT, LOT, THOUGHT, FOOT, GOOSE, and evidence for the TRAP–BATH split in the Glaswegian choirs. Figure 7.16 gives a synchronic snapshot by plotting F1 and F2 for each vowel separated by corpus, not separated by time.

As can be seen in Figure 7.16, the choir of King's College, Cambridge, and the Glasgow Orpheus and Pheonix choirs have front vowel systems that look



(a) Glasgow Orpheus and Phoenix choirs

(b) Choir of King's College, Cambridge

Figure 7.16: Combined: Vowel plots of raw formant measures by Corpus. Ellipses show 1 Standard Deviation from the mean.

remarkably similar in both in phonology and realisation. That is, there is a similarity in the way the vowel ellipses are positioned spatially in reference to each other within and across corpora. This shared system appears to be based on a SSBE phonology as suggested by Potter (1998); Sagrans (2016), and Day (2018) about King's. For front vowels at least, there is evidence of a Standard British choral accent. The finding of separation in acoustic qualities for TRAP and BATH lexical sets in the Glasgow choirs, distinct in both F1 and F2, is unexpected. This suggests that the vowel phonology of choral singing in Glasgow is at least partly based on a non-regional standard accent linked to SSBE rather than to local varieties of SSE or Glaswegian English where there is a single vowel phoneme, and hence a low vowel continuum from [a – ɑ] (Abercrombie, 1979; Johnston, 1997; Stuart-Smith, 2003). This evidence for the TRAP–BATH split in the Glasgow choirs is surprising, since, as Wells comments, 'RP does not enjoy the same tacit status in Scotland as it does in England or Wales' (Wells, 1982b, p. 393).

In the case of TRAP–BATH, the findings perhaps reflect those of Caillol & Ferragne (2019) relating to the FOOT–STRUT split produced by the singers of British heavy metal bands. FOOT and STRUT were both realized as [ʊ] in the spoken interviews with Def Leppard (from Sheffield). However, FOOT and STRUT were realized as [ʊ] and [ʌ] respectively in the recordings of their singing. In contrast, Iron Maiden (from London) produced the split in both interviews and sung recordings. Caillol & Ferragne (2019) suggest that this is evidence of Def Leppard adapting to a USA model of singing pronunciation. Specifically, producing the FOOT–STRUT contrast was deemed more stylistically appropriate for the performance of heavy metal because it is more consistent with an 'American' accent. This brings us back to Morrissey's (2008) notion of the 'reference style'. British heavy metal bands exist within the domain of the popular reference style which is largely considered to be based on 'American' norms. Similarly, I suggest that British choirs exist within the domain of a classical reference style which is modelled on SSBE norms. This argument assumes Morrissey (2008) and Beal's (2009) notions of stylistic appropriateness for a particular musical genre, existing within a larger 'reference style'. Thus, in this case, the TRAP–BATH split found in recordings of choirs in a dialect area where there is no TRAP–BATH split present in speech, suggests that producing the TRAP–BATH split is stylistically appropriate for classical choral singing. I will now discuss further evidence for British classical choral singing being based on a non-regional standard accent.

7.3.2 British classical choirs show contrasting back vowel systems

As can be seen in Figure 7.16, there is also evidence of a difference in back vowel phonology. The choral singing data supports the LOT–THOUGHT merger of Standard Scottish English in the Glasgow corpus. That is, for the lexical sets LOT and THOUGHT in SSE there is only one target vowel quality, /ɔ/. In contrast, in the King's corpus, there is a distinct separation for the phonemes LOT /ɒ/ and THOUGHT /ɔ/. If we turn back to Table 7.13, we can see that the pair LOT–THOUGHT is distinct only in the Duration dimension for Hugh S. Roberton (1925–1951), and Peter Mooney (1959–1975). However, LOT–THOUGHT appears to have become distinct in F1 (vowel height) under Marilyn J. Smith (1987–2019), and is no longer distinct in vowel duration. This tendency may reflect the patterns of her own SSBE speech variety.

Surprisingly, the vowel pair GOOSE–FOOT appears to be merged for both Glasgow and King's; however, King's produces a much higher F2, meaning that the vowels are more central and closer to [ʉ] in quality, whereas, in Glasgow, GOOSE–FOOT are more cardinal-like [u]. GOOSE and FOOT are statistically different for Glasgow corpus in duration and height for Marilyn J. Smith (1987–2019) and also backness for Peter Mooney (1959–1975). The recordings made under the Phoenix choir appear to make an extra effort to unmerge Scottish BOOT, but on the whole, King's does not distinguish them.

The findings of Caillol & Ferragne (2019) do not necessarily hold true for the pair LOT–THOUGHT. It appears that, for Scottish classical choral singing, distinguishing the LOT–THOUGHT contrast is not necessary. There are a number of possible reasons: The high-back vowels, in general, are closer together in acoustic space than the front vowels, and as a consequence are harder for listeners to distinguish. Therefore they are less perceptually salient than the contrast TRAP–BATH; it is possible that the LOT–THOUGHT merger is less culturally salient. LOT–THOUGHT may have a lower indexical order than TRAP–BATH. TRAP–BATH is particularly associated with SSBE norms; Alternatively, the LOT–THOUGHT merger may be beneficial from a singing-aesthetic point of view, as having fewer 'pure' vowel qualities may be advantageous. For example, singing training exercises often work with a reduced number of cardinal qualities (e.g. /a e i o u/).

The same perceptual and aesthetic possibilities apply to the vowel contrast GOOSE–FOOT for both King's and Glasgow. However, I believe that these categories may, in fact, be different, although there was not enough evidence in the data to support the distinction. If we look again at Figure 7.14, we can see that the 95% Credible Intervals for FOOT are quite a lot wider than for any other vowel. If there were more data, these wide intervals, where there is a lack of certainty about the estimates, would narrow, and the GOOSE–FOOT distinction might emerge in both corpora. This is not the case for the LOT–THOUGHT contrast in the Glasgow corpus, because both vowels are well represented in the corpus and the narrower credible intervals do significantly overlap, meaning that they are not different. Further research will need to examine the GOOSE–FOOT contrast with more data.

7.3.3 British classical choral vowels have changed over time

Thus far, we have outlined both a musicological and sociolinguistic motivation for British choral accent being based on a non-regional variety. There is also motivation from previous phonetic and musicological research to ask whether there is evidence of change over time in these choral corpora. As discussed in the Introduction, there is disagreement among musicologists about whether the choral accent of King's choir remained stable (per Sagrans, 2016), or changed, as Day (2018) writes about how the sound unintentionally developed under the direction of both David Willcocks and Stephen Cleobury. Diachronic phonetic studies of speech have showed that the prestige form of Southern British English has changed over time and this is particularly salient for the TRAP vowel in the twentieth century with, for example, the phonetic realisation of *cat* /kat/, changing from [kæt] to [kat] (Fabricius, 2007; Harrington et al., 2000; Wells, 1982a). In this study, we find evidence for a main effect of Time/Director for front vowel F1 reflecting lowering over time, as predicted, but in both choir corpora, irrespective of spoken accent. This finding is, therefore, also consistent with the notion that the accent of British classical choral singing is based on a SSBE.

Recordings produced under the choir directors Hugh S. Roberton (Glasgow, 1925–1951) and David Willcocks (King's, 1957–1974) do not statistically differ in vowel height for FLEECE, KIT, and TRAP, despite not overlapping in time. The only difference is for DRESS, for which Willcocks produces a strikingly more raised realisation, akin to [e]. This finding lends further credibility to the directors

Roberton and Willcocks having an RP speech target. It also supports the connection Day (2018) draws between the sound produced by the choir of King's College, Cambridge under the director David Willcocks and conservative RP with the particularly raised realisation of DRESS [eɪ] (see U-RP in Wells, 1982a).

Both Stephen Cleobury (King's, 1982–2019) and Marilyn J. Smith (Glasgow, 1987–2019) produce a similar front vowel height overall to Boris Ord (King's, 1945–1958). This suggests that the predicted lowering was already complete at King's *before* David Willcocks took over as director. It is unknown whether King's had a more raised front vowel height earlier in the century, as there are very few recordings before 1945.

What can we infer about the influence of a choir director on a choir's sound? When David Willcocks became director of King's, in time, he reintroduced the raised [kæt] variant of the TRAP vowel which is consistent with early twentieth-century conservative-RP pronunciation. This is similar to the front vowel height produced by the Glasgow Orpheus choir under Roberton (in recordings from 1945–1951), which may have been modelled on RP, or perhaps the contemporary prestigious Kelvinside/Morningside accents of Glasgow and Edinburgh which were also known for extremely raised realizations of DRESS (Johnston, 1985). The connection between the King's style developed under Willcocks and conservative-RP is quite convincing, as Day writes:

> Inevitably, Willcocks cultivated certain sounds which reflected his own style of spoken English, perhaps more the received pronunciation of English he heard as a chorister at Westminster Abbey in the 1930s than that of the 1960s. So *alleluia* became 'e-lleluia'. 'I know thett my Redeemer liveth, ent thett he shell stent...' (Day, 2018, p. 261).

Phonetically, just as we have seen, /alɛluːjə/ became [æleluːjə].

A possible scenario is that front vowel lowering took place in the King's choral accent, alongside the documented shift in RP, and likely the choir members own accents over time. However, under Willcocks' direction, the choir reverted to the conservative RP front vowel realizations he himself had experienced when he was a chorister at Westminster Abbey in the 1930s.

Since Marilyn J. Smith became director of the Glasgow Phoenix Choir there has been a subtle change. LOT–THOUGHT have become distinct in height for the first time – they were not distinct under Peter Mooney or Hugh S. Roberton. It is possible that this is due to her own SSBE accent, or to subconsciously orientating the choir towards an SSBE referee. These findings need to be further substantiated in the consonant analyses. Is there further evidence supporting a shift from a Scottish to a British referee for choral singing?

7.4 Conclusion

Chapters 5 and 6 and the present chapter provide the first empirical quantitative evidence supporting the connection between British classical choral singing and SSBE. The results show a shift in vowel height in British choral singing, with KIT, DRESS, and TRAP lowering over time, mirroring diachronic phonetic studies of spoken RP (e.g. Harrington et al., 2000; Bjelaković, 2017). There is evidence for the TRAP–BATH split present in recordings of choral singing from both Cambridge and the Glasgow choirs, where spoken Scottish English maintains a single vowel phoneme: and, there is also evidence for a convergence of acoustic vowel quality across the two choral datasets. However, there are separate LOT–THOUGHT phonemes in the King's corpus, but only one target in the Glasgow data, showing the SSE LOT–THOUGHT merger. This suggests that not only SSBE features are stylistically appropriate for the performance of classical choral singing, and choral singing in Scotland incorporates features from SSBE and SSE.

Front vowel lowering was already far advanced in the King's choir recordings of the 1950s. However, when David Willcocks became director (1959–1974), he raised the habitual tongue height '[cultivating] certain sounds which reflected his own style of spoken English, perhaps more the received pronunciation of English he heard as a chorister at Westminster Abbey in the 1930s than that of the 1960s' Day (2018, p. 261). The front vowel height of the more recent recordings of King's then returned to its original trajectory of lowering, first observed in the 1950s under Boris Ord. This provides evidence of the impact a particular director can have on variation and change in a choir's sound. The following chapters will investigate the extent to which other phonological variables are amenable to choral direction, and/or regional variation, in classical British choir singing. Chapter 8 will investigate rhoticity and Chapter 9 reports on the realisation of word-final /d/ in the recordings of choral singing from Glasgow and King's.

Chapter 8

/r/ in choral singing from Glasgow and Cambridge[1]

Chapters 5, 6, and 7 showed that the front vowels of choral singing lowered over time following a pattern of change observed in spoken Received Pronunciation (for example, Wells, 1982a) and/or high-status Scottish varieties like Morningside or Kelvinside accents (Johnston, 1985). This supports the notion that the accent of choral singing is based on a 'High' form of the language (Potter, 1998; Sagrans, 2016; Day, 2018). The two choirs in Glasgow and Cambridge have a similar front vowel inventory, with a similar allophonic distribution, but a contrasting back vowel inventory with the Glasgow choirs showing the LOT–THOUGHT merger of SSE. Are there any phonetic and/or phonological differences in the consonant inventories of these choirs that *are* conditioned by dialect area, or by choir Director? To answer this research question, the next two chapters will focus on consonants in choral singing, specifically /d/ (Chapter 9), and /r/ in this chapter.

/r/ can be found in many linguistic contexts in English: in word-initial position, e.g. *running*: in intervocalic position, in the middle of a word e.g. *very*: or in postvocalic position, following a vowel e.g. *car* or *card*. /r/ is usually articulated in all accents of English in initial and medial contexts (e.g. *running*, *very*) albeit with different allophonic realisations (e.g. you cannot have /ʌnɪŋ/ for *running* /rʌnɪŋ/). Likewise, it is extremely rare to have /vɛːɪ/ for *very* instead of /vɛri/. In contrast, postvocalic /r/ can be articulated /kar/ or not articulated /kɑː/ in *car* – whether you articulate /r/ in this context distinguishes between 'rhotic' and 'non-rhotic' dialects (e.g. Wells, 1982a). As such, postvocalic /r/ is the perfect variable for exploring phonological differences between rhotic and non-rhotic dialect areas.

[1] An earlier version of some of the sections of this chapter appears in Marshall (2023).

All the evidence points to Scottish Standard English (SSE) as a 'rhotic' variety (Abercrombie, 1979; Jauriberry, 2021; Wells, 1982a) meaning that postvocalic /r/ is usually articulated (Stuart-Smith, 2003), though there is some evidence that both the frequency and strength of the /r/ variants produced is reducing over time in working-class speech (Stuart-Smith & Lawson, 2017). In SSE, /r/ in words like *car* would be articulated e.g. /kar/, and could be phonetically realised as a post-alveolar approximant [ɹ], retroflex approximant [ɻ] (tip-up), or bunched (Lawson et al., 2018), as a tap [ɾ], or as a trill [r] (Watt et al., 2014). In SSE, in all contexts, historically we would expect a higher frequency of taps and trills compared to Southern Standard British English where we would expect more approximants (Jauriberry, 2021; Stuart-Smith, 2003; Wells, 1982b). In contrast, SSBE is a 'non-rhotic' variety of English meaning that postvocalic /r/ is usually *not* articulated (Wells, 1982a). In other words, in SSBE the /r/ in the word *car* would not be produced at all e.g. /kɑː/, apart from when followed by a vowel (e.g. *car and*, which could be realised as [kɑɹand]). This phenomenon is known as linking /r/. In SSBE, /r/ can also be articulated between two vowels where there is no etymological /r/ (e.g. *vanilla*[ɹ]*icecream*). This phenomenon is known as intrusive /r/.

This chapter, therefore, is concerned with two kinds of analyses. Firstly, a phonetic analysis: that is, what are the phonetic variants of articulated /r/ in initial, intervocalic and postvocalic positions in choral singing? The distribution of variants of articulated /r/ are predicted to differ by dialect area. Secondly, I present an empirical phonological analysis: is choral singing rhotic or non-rhotic? If the choral accents in the Glasgow and Cambridge singer groups relate to the spoken accent in each region, we would predict articulated postvocalic /r/ in Scotland but not in Southern England. If the choral accents are not related to the spoken accent of each region, we would expect both groups to produce postvocalic /r/ in linking /r/ contexts. Orthographic /r/ was coded, so these data do not provide insight into intrusive /r/.

8.1 Previous studies of English and Scottish /r/ in speech

8.1.1 /r/ in Southern Standard British English

Wells (1982a) gives an account of how in the eighteenth century prestige varieties of southern British English stopped producing postvocalic /r/, before a following consonant or a pause, in favour of the centring diphthongs which characterise SSBE today e.g. *near* RP /nɪə/ compared to SSE /niːr/. /r/ in initial or intervocalic positions were not affected by the change. When a word ending with postvocalic

/r/ is followed by a word beginning with a vowel (e.g. *car and*) the /r/ is usually produced, and this phenomenon is known as 'linking /r/'. Wells (1982a) then outlines 'intrusive /r/', which is where speakers of non-rhotic varieties like SSBE insert a phonetic [ɹ] where there is no underlying historical phonological /r/. For example, in the phrase *the idea*[ɹ] *of*, or *vanilla*[ɹ] *icecream*, [ɹ] is inserted where there is no etymological /r/. Wells notes that 'linking /r/ and intrusive /r/ are distinct only historically and orthographically' (Wells, 1982a, p. 223) and when people are speaking they are unlikely to be thinking about orthography. Singers also produce intrusive /r/. That is, they insert /r/ between a word ending with a vowel and a following word that begins with a vowel. This habit has been recognised to carry over into singing in other languages, as Wells comments: 'choirmasters have to admonish against *alpha*/r/ *es et O*, *gloria*/r/ *in excelsis*, and *Viva*/r/ *España*.' (Wells, 1982a, p. 226)

8.1.2 /r/ in Scottish English

In contrast to SSBE, Scottish English is 'strikingly conservative' and did not undergo the same processes which led to SSBE becoming non-rhotic (Wells, 1982a, p. 407). This is why Scottish English does not have any of the centring diphthongs of SSBE. 'Most Scottish speech is firmly rhotic, with /r/ retained in all positions where it occurred historically' (Wells, 1982a, p. 410).

Auditory-acoustic sociophonetic studies of Scottish English have reported derhoticisation over time (Romaine, 1978; Macafee, 1983; Stuart-Smith, 2003; Jauriberry et al., 2012). The strength of rhoticity produced in postvocalic position in Glasgow vernacular English has weakened over the twentieth century, in words such as *better*, *car*, and *card* (Lawson et al., 2014; Lawson et al., 2018).

Gradient rhoticity has been found to be a cue to socio-economic identity in Scotland (Lawson et al., 2014). Most SSE speakers are rhotic, however, the /r/ is weakening in auditory, articulatory, and acoustic domains, particularly in Central Scotland. Working-class speakers tend to have much weaker realisations of /r/ whereas middle-class speakers have strengthened their postvocalic /r/ (Lawson et al., 2014). The alveolar trill remains a stereotype of Scottish English, despite its infrequent use by Scottish speakers today (Lawson et al., 2014; Watt et al., 2014).

8.2 Previous linguistic studies of /r/ in singing

As we saw in Chapter 3, nearly all sociolinguistic studies to date have focused on popular singing styles such as rock, pop, punk and indie (Morrissey, 2008). Previous studies tended to conduct auditory coding of consonant realisations in solo singing in a popular style. For example, Trudgill (1983) on the Beatles and the Rolling Stones; Beal (2009) on Arctic Monkeys (a rock band from Sheffield); Krause & Smith (2017) on the Twilight Sad and the Unwinding Hours (indie bands from Glasgow); Yang (2018), Lenka (a pop singer from Australia); Caillol & Ferragne (2019), British heavy metal bands Def Leppard and Iron Maiden. These studies use a variationist Labovian approach (e.g. Labov, 1972) correlating variation and change in phonetic realisation of popular artists with changes in style.

Trudgill (1983) showed that British pop singers performing in the 1960s–70s used different accent features when they were singing than when speaking. He argued that this phenomenon of 'modified pronunciation' had existed in popular music 'probably since the 1920s'. He analysed a set of consonantal variables including intervocalic tap variants of /t/ e.g. in *better* and postvocalic /r/. He focused on cultural 'domination' as a way of explaining popular singing practices, including the early adoption of rhoticity by groups such as the Beatles. For example, Trudgill's analysis of postvocalic /r/ found that rhoticity decreases over time in recordings of the Beatles and the Rolling Stones (1963–1969). Trudgill writes 'British pop music acquired a validity of its own, and this has been reflected in linguistic behaviour' (Trudgill, 1997, p. 161).

More recently, Krause & Smith (2017) investigate the enregisterment (Agha, 2003) of local features in the Scottish indie music scene, focusing on the realisation of postvocalic /r/ by the lead singers of The Twilight Sad and The Unwinding Hours in spoken and sung contexts. The authors analyse variants of postvocalic /r/ which range from weakly rhotic to strongly rhotic. They find that 'overall, there is a high rate of the variants at the weakly, rather than the strongly rhotic end of our continuum. This is despite postvocalic /r/ being a classic stereotype of Scots.' (Krause & Smith, 2017, p. 228). The authors attribute this finding to the reduction of postvocalic /r/ in working class speech in the Central Belt (Stuart-Smith & Lawson, 2017).

What we know about realisation of postvocalic /r/ in classical singing is largely limited to classical singing pronunciation guides (for example, Adams, 2008). What are the constraints on the realisation of postvocalic /r/ within the classical reference style?

Performance itself has been found to impact the phonetic realisation of variables in solo singing in popular styles. For example, African-American English is known for copula deletion (e.g. Labov, 1972); copula deletion occurs in speech approximately 60% of the time but, in performances of Hip Hop, where copula deletion is enregistered as a feature of the style, the figure rises to 98% (Alim, 2006). Alim interprets the increase in copula deletion as the artists' construction of a street-conscious identity. These stage styles or linguistic personae have been found in multiple styles of popular singing.

What about the performance aspect in Western classical singing? There is the perception that /r/ is often trilled or tapped in classical singing. Both Wells (1982a) and Johnston (1997) draw attention to [r]'s ability to be used as an 'emphatic realisation' and in 'formal declamatory styles' in speech. We might therefore expect to find trills as part of the performative hyperdialect of classical choral singing, particularly from earlier in the century.

8.3 Musicological/singing pedagogical commentary on /r/

8.3.1 Manuals for solo singing

There is an assumption in the singing technical literature that the accent of classical singing in English is based on a non-regional variety, either of Received Pronunciation, General American English, or Transatlantic English (Johnston, 2016). While Johnston (2016) recognises that singers use features from both RP and GenAm and that 'successful English diction results in a standardised version of a language that is created and honed especially for the singer' (Johnston, 2016, p. 42), they do not account for regional variation affecting the realisation of /r/ *within* a style.

> One of the prime characteristics of Mid-Atlantic English is the treatment of *r*, namely the use of RP diphthongs in place of retroflex [ɹ]. Furthermore, it is standard to avoid R-colored vowels and rather replace them with their R-less counterparts – for example, mother [mʌðə] vs. [mʌðɚ]. However, when singing musical theatre repertoire, the lack of R-colored vowels can immediately distance the listener and result in a posh delivery of what is supposed to be vernacular. (Johnston, 2016, p. 43)

They argue that vowels in musical theatre must be 'R-colored', otherwise resulting in a posh delivery – does this mean that vowels in classical choral singing must not be R-colored, otherwise resulting in an unidiomatic delivery? Decker (1977) writes:

> The American "r" is another ugly sound when improperly elongated. Many conductors prefer to omit it altogether, but the omission often makes intelligibility impossible. For those who believe that American

> English should be sung without a British accent, a touch of the “r” is essential. When “r” occurs at the end of a word or at the end of a prominent syllable, the vowel preceding it should be elongated as much as possible with only the thought of an “r” added at the very end. (Decker, 1977)

Above, Decker (1977) expresses the importance of rhoticity to the identity of American choral singing – not to do with an American genre or repertoire, but a specifically American choral accent. What about the importance of rhoticity to a Scottish choral accent? There is a tension between whether it is ‘appropriate’ to produce rhoticity in singing within the classical genre, and sounding distinct – anything other than ‘posh’ or ‘British’.

8.3.2 Manuals for choir directors

Early writers on choral pedagogy comment on regional variation and how it is negatively perceived in the context of singing. For example, in 1892 George Martin writes:

> A provincial rustic ‘burr’ must be eliminated. So must the Londoners’ ‘foice’ or ‘fece’ for ‘face’. The tendency to slur spoken words together must be eliminated, where ‘my stony rock, and my defence’ becomes ‘mystonyrockon myde fence’, and ‘As it was in the beginning, is now’ becomes, ‘ As it was sin the beginnin’ nis now’. (G. C. Martin, *The Art of Training Choir Boys, 1892, p. 12*, in Day, 2018, p. 83)

An early twentieth century choralist (Coward, 1914) demonstrates the general attitude to Scottish accents in classical singing practice:

> The importance, in an artistic sense, of being absolutely correct was shown to me by a famous Scotch baritone singer. I asked him how a common friend, who had a really good voice, was getting on in the profession. He answered, ‘Oh, he is not getting on at all, and won’t because he sings English songs like a Scotchman’ – *i.e.*, with a Scotch accent. In every case the conductor must be sure of King’s English, and, if necessary, pattern every doubtful word (Coward, 1914, pp. 86–87).

Coward (1914) demonstrates how regional variation in sung accent is perceived negatively, specifically with regard to Scottish English, and as early as 1914. Given that one of the most salient features of a Scottish accent is articulated postvocalic /r/, instead of the RP centring diphthongs, we might expect to find rhoticity in the singing of Scottish choirs. Regarding rhoticity in the choir of King’s, Day (2018) writes that:

> In 2015 Cleobury complained that, because of the 'sloppy way' the boys and men spoke – much lazier than in the recent past – he had to work harder to encourage the choir to articulate clearly. But if they said 'twenny' instead of 'twenty' and 'law r'un order' instead of 'law and order', they were perhaps simply articulating a new received pronunciation. (Day, 2018, p. 261)

This is evidence of a director of one of the choirs under investigation commenting on intrusive /r/ (*law*[ɹ]*un order*) mentioned previously. Intrusive /r/ occurs frequently in speech of non-rhotic varieties of English such as SSBE. However, as it is difficult to search for absences in the corpora, this is not something I will be able to inspect in this study. I will however report on the other liaison feature, linking /r/, as this can occur wherever there is an orthographic (written) /r/ at the end of a word when followed by a vowel (e.g. *car and*).

This chapter seeks to answer whether rhoticity plays a role in characterising a particularly Scottish choral accent. While there are some recordings of Scottish popular songs in the Glasgow corpus these are far outnumbered by recordings of church music (in English), which is the largest category. Irrespective of genre, is there a Scottish choral accent?

8.4 Method

In order to answer these research questions I return to the corpora we constructed previously. This excerpt is repeated here for convenience: *Two electronic time-aligned corpora were constructed in LaBB-CAT Fromont & Hay (2012). The Glasgow corpus consists of commercially released recordings of the Glasgow Orpheus (1906–1951) and Glasgow Phoenix (1951–present) choirs with audio recordings from 1925 to present day. The King's corpus consists of commercially released recordings and public broadcasts of the choir of King's College, Cambridge, with audio recordings from 1945 to 2019. Audio recordings and texts were aligned in LaBB-CAT (Fromont, 2019) using Praat (Boersma & Weeninck, 2018).*

All tokens of /r/ in the Glasgow and King's Cambridge corpora (8,407 tokens) were extracted and auditorily coded for /r/ realisation. This yielded 2,748 tokens of onset /r/; 643 tokens of intervocalic /r/; and, 5,016 tokens of postvocalic /r/, as shown in Table 8.1 and Figure 8.1. I present two analyses: the first investigates the realisation of /r/ in each position: the second investigates rhoticity – whether /r/ is articulated or not in postvocalic position.

Table 8.1: All /r/ tokens by Time/Director and Context. 'HSR' = Hugh S. Roberton; 'PM' = Peter Mooney; 'MJS' = Marilyn J. Smith; 'BO' = Boris Ord; 'DW' = David Willcocks; 'PL' = Philip Ledger; 'SC' = Stephen Cleobury.

Corpus	Time/Director	Context	N	(%)
Glasgow	HSR (1925–1951)	Initial	149	32%
Glasgow	HSR (1925–1951)	Intervocalic	49	11%
Glasgow	HSR (1925–1951)	Postvocalic	268	58%
Glasgow	PM (1959–1975)	Initial	717	36%
Glasgow	PM (1959–1975)	Intervocalic	123	6%
Glasgow	PM (1959–1975)	Postvocalic	1161	58%
Glasgow	MJS (1987–2019)	Initial	160	35%
Glasgow	MJS (1987–2019)	Intervocalic	35	8%
Glasgow	MJS (1987–2019)	Postvocalic	268	58%
King's	BO (1945–1958)	Initial	231	29%
King's	BO (1945–1958)	Intervocalic	80	10%
King's	BO (1945–1958)	Postvocalic	482	61%
King's	DW (1959–1974)	Initial	353	27%
King's	DW (1959–1974)	Intervocalic	95	7%
King's	DW (1959–1974)	Postvocalic	857	66%
King's	PL (1976–1982)	Initial	278	34%
King's	PL (1976–1982)	Intervocalic	66	8%
King's	PL (1976–1982)	Postvocalic	472	58%
King's	SC (1984–2019)	Initial	860	34%
King's	SC (1984–2019)	Intervocalic	195	8%
King's	SC (1984–2019)	Postvocalic	1508	59%

8.4.1 /r/ realisation and rhoticity coding schemes

The coding scheme for /r/ realisation can be found in Table 8.2. There were a range of auditory variants which were categorised into five higher level categories as follows. Generally, following Lawson et al. (2014), 'n' zero /r/ e.g. [kɑː] refers to no auditory percept of /r/. 'w' refers to approximants (usually postalveolar e.g. [kaɹ]). 't' refers to tap variants (e.g. [kaɾ]), and 'r' is an alveolar trill [kar]. Tokens with multiple different realisations were coded in as much detail as possible. The majority percept was coded first e.g. 'wr' – where most people are producing an approximant with a few trills. For the /r/ realisation analysis these tokens were collapsed into the majority percept category. For the rhoticity analysis of postvocalic /r/ the variants were grouped into the categories: no audible /r/ 'NoR' vs. articulated /r/ 'R' (= all other possible variants).

Sometimes I found it difficult to tell apart taps from trills, and taps from approximants. Thus the category 'w' (approximant) was treated as a catch-all for any sounds that were deemed rhotic, but the particular kind could not be

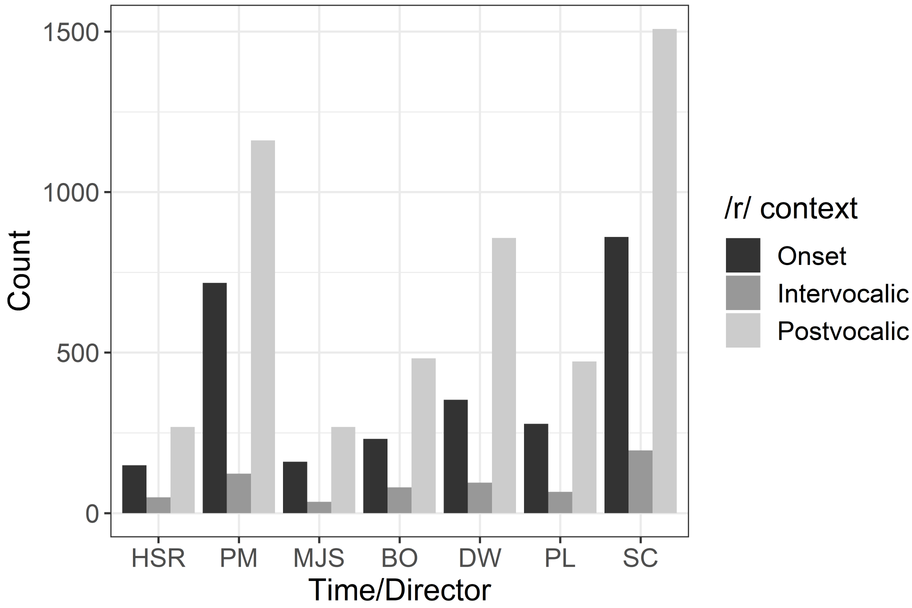


Figure 8.1: Distribution of /r/ by context. Glasgow: 'HSR' = Hugh S. Roberton 1925–1951, 'PM' = Peter Mooney 1959–1975, 'MJS' = Marilyn J. Smith 1987–2019. King's: 'BO' = Boris Ord 1945–1958, 'DW' = David Willcocks 1959–1974, 'PL' = Philip Ledger 1976–1982, 'SC' = Stephen Cleobury 1984–2019.

distinguished by the researcher. As we will see, the realisation of articulated postvocalic /r/ was largely approximants (around 95%), so I decided to collapse the factor levels to a binary factor (Articulated versus Not articulated).

Table 8.2: /r/ realisation and rhoticity auditory coding schemes. 'R' = articulated /r/; 'NoR' = no auditory percept of /r/.

coding	V1 phonetic realisation	V2 rhoticity
r	trill [r]	R
t	tap [ɾ]	R
w	approximant [ɹ]	R
n	no audible percept of /r/ [∅]	NoR
e	exclude	

8.4.2 Reflections on auditory coding method

Ideally, I would follow Stuart-Smith & Lawson (2017) with the first author coding all the /r/ tokens and then the second author re-coding them randomly to get an idea of intra-coder reliability – and subsequently exclude tokens with disagreement. However, this approach is impractical for doctoral research due to time and budget constraints.

Given the variable quality of the recordings in the corpora, and the number of people singing at once, it was not possible to distinguish derhoticised tokens from unrealised tokens, so I exclude this category. I also believe that it is unlikely that these forms would be used in choral singing as pharyngealisation/velarisation of /r/ is stigmatised in English – perhaps because they are enregistered as working-class variants (Stuart-Smith & Lawson, 2017).

While these variants could be used in popular styles to index working-class identity as found in indie music in Krause & Smith (2017), in classical styles it is likely to be viewed by others as unidiomatic (Johnston, 2016). An analogy for this is what Adams (2008) writes about the appropriateness of using the uvular trill [ʀ] or fricative [ʁ] spoken French variants of /r/ in French chansons in place of the tap [ɾ], commenting that their use is to be cautioned. In the case of singing English /r/, it is unlikely that [ʋ] or [ʋ̠] would be used, for example, though they are perfectly good spoken realisations of /r/.

8.4.3 Genre

Genre could play a significant role in the realisation of /r/ and/or rhoticity. Broadly, I believe that the realisation of /r/ might differ between the classical and popular reference styles. For example, Trudgill (1983) noted that British popular singers produced rhoticity in an attempt to sound 'American' (even when the rhoticity was incorrectly applied). However, it is not clear how /r/ operates within the classical reference style. In this chapter, and the following, genre is not included explicitly in the models. Genre is partially controlled for in the varying effects structure of Album, Song and Word. Genre is also partially controlled for as the largest chunk of both the Glasgow and King's corpora are 'Church Music' or 'Evensong' which typically include hymns, psalms and liturgical music which are shared repertoires between the choirs. There are some ways in which the corpora differ. In the Glasgow corpus, the emphasis is often on Scottish hymns and psalms, for example 'Crimond' (a well-known Scottish hymn tune setting of Psalm 23), 'O light of life', 'Onward Christian Soldiers', 'Worship the Lord', 'Scotland's favourite songs of praise', 'Highlands of praise'. There are also recordings of choral arrangements of Scottish folk/popular songs including: 'Auld Lang Syne', 'Loch Lomond', 'Annie Laurie', 'Ca' the yowes', 'Ae fond kiss' and 'Scots wha hae'. I was concerned that the repertoire itself may influence the way that the choirs sing. That is, the church music might be produced with an Anglo-English (non-rhotic, *car* = /kɑː/) phonology, whereas arrangements of Scottish folk tunes might elicit a Scottish English (rhotic, *car* = /kar/) phonology. In order to make the argument, that there is a Scottish way of doing choral singing – not merely an effect of repertoire (or genre) – I must show that there is no effect of genre. For this reason, I include Figures 8.2 and 8.3.

The effect of Genre that we might expect does not materialise. In fact, as we can

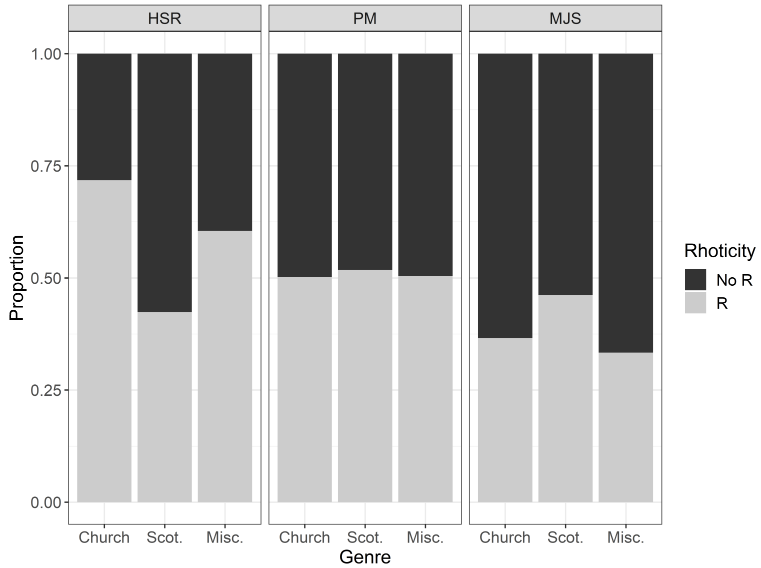


Figure 8.2: Glasgow articulation of postvocalic /r/ by Genre and Time/Director (proportion). y-axis: Proportion of rhoticity. N = 1,546. HSR = Hugh S. Roberton (1925–1951); PM = Peter Mooney (1959–1975); MJS = Marilyn J. Smith (1987–2016)

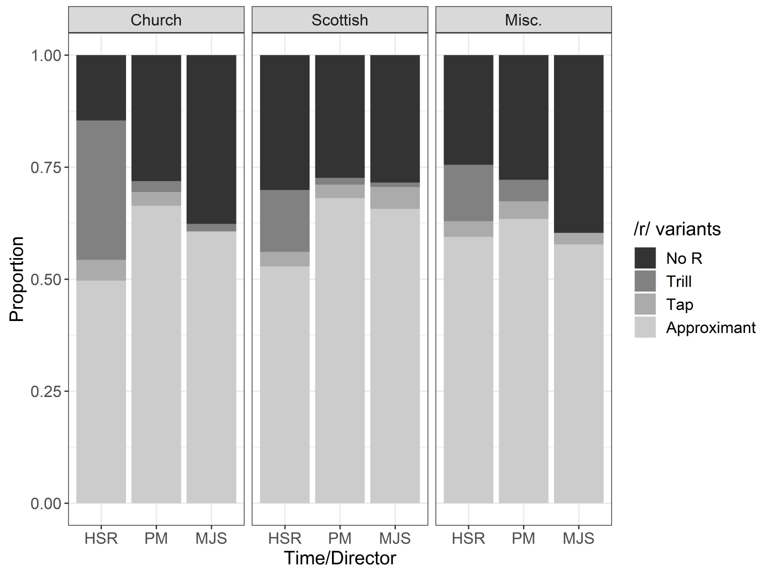


Figure 8.3: Realisation of Glasgow /r/ by Genre and Time/Director (proportion). y-axis: Proportion of variants of /r/. N = 2,779. HSR = Hugh S. Roberton (1925–1951); PM = Peter Mooney (1959–1975); MJS = Marilyn J. Smith (1987–2016)

see in Figure 8.2, for the early time period (Hugh S. Roberton, 1925–1951), Scottish traditional music is *less* rhotic than Church music! While the Genre divisions are quite coarse, we would expect to see evidence of an overall difference in the raw data. As we do not, I decided to remove Genre from the statistical analyses. Genre for King's was previously divided into Evensong, Nine Lessons, and Miscellaneous. However, this division is done purely by function rather than any other metric, and it was not thought to affect realisation of /r/.

8.5 Results

The raw data, code and models reported in this chapter can be found on the OSF at osf.io/8tr7w.

In this chapter, there are two types of analysis presented. The first is a phonetic analysis that investigates the distribution of variants in the realisation of /r/ in initial, intervocalic and postvocalic positions. The second is a phonological analysis that investigates whether the orthographic /r/ is Articulated or Not Articulated in postvocalic position. I expect postvocalic /r/ in choral singing to be articulated in rhotic dialect areas, but not in non-rhotic dialect areas. In a sense, the phonological analysis is a subset of the phonetic analysis restricted to coda position, but instead of a list of variants, it is reduced to a binary variable. These two analyses are complementary but different and allow me to answer different research questions. For example, the variants used may differ between dialect areas, and a binary analysis would not be able to tell us this. Conversely, the phonological analysis aims to give us an insight into the effect a spoken dialect may have on the choral sung signal at a structural level.

8.5.1 Realisation of initial and intervocalic /r/

As previously mentioned, word-initial /r/ is usually articulated, meaning that only the type of realisation of /r/ may vary. In intervocalic position, it is possible for /r/ to be not articulated at all (hiatus), though this is very rare, and restricted to conservative or 'upper-crust' RP (Wells, 1982b). Alveolar trills [r] have been associated with Scottish varieties of English; however, this may reflect a historical stereotype. There are not enough tokens to build a statistical model with the interaction term Time/Director by Context. Therefore I proceed to give a quantitative (but not statistical) analysis of the variants used in initial and intervocalic position. Figures 8.4 and 8.6 show proportional bar charts of the raw data in initial and intervocalic contexts, respectively.

As shown in Figure 8.4, tokens of initial /r/ in recordings of the Glasgow Orpheus

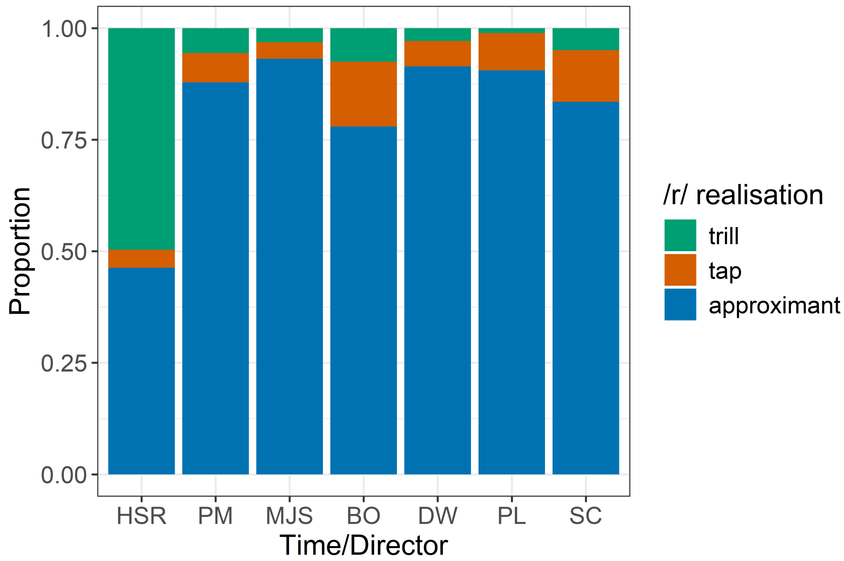


Figure 8.4: Initial /r/ realisation by Time/Director (proportion). y-axis: Proportion of variants of /r/. N = 2,748. Glasgow: HSR = Hugh S. Roberton (1925–1951); PM = Peter Mooney (1959–1975); MJS = Marilyn J. Smith (1987–2016). King's: BO = Boris Ord (1945–1958); DW = David Willcocks (1959–1974); PL = Philip Ledger (1976–1982); SC = Stephen Cleobury (1984–2019).

choir made under Hugh S. Roberton (1925–1951) were realised as trills 50% of the time. This looks very different to the pattern shown by all other Time/Directors.

There appears to be a slight tendency for King's to make use of more taps in initial position than trills. In Figures 8.4, 8.5, and 8.6, bear in mind that we cannot control for the effects of Word, Genre, or phonetic context (that is, whether the /r/ is preceded or followed by a vowel or consonant across word boundary).

Figure 8.5 shows the realisation of initial /r/ by Context for each Corpus. There is a tendency for trills to be produced more frequently in word-initial position following a pause (Context 'rV'), however, this Context suffers from particularly low number of tokens (Glasgow N = 21; King's N = 41) and I am wary of making generalisations based on this amount of data.

There are fewer tokens of /r/ in intervocalic position overall (N = 643). As seen in Figure 8.6, King's shows a tendency to produce more taps in intervocalic context than the Glasgow choirs.

8.5.2 /r/ realisation: postvocalic

The distribution of variants of /r/ used in postvocalic position when /r/ is articulated (e.g. *car* = /kar/) are shown in Figure 8.7. The majority of tokens of articulated /r/ in postvocalic position are realised as approximants (e.g. *car* = [kaɹ]). This is unsurprising as it is a high-status variant of /r/, the 'English' variant

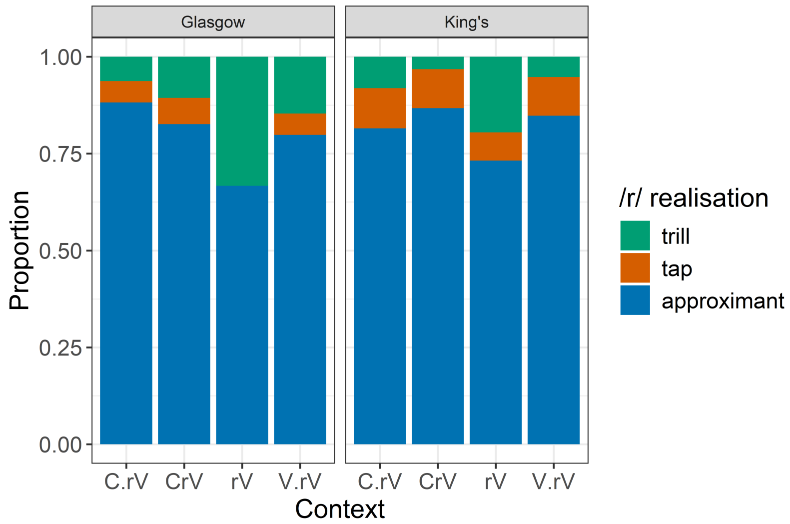


Figure 8.5: Initial /r/ realisation: Corpus by Context. y-axis: proportion of variants of /r/. N = 2,748. 'C.rV' = and ring; 'CrV' = string; 'rV' = #ring; 'V.rV' = a ring.

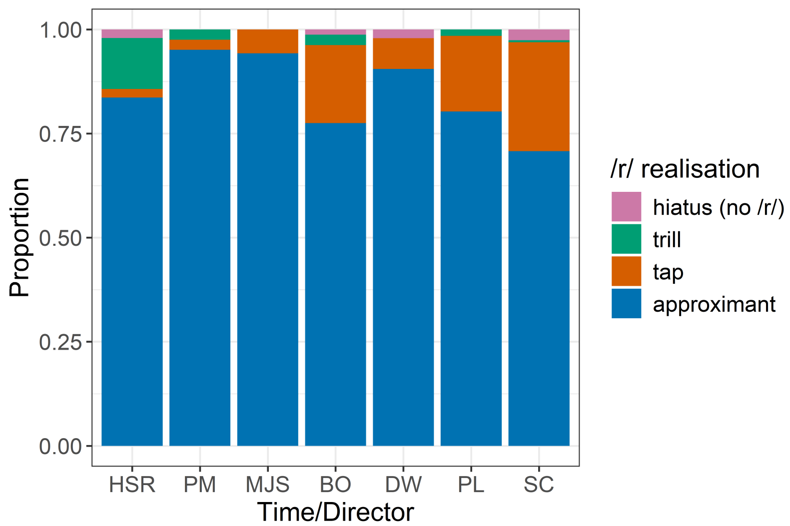


Figure 8.6: Intervocalic /r/ realisation by Time/Director. y-axis: proportion of variants of /r/. N = 643. Glasgow: 'HSR' = Hugh S. Roberton (1925–1951); 'PM' = Peter Mooney (1959–1975); 'MJS' = Marilyn J. Smith (1987–2016). King's: 'BO' = Boris Ord (1945–1958); 'DW' = David Willcocks (1959–1974); 'PL' = Philip Ledger (1976–1982); 'SC' = Stephen Cleobury (1984–2019).

commonly used in SSBE, but also increasingly in middle-class speech in the Central Belt of Scotland. Under Hugh S. Roberton (1925–1951) and just about persisting under Peter Mooney (1959–1975) it was possible to have an alveolar trill realisation in postvocalic position. The trill variant reduced over time in the Glasgow corpus until it was no longer a possible realisation in postvocalic position under Marilyn J. Smith (1987–2019).

Given the distribution of variants in intervocalic position (See Figure 8.6), it is perhaps unsurprising that there is evidence of a low prevalence of tap realisations at King's in postvocalic position; all tokens of articulated /r/ from King's in postvocalic position are in *car and* linking /r/ contexts which are intervocalic (between two vowels, but across word boundary rather than within word). At King's, it appears it is possible to tap in intervocalic position across word boundary, not just within words such as *very*, but also in linking /r/ contexts such as *car and*.

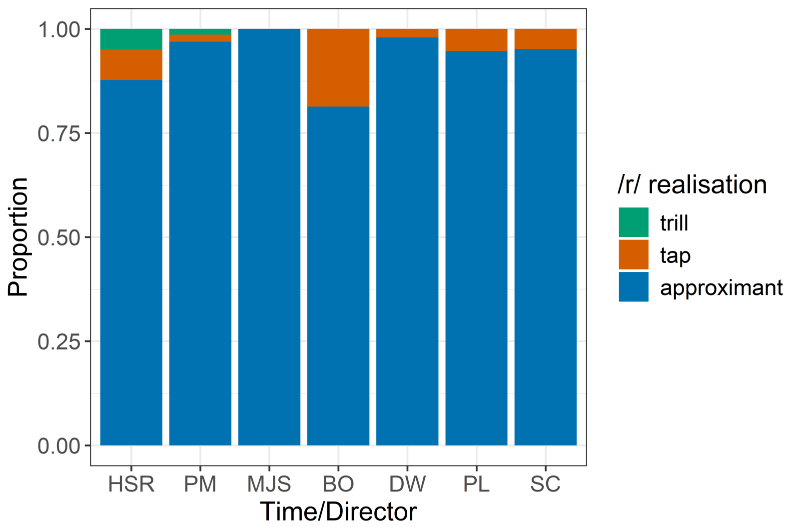


Figure 8.7: Realisation of articulated postvocalic /r/ by Time/Director. y-axis = proportion of variants of /r/. N = 1,335. Glasgow: 'HSR' = Hugh S. Roberton (1925–1951); 'PM' = Peter Mooney (1959–1975); 'MJS' = Marilyn J. Smith (1987–2016). King's: 'BO' = Boris Ord (1945–1958); 'DW' = David Willcocks (1959–1974); 'PL' = Philip Ledger (1976–1982); 'SC' = Stephen Cleobury (1984–2019).

8.5.3 /r/ realisation interim summary

As predicted, we found evidence of trills being used by the Scottish choirs for syllable onsets. This was most noticeable for the Glasgow Orpheus choir under Hugh S. Roberton. There is a reduction in the use of trills in the subsequent time periods for the Glasgow Phoenix choir, and there appears to be little difference between the use of trills for the Phoenix choir and the choir of King's College, Cambridge. There is a general tendency for trills to be more likely in word-initial position following a pause. While King's does not make much use of the alveolar trill, there are more alveolar taps in initial and intervocalic position.

Regarding articulated /r/ in postvocalic position, the vast majority of tokens are approximants. However, there was evidence of trills in the Glasgow corpus declining over time. I will now present the results for the second /r/ variable, postvocalic /r/.

8.5.4 Rhoticity: postvocalic /r/

In this analysis, there are two levels, with variants from the previous analysis recoded as: zero = Not articulated; all other variants = Articulated, equating to non-rhotic and rhotic respectively.

Postvocalic /r/ linguistic contexts

For postvocalic /r/ in speech, just as we have seen above for intervocalic /r/, in Figure 8.6 there is a strong effect of following context on production. Articulated /r/ is most likely pre-vocalically (e.g. *car and*), less so pre-pausally (e.g. *car#*) and least likely pre-consonantally (e.g. *car could*) (Stuart-Smith, 2003). There are four main contexts for postvocalic /r/ as shown in Table 8.3.

Table 8.3: Postvocalic /r/ Context

coding	example	name
r.V	*car and*	pre-vocalic (linking /r/)
r	*car#*	pre-pausal
r.C	*car could*	pre-consonantal word boundary
rC	*card*	pre-consonantal within word

The four contexts are listed in the order of most likelihood of rhoticity to least likelihood (Stuart-Smith & Lawson, 2017). That is, /r/ is most likely to be produced in *car and* (linking /r/ context) in all varieties of English, including SSE and SSBE, whereas the /r/ in *card* is least likely to be produced. Each of the four linguistic contexts (*car and*, *car#*, *car could*, and *card*) can be stressed or unstressed. For example, for linking /r/, there can be *car and* (stressed) or *father and* (unstressed). In the sung data there appeared to be no difference between postvocalic /r/ in stressed and unstressed tokens. This reflects what I found for vowels in Chapters 5, 6, and 7, as far more vowels in singing are stressed than they are in speech. Therefore I collapsed by stress and have 4 contexts instead of 8. In Table 8.4 the binary articulation of /r/ is broken down by Corpus and Context.

Modelling articulation of postvocalic /r/

The data were analysed with Bayesian binomial mixed models using `brms` (Bürkener, 2018) [version 2.18.0] in R (R Core Team, 2021) [version 4.1.2]. Tables were produced with `xtable` (Dahl et al., 2019) [version 1.8-4] and

Table 8.4: Articulation of postvocalic /r/ by Corpus and Context. ‘r’ = Articulated; ‘noR’ = Not Articulated.

Corpus	Context	Articulated /r/	No /r/	Articulated %
Glasgow	r	102	89	53%
	r.C	329	282	54%
	r.V	176	13	93%
	rC	247	459	35%
Cambridge	r	6	273	2%
	r.C	126	1046	11%
	r.V	219	158	58%
	rC	130	1361	9%

`BayesPostEst` (Karreth et al., 2021) [version 0.3.2]. Firstly, I model all of the data together to investigate synchronic differences between the Corpora. Then I model each Corpus separately to investigate change over time. The model structures were:

```
Combined_binary_r_articulation ~ Corpus + Context + Corpus:Context +
(1|Album) + (1|Song) + (1|Corpus:Word)

Glasgow_binary_r_articulation ~ Time/Director + Context +
Time/Director:Context +
(1|Album) + (1|Song) + (1|Time/Director:Word)

Kings_binary_r_articulation ~ Time/Director + Context +
Time/Director:Context +
(1|Album)+ (1|Song) + (1|Time/Director:Word)
```

Summary of Variables

The dependent variable of all models is whether postvocalic /r/ is Articulated or Not Articulated. The predictor variables for the Combined model were the factors Corpus (Cambridge, Glasgow) and Context (r.V, r, r.C, rC). For the separate dialect area models, Context is the same, but instead of corpus we have Time/Director. For the Glasgow model Time/Director is a three-level factor: Hugh S. Roberton (1925–1951), Peter Mooney (1959–1975), Marilyn J. Smith (1987–2016). For the King’s model Time/Director is a four-level factor: Boris Ord (1945–1958), David Willcocks (1959–1974), Philip Ledger (1976–1982), and Stephen Cleobury (1984–2019).

Varying effects structure

In these models, random intercepts for Album and Song are included as with the vowel models outlined in Chapters 5, 6, and 7. However, in the postvocalic /r/ models a slope is included for Word. In the combined model there is a by corpus slope for Word `(1|Corpus:Word)` which allows a separate slope for Word for each Corpus, as there is reason to believe that *car* would be produced differently for the different corpora, for example, in an SSBE dialect area and an SSE dialect area. In the Glasgow and King's separate models, a by Time/Director slope for Word is included `(1|Time/Director:Word)` which allows separate slopes for Word for each Time/Director. As we are interested in a possible effect of change over Time/Director, it is important to include this slope as it is feasible that the way of producing a particular Word is different for different Time/Directors (Barr et al., 2013).

Priors

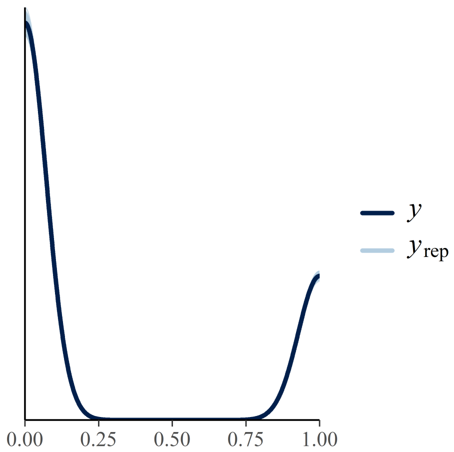
Following recommendations by Gelman et al. (2008), I used weakly-informative regularising priors using Cauchy distributions centred on 0 with a scale factor of 2.5 for all fixed and varying effects. A Cauchy distribution centred on 0 with a scale factor of 10 was used for the intercept. Cauchy distributions were selected as opposed to normal distributions as they have more weight in the tails and therefore allocate more probability space to values further from zero while still giving values closer to zero greater probability (Kimball et al., 2019).

Convergence criteria

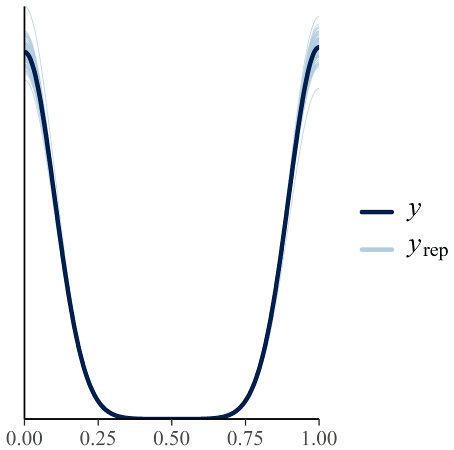
Posterior predictive checks are visualised in Fig. 8.8. Model chains were visually inspected for convergence, Rhat was 1 for all coefficients and the minimum effective sample size for all coefficients was greater than 100 $\times$ the number of chains. I was satisfied that the models converged successfully and that the posterior summaries are amenable to interpretation.

Contrast coding

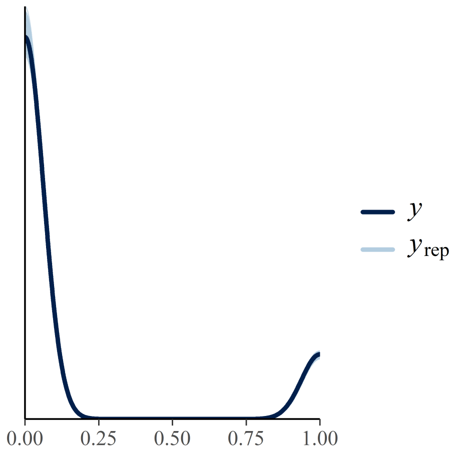
For the combined model, reported in Table 8.5, the two-level factor variable Corpus was sum coded ('King's' vs 'Glasgow': -0.5, 0.5) such that the main effect reported in the model summary table is the difference between the two corpora (not to the grand mean). This also affects the interpretation of the interaction term. All other factor variables are sum coded, meaning each level reported in the model summary is being compared to the grand mean for that factor.



(a) Combined postvocalic /r/ model



(b) Glasgow postvocalic /r/ model



(c) King's postvocalic /r/ model

Figure 8.8: Posterior predictive checks for Combined, Glasgow, and King's postvocalic /r/ models

8.5.5 Results: Postvocalic /r/

In the following section three models are outlined that aim to investigate, firstly synchronic differences between the two corpora, secondly diachronic change separately within the Glasgow corpus and the King's corpus.

Table 8.5: Combined: Rhoticity model posterior summary

	Estimate	95% CI	
Intercept	**−0.69**	**−0.95**	**−0.45**
CorpusGlasgow	**2.91**	**2.41**	**3.44**
Context_r	**−1.49**	**−1.90**	**−1.13**
Context_r.C	−0.20	−0.41	0.01
Context_rC	**−0.99**	**−1.24**	**−0.74**
CorpusGlasgow:Context_r	**1.20**	**0.48**	**2.01**
CorpusGlasgow:Context_r.C	−0.36	−0.79	0.05
CorpusGlasgow:Context_rC	**−0.82**	**−1.31**	**−0.34**

Point estimate displayed: median

Results are given on the log odds ratio (not the response) scale.

Bold type indicates 0 outside 95% credible interval.

As shown in Table 8.5, the model revealed a main effect of Corpus; the predicted probability of articulating postvocalic /r/ was 0.10 for Cambridge and 0.68 for Glasgow (logit difference 2.91, CI [2.41; 3.44]). The model presents an interaction of Corpus by Context. Overall, Glasgow is more likely to articulate postvocalic /r/ than Cambridge in all contexts. As articulated /r/ is least likely pre-pausally, there is a positive adjustment for pre-pausal tokens in the Glasgow corpus. As the likelihood of articulated /r/ is so high for Glasgow overall, there is a negative adjustment for pre-consonantal contexts. The predicted probability for articulating postvocalic /r/ in pre-pausal context *car#* (context_r) was 0.025 for Cambridge and 0.47 for Glasgow. The predicted probability of articulating postvocalic /r/ in pre-consonantal context across word boundary *car could* (context_r.C) was 0.09 for Cambridge and 0.59 for Glasgow (interaction visualised in Fig. 8.9).

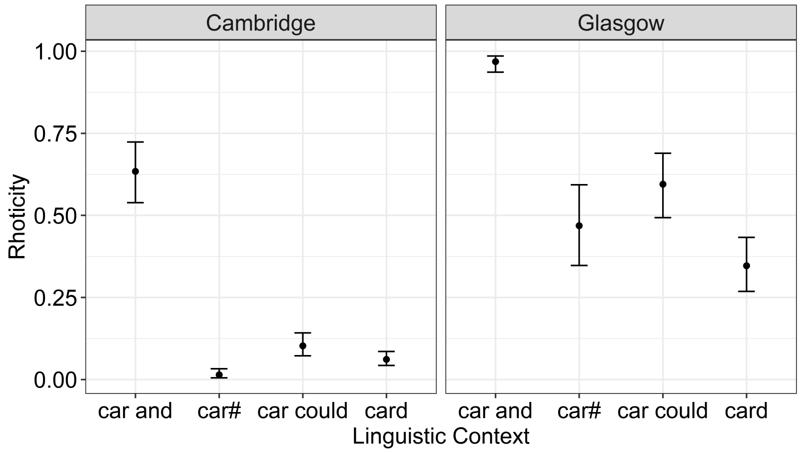


Figure 8.9: Combined: Rhoticity model, Corpus by Context interaction

8.5.6 Glasgow diachronic rhoticity model

The following model investigates change over time in rhoticity in Glasgow choral singing.

Table 8.6: Glasgow: Rhoticity model posterior summary

	Estimate	95% CI	
Intercept	**0.73**	**0.24**	**1.24**
DirectorPM (1959–1975)	0.10	−0.46	0.66
DirectorMJS (1987–2016)	**−0.89**	**−1.65**	**−0.18**
Context_r	**−1.48**	**−2.18**	**−0.89**
Context_r.C	−0.12	−0.54	0.30
Context_rC	**−1.44**	**−1.89**	**−1.01**
DirectorPM:Context_r	0.64	−0.02	1.38
DirectorMJS:Context_r	**−1.73**	**−2.95**	**−0.75**
DirectorPM:Context_r.C	−0.38	−0.85	0.09
DirectorMJS:Context_r.C	0.32	−0.34	0.98
DirectorPM:Context_rC	−0.15	−0.65	0.35
DirectorMJS:Context_rC	0.36	−0.32	1.05

Point estimate displayed: median

Results are given on the log odds ratio (not the response) scale.

Bold type indicates 0 outside 95% credible interval.

In a model of the Glasgow data (as found in Table 8.6), there is a main effect of Time/Director. For Time/Director Peter Mooney (1959–1975), the predicted probability of articulating postvocalic /r/ is 0.7. The predicted probability for postvocalic /r/ being articulated for Marilyn J. Smith (1987–2016) is 0.46. The credible interval for Marilyn J. Smith does not include zero (logit difference -0.89, CI [-1.65; -0.18]) meaning that it is different to the grand mean for Time/Director. As Peter Mooney (1959–1975) is not different to the grand mean, but Marilyn J. Smith (1987–2016) is, there is evidence of change over time. That is, postvocalic /r/ is least likely to be articulated in the later time period.

The model also supports an interaction of Time/Director by Context. The interaction is driven by Marilyn J. Smith (1987–2016) and the pre-pausal Context *car#* as shown in Figure 8.10. In Figure 8.10, rhoticity decreases over time in all Contexts apart from *car and* (pre-vocalic) which is categorical (always articulated). The late time period Marilyn J. Smith (1987–2016) is much less likely to articulate postvocalic /r/ in pre-pausal Context than previous Time/Director pairs. The predicted probability of articulating postvocalic /r/ in pre-pausal context for Marilyn J. Smith was 0.03 (logit difference -1.73, CI [-2.95; -0.75]).

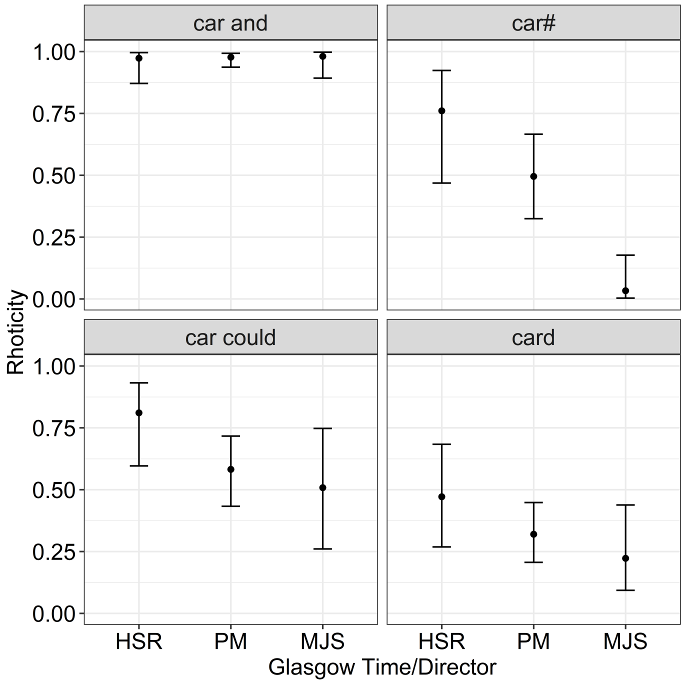


Figure 8.10: Glasgow rhoticity model: interaction of Time/Director by Context. y-axis: estimated proportion of rhoticity. 'HSR' = Hugh S. Roberton (1925–1951); 'PM' = Peter Mooney (1959–1975); 'MJS' = Marilyn J. Smith (1987–2016).

8.5.7 King's diachronic rhoticity model

The following model investigates change over time in rhoticity in the King's corpus as summarised in Table 8.7.

The model intercept for the King's corpus is negative, reflecting what we know from the combined model; King's rarely articulates postvocalic /r/ overall (logit difference -2.33, CI [-2.78; -1.95]). The model supports a negative main effect of pre-pausal Context_r *car#* with a predicted probability of articulated /r/ in this context of 0.008 (logit difference -2.45, CI [-3.60; -1.61]). This means that postvocalic /r/ is extremely unlikely to be articulated in pre-pausal Context at King's. The model does not support change over time in the King's data. The only Context of interest is pre-vocalic (or linking /r/) where the Time/Directors range from about 50%–75% with an average of around 60%, as visualised in Figure 8.11. This means that postvocalic /r/ in pre-vocalic position is variable for King's.

Table 8.7: King's: Rhoticity model posterior summary

	Estimate	95% CI	
Intercept	**−2.33**	**−2.78**	**−1.95**
DirectorDW (1959–1974)	−0.15	−0.71	0.39
DirectorPL (1976–1982)	−0.14	−1.14	0.58
DirectorSC (1984–2019)	0.20	−0.27	0.69
Context_r	**−2.45**	**−3.60**	**−1.61**
Context_r.C	−0.18	−0.55	0.27
Context_rC	−0.40	−0.79	0.05
DirectorDW:Context_r	0.66	−0.65	1.95
DirectorPL:Context_r	−1.56	−4.35	0.23
DirectorSC:Context_r	0.27	−0.84	1.52
DirectorDW:Context_r.C	−0.14	−0.71	0.44
DirectorPL:Context_r.C	0.12	−0.63	1.12
DirectorSC:Context_r.C	0.46	−0.05	0.94
DirectorDW:Context_rC	−0.28	−0.85	0.30
DirectorPL:Context_rC	**0.77**	**0.02**	**1.77**
DirectorSC:Context_rC	0.01	−0.51	0.51

Point estimate displayed: median

Results are given on the log odds ratio (not the response) scale.

Bold type indicates 0 outside 95% credible interval.

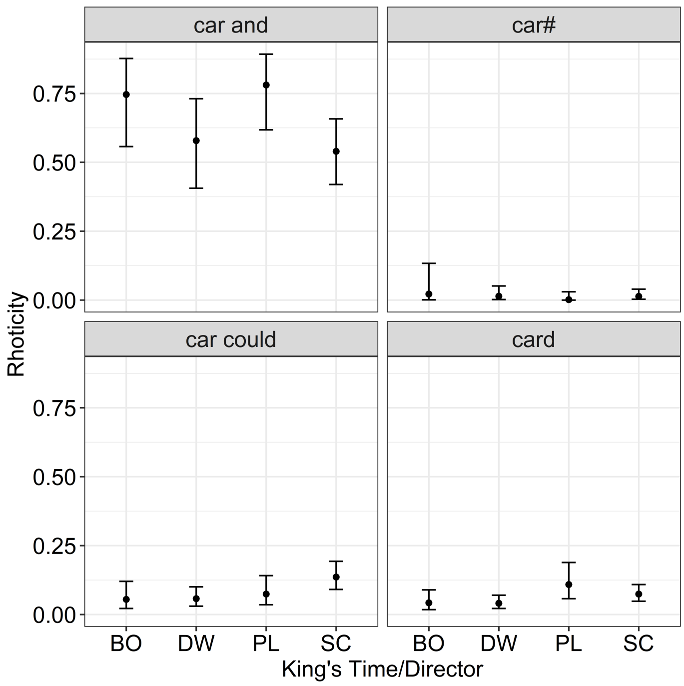


Figure 8.11: King's rhoticity model: interaction of Time/Director by Context. 'BO' = Boris Ord (1945–1958); 'DW' = David Willcocks (1959–1974); 'PL' = Philip Ledger (1976–1982); 'SC' = Stephen Cleobury (1984–2019).

What factors might affect the articulation of /r/ in pre-vocalic position? A point of interest is that, where there is no articulated /r/, these tokens are examples of true hiatus (for example, *for a* realised as [fɔ:ə] instead of [fɔ:ɹə]). Hiatus is where there is no linking /r/ produced between two adjacent vowels (word-final and word-initial). In these cases, there is usually a short pause, or glottal before the onset of the following vowel which reflects findings in SSBE speech data (see Mompeán & Gómez, 2011). As hiatus is generally dis-preferred, its existence in the recordings of King's may contribute to the 'affected' sound described by musicologists (Potter, 1998; Sagrans, 2016; Day, 2018).

8.6 Discussion

In this chapter so far, I have investigated the variant distribution for the realisation of articulated /r/ in initial, intervocalic, and postvocalic positions in the Glasgow and King's choir corpora. I followed this by modelling the factors that influence the probability of rhoticity in postvocalic position. This discussion will first relate the results to the primary research questions before a wider discussion of style.

8.6.1 Does /r/ realisation vary by dialect area?

Trills appear to be more common in word-initial position for the Orpheus choir under Hugh S. Roberton than for any other Time/Director pair. There was a subsequent reduction in the use of trills for the Phoenix choir under Peter Mooney (1959–1975) and Marilyn J. Smith (1987–2019). This reflects change in the distribution of /r/ variants in SSE speech over the twentieth century, however, we cannot be sure if the change in singing was driven by change in speech patterns, as trills were already comparatively rare in speech at the time the Orpheus was recording (Wells, 1982b). And, the singers in the Orpheus may have been more likely to use the SSE high-prestige alveolar approximant [ɹ] in their speech (Johnston, 1985; Watt et al., 2014). There is a tendency for the choir of King's College, Cambridge to use alveolar taps in intervocalic position which were largely absent from the Glasgow corpus. Likewise, in postvocalic position there was a tendency for King's to produce alveolar taps, but this is likely because articulated postvocalic /r/ at King's is in fact always intervocalic, and across word boundary i.e. *car and* = 'Vr.V' or linking /r/ contexts. The Glasgow choirs do not share the tendency to use taps in intervocalic position, where approximants are preferred.

8.6.2 Are choirs from SSE and SSBE dialect areas equally likely to articulate postvocalic /r/?

As I predicted based on spoken phonology, the Glasgow choirs do articulate postvocalic /r/ variably in all contexts, whereas King's only articulates postvocalic /r/ in linking /r/ contexts. That is, the Glasgow choral singers are using their underlying SSE phonology which contains postvocalic /r/ in both linking /r/ and non-linking /r/ contexts. King's underlying phonology based on SSBE does not have postvocalic /r/, apart from in the linking /r/ context. Linking /r/ at King's is articulated approximately 60% of the time. These findings together show that, while evidence from front vowels may indicate a standard accent of British choral singing based on a non-regional spoken phonology, as reported in Chapter 7, this chapter demonstrates that a choir's sung consonant phonology can also be impacted by the phonology of the spoken accent of the singers and/or their choir directors.

8.6.3 If Scottish choirs articulate postvocalic /r/, is there evidence of change over time?

Frequency of articulated /r/

There is evidence of change over time in the Glasgow corpus, with a reduction of articulated postvocalic /r/ in pre-pausal contexts. One explanation is that choir's director in the later time period speaks with an SSBE accent. Whether the singers imitate the director, or their pronunciation is 'corrected' in this case is unknown, but it appears that the choir has orientated towards an SSBE referee which does not contain postvocalic /r/. The reduction of postvocalic /r/ may reflect the pattern of derhoticisation in Scottish English (Stuart-Smith & Lawson, 2017) as found by Krause & Smith (2017) in indie bands in Glasgow. Future research is needed to establish whether this reduction of postvocalic /r/ in pre-pausal contexts is restricted to these choirs and directors, or if it is part of a wider pattern of change.

Distribution of /r/ realisation

Approximants are by far the most frequent realisation of /r/ in all contexts. While there are few instances, it is clear that trills were possible in postvocalic position in the early time period under Hugh S. Roberton (1925–1951), and that these decreased under Peter Mooney (1959–1975), till they were no longer possible under Marilyn J. Smith (1987–2019). In summary, there are some trends indicating differences in the realisation of /r/ between the corpora. And, there is strong evidence supporting the influence of Scottish Standard English phonology on the singing of the Glasgow choirs. We now move to a broader discussion of the enregisterment of these variants and the identities they may index.

8.6.4 Twentieth-century 'tartan' stereotypes

The trilled variant of /r/ is now rarely heard in the Central Belt, with approximants (middle-class) and uvular approximants and derhotacised (working-class) becoming more frequent (Lawson et al., 2014). While the Orpheus was growing both in number and in popularity, Harry Lauder was the first international popular music star. Lauder was known for his hammed-up Scots, kilt, and cromach (rustic walking-stick). His hits included 'Roamin' in the gloamin', 'A wee deoch-an-doris' and 'I love a lassie'. Lauder's stage tartan cultural projection included frequent use of the variants that Watt et al. (2014) reference as the American mental image of Scottishness – and, as Russell (2011) writes, 'Lauder, while not inventing the stage Scotsman, did much to construct and reinforce certain notions of Scottish identity'. The linguistic features characterising this 'stage Scotsman' identity include: the alveolar trill variant of /r/; articulated postvocalic /r/, also often realised as a trill; noticeably Scots vowel qualities; and Scots lexis and grammar.

How is Harry Lauder, a popular music hall and variety performer, relevant to classical choral singing? As we saw in Chapter 5, there was not the same degree of separation between classical and folk music in nineteenth-century Scotland (Mallinson, 2015). Therefore, I argue that variants enregistered as Scottish in the early twentieth century also transcended the popular–classical divide. Or, at that time, Scottish music had its own genre and its own norms. Lauder '[took] great care that his act, while distinctively Scottish, avoided the excessive use of dialect that had hitherto handicapped Scottish performers in the metropolis' (Russell, 2011). There was an overlap in repertoire as both Lauder (1926) and the Glasgow Phoenix choir (1959) recorded versions of 'The Road to the Isles'. According to Roberton (1963) it was also performed by the Orpheus, though there is unfortunately no recording. Lauder (1927) and the Orpheus (1926) and Phoenix (1970) choirs each recorded the well-known 'Loch Lomond' too. So there does seem to be evidence of a shared repertoire at least, and perhaps a shared stylistic way of performing said repertoire.

8.6.5 A 'Scottish note'?

Roberton (1963) wrote, perhaps fancifully, that although many choirs in England were more proficient than choirs in Scotland, there was a 'distinctive note' in Scottish choral singing. And, as we saw in Section 8.4.3, this is not only due to them singing Scottish songs. Is there evidence of this 'Scottish note' in the recordings of the Orpheus? We have already demonstrated that the vowel inventories of the Orpheus under Roberton and King's under David Willcocks were similar, and they seemed to be based on a prestigious non-regional language variety. What about the realisation of /r/? In the early time period, under the leadership of Roberton, the trill is used far more frequently than under any other director of both the Glasgow and King's corpora. Trills occur in 50% of word-initial tokens under Roberton. We can only speculate whether this usage relates to the Orpheus representing Scotland internationally – indexing a Scottish identity through the use of the recognisably Scottish variant: the trill. But, we can say, with some certainty, that trills are a stylistic feature of the Orpheus under Roberton.

Recordings of the Phoenix choir show a marked reduction in the proportion of word-intial /r/s that are realised as trills. This does not necessarily indicate a move away from the tartan stereotype, but the importance of /r/ in the characterisation of the choir's sound has shifted. There is arguably a legacy of the Orpheus' sound, as certain words which were particularly emphasised with initial trilled /r/s under Roberton continued to be trilled in later recordings of the Phoenix choir. This is often true of word-intial /r/s which are preceded by a pause. This context appears to promote trill realisations. For example, in Roberton's own composition 'All in the April Evening', the word *rest* in the phrases 'Rest for their little bodies' and 'Rest for their little feet' tends to be realised as a trill as recently as recordings made in 2000 to 2004. This is exceptional as trill realisations in word-initial positions make up just over 3% of tokens under Marilyn J. Smith (1987–2019). A summary of all of the instances of *rest* can be found in Table 8.8.

While there is no clear pattern in Table 8.8, it is possible to trill word-initial /r/ following a pause as late as 2000 to 2004. The trills in later recordings may be echoes of the Orpheus' style from earlier in the century.

8.6.6 An RP note? Realisation of /r/ in recordings of King's

Although there is not enough evidence at this stage to say that the alveolar tap characterises the King's style, there is a clear tendency for using the alveolar tap [ɾ] variant of /r/ in initial, intervocalic, and postvocalic positions (in linking /r/ contexts). Is there a musical or linguistic explanation for why this might be the case? Wells (1970) writes that 'intervocalically, an alveolar tap, [ɾ], is now not as common in RP as a post-alveolar approximant [ɹ]', implying that in the past taps were a more common realisation of /r/ in intervocalic position. A decade later Wells writes that 'a certain kind of RP has free variation between the approximant and an alveolar tap, [ɾ]' (Wells, 1982a, p. 75). At King's, where a more conservative variety of RP was historically spoken, we might expect to find recessive variants such as the tap [ɾ] which are now rather less common in SSBE,

Table 8.8: Token of the word ‘rest’ produced by Glasgow choirs

Album	Year	Director	Word	r_context	r_realisation
20 Classic Recordings	1945	HSR	rest	rV	trill
20 Classic Recordings	1945	HSR	rest	rV	trill
The Road to the Isles	1959	PM	rest	rV	approximant
The Road to the Isles	1959	PM	rest	C.rV	approximant
Songs From Scotland	1968	PM	rest	rV	approximant
Songs From Scotland	1968	PM	rest	rV	approximant
Jesu Joy of Man’s Desiring	1970	PM	rest	rV	trill
Jesu Joy of Man’s Desiring	1970	PM	rest	C.rV	approximant
Scotland Land of Praise	1999	MJS	rest	rV	approximant
Scotland Land of Praise	1999	MJS	rest	C.rV	approximant
Celebrating 100 years...	2000	MJS	rest	rV	trill
Iona Abbey	2004	MJS	rest	rV	trill
Iona Abbey	2004	MJS	rest	C.rV	approximant
Feel Good	2006	MJS	rest	rV	approximant
Feel Good	2006	MJS	rest	C.rV	approximant
Orkney St Magnus Cathedral	2016	MJS	rest	rV	approximant
Orkney St Magnus Cathedral	2016	MJS	rest	C.rV	approximant

in intervocalic position, in words such as *sorry*, *very*. In the King’s recordings, there is no evidence of a reduction over time, with the rate of taps in intervocalic position staying relatively stable (approximately 20–25%), apart from recordings under David Willcocks which show a much lower proportion of taps (approximately 10%). It is particularly interesting that the tap variant is used more frequently in the King’s corpus than in the Glasgow corpus despite the tap variant being a current variant in use in Scottish English. However, this may be because the tap variant is associated with working class Glasgow English (Stuart-Smith, 2003). Perhaps the alveolar tap was never enregistered as distinctly Scottish in the same way that the alveolar trill was – rather, in intervocalic contexts, it was enregistered as a feature of conservative RP and was retained at King’s.

8.6.7 Why does articulated postvocalic /r/ become less frequent in Glasgow over time?

As alluded to previously, the reduction of articulated postvocalic /r/ pre-pausally could relate to a number of factors. Consonants in word-final position before a pause are more likely to be deleted in speech. Much of the literature on choral conducting bemoans choirs’ inability to place consonants in final position (for example, Coward, 1914; Roberton, 1963; Emmons & Chase, 2006). Perhaps how pernickety a director is will have an impact on the realisation of final consonants too.

Sociophonetic work has shown that rhoticity has decreased in Central Scotland over the twentieth century, both in terms of the frequency of articulated /r/ and also in the strength of the variants of /r/ produced (Abercrombie, 1979; Wells, 1982b; Johnston, 1985; Stuart-Smith, 2003; Lawson et al., 2014; Lawson et al., 2018). It could be argued that the recordings of the Glasgow choirs track the findings from speech, demonstrating both a reduction of articulated /r/ in pre-pausal contexts, and also the reduction of the use of the alveolar trill in later recordings from the Glasgow corpus. However, the situation in the speech data is more complex than this as the reduction in rhoticity is driven by working-class speakers who now produce uvular or pharyngeal approximants or fricatives, whereas middle-class speakers have gone in the other direction becoming 'hyper-rhotic' and producing more strongly rhotic variants like the post-alveolar or retroflex approximants. This may explain why approximants have become the most common realisation of /r/ across the board in Glasgow. However, it does not provide a satisfactory explanation for the change in the singing, as it is unlikely for working-class speech variants to be used in a middle-class-dominated art form. As previously noted, classical singing pedagogy often prescribed the 'High form' of the language. For example, in Chapter 5, I found that the Glasgow GOOSE vowel was realised markedly more backed than at King's. I argue that this might be evidence of an M/K target accent in juxtaposition with the Glaswegian spoken GOOSE vowel which is extremely socially salient and ranges from [ʉ] to as front as [ʏ] in working-class varieties. The choirs seemingly distance themselves from the working-class fronted spoken realisations of /u/.

Another explanation – stemming from Wells' comments on Romaine (1978) – is that the singers are adopting the SSBE non-rhotic prestige form because it is deemed stylistically appropriate for the performance of classical choral singing. Or, indeed, a non-rhotic sound could have been encouraged knowingly, or otherwise, by the choir's director. As we saw in Chapters 6 and 7, exemplified by the impact of David Willcocks on King's sound, a choir director's own accent can influence the choir's sound. On the Glasgow Phoenix Choir website, there is an audio clip of Marilyn J. Smith being interviewed on the BBC Radio Scotland programme 'The Reel Blend' (April, 2000). Listening to the interview, it is clear that Marilyn J. Smith speaks with an SSBE (non-rhotic) accent.

Is it surprising, either that the singers imitate her, or perhaps that she corrected some forms that she would not have been used to in her own variety? This would explain the reduction in articulated /r/ before a pause. As we have seen in the King's data, articulated /r/ is not possible in this context in SSBE classical choral singing. Interestingly, postvocalic /r/ in linking /r/ contexts is consistently produced in the recordings of the Glasgow choirs, whereas it is variable at King's.

Perhaps the attention to detail in consonants for which King's became known did not extend to rhotics. Or rather, rhotics generally are not as much of a salient feature of the King's style, with the exception of intervocalic taps. This is in contrast to the Orpheus Choir where the articulation and realisation of /r/ was characteristic of a particularly Scottish sound. In other words, the findings relating to postvocalic /r/ in the Glasgow corpus also support a shift from an SSE referee – with rhoticity in all contexts – to an SSBE referee – with rhoticity only possible in pre-vocalic contexts.

8.6.8 Why is linking /r/ more common in Glasgow?

The higher frequency of linking /r/ in the Glasgow data may indicate another model at play. Almost every orthographic /r/ with a following vowel is articulated. This suggests that the singers are paying attention to orthography and raises the potential impact of Labov (1972)'s Attention-to-speech model. That is, in choirs which typically read or learn from sheet music notation, we might expect there to be a greater consistency in phonological realisation driven by orthography. In elite church music contexts, where sight-reading ability is highly prized, and singers pride themselves on their ability to reproduce the 'notes on the page' accurately with minimal rehearsal, what about the realisation of the 'text on the page'? As choral contexts are typically formal and involve reading, and the output of choral singing in these contexts can be conceptualised as read speech, perhaps it is not surprising that the Glasgow singers are consistently articulating /r/ in linking /r/ contexts.

8.7 Conclusion

While previous chapters have shown that there are shared accent features, particularly regarding front vowel phonology and realisation, this chapter has demonstrated that regional consonant phonological features, specifically, rhoticity, do impact the sung signal. That is, the phonology of regional dialects can form part of the sung accent in those regions: the accent of choral singing is not the same in Glasgow and Cambridge. There is a particular 'Scottish note' which in linguistic terms relates to the articulation of postvocalic /r/ and the realisation of /r/ in all contexts. Channelling Scottish identities in choral singing using the phoneme /r/ has changed over time. Earlier in the twentieth century under Roberton, the Orpheus cultivated a distinctly Scottish sound using the alveolar trill which could occur in all positions, but particularly in word-initial position following a pause. Crucially, this realisation of /r/ is independent of genre. Trill realisations reduced over time in recordings of the Phoenix choir in favour of the alveolar approximant [ɹ]. Furthermore, there is a reduction in postvocalic /r/ in recordings of the Glasgow Phoenix Choir in all contexts apart from *car and*. However, linking /r/ is produced categorically in the Glasgow corpus for all Time/Directors. In the King's corpus, linking /r/ is variable (50–75%). Rhoticity is a key stylistic feature of the Scottish choirs, despite reducing in some contexts over time. The reduction in rhoticity in the recordings of the Glasgow Phoenix Choir may be evidence of the impact of a choir director's accent, or perhaps their vision – Marilyn J. Smith may have orientated the choir towards a choral singing referee based on SSBE. Intervocalic taps at King's, while rare, are also evidence of 'upper-crust' RP having an impact on the sung signal in Cambridge. As we have seen, the articulation and realisation of word-final consonants are of particular interest in choral singing and are often commented on explicitly in the choral literature. Chapter 9 will investigate the realisation of word-final voiced alveolar plosives (for example, *Lord*), and whether this principally musical aesthetic variable varies by Time/Director.

Chapter 9

‘O–hel–pu–slor’: Realisation of word-final /d/ in choral singing from Glasgow and Cambridge

Chapters 5, 6, and 7 demonstrated that choirs from an SSBE dialect area and a non-SSBE dialect area exhibit a shared vowel phonology alongside a contrasting consonant phonology; Both corpora show distinct TRAP and BATH phonemes, whereas rhoticity occurs in all contexts in the Glasgow corpus, but only in linking /r/ contexts in the King’s corpus. These findings support both the notion of a wider Standard British Choral Accent (Chapter 7) as well as regional variation in choral singing based on regional spoken accent features (Chapter 8). This chapter investigates a primarily musically and aesthetically motivated variable: word-final /d/ (e.g. *lord*). The realisation of word-final /d/ is particularly salient in Western classical choral singing. Released variants of /d/ could be described as a hallmark of the Western classical choral style, though there is little previously written about them.

Unlike the previous consonant variable postvocalic /r/, /d/ is usually articulated in most varieties of English. /d/ can be phonetically realised as the voiced alveolar plosive [d], it can also be devoiced [d̥], or unreleased [d̚]. In African American English word-final /d/ can also be realised as a glottal stop [ʔ] or deleted (Farrington, 2018). Word-final /d/ can also be deleted in spoken Southern Standard British English and Scottish Standard English. However, glottalisation is typically restricted to the voiceless alveolar stop /t/ in SSBE, whereas it can function as an allophone of /p, t, k/ in Glasgow English (Stuart-Smith, 2007). The present chapter, therefore, presents not a binary analysis of the presence vs absence of /d/ but attempts to capture the range of variation in the realisation of

/d/.

9.1 Previous sociolinguistic research on stops in singing

One of the most salient features of British Englishes, both Anglo and Scottish, is the prevalence of glottal stops as an allophone (potential realisation) of /t/[1]. T-glottalling has been investigated in sociolinguistic studies of popular singing (for example, Trudgill, 1983; Simpson, 1999; Beal, 2009, Westphal & Jansen, 2021). Generally, it has been interpreted that if bands want to align themselves with the pop standard, they produce tap [ɾ] variants of /t/, as in the USA-5 model (Trudgill, 1983; Simpson, 1999). If bands want to index a regional identity, then they diverge from the norms of the reference style by selecting regional variants; For many British bands, this meant employing the glottal stop [ʔ] variant, for example: Ian Drury (Trudgill, 1983), Dire Straits (Simpson, 1999), Arctic Monkeys (Beal, 2009), and most recently, Stormzy (Westphal & Jansen, 2021). In the sociolinguistic singing literature, much less attention has been paid to the realisation of the voiced alveolar plosive /d/.

9.2 Motivation for word-final /d/

Many choral conductors that have written about diction in choral singing in English have noted variation in the realisation of word-final, and particularly, phrase-final consonants. For example, Roberton, writing in 1929 (in Roberton, 1963) illustrates the perceptual salience of word-final consonants in choral contexts:

> We got this recently from the men:
>
> *When–nyam–deh*
>
> For some time we could not make it out. And then it dawned on us that the pretty creatures were trying in their own delightful way to give us a little bit of Christina Rossetti – 'When I am dead.'. And, some quite charming sopranos, whose sense of propriety in other things is unimpeachable, will and do give us this regularly:
>
> *O–hel–pu–slor*
>
> under the mistaken idea that they are singing – 'O help us, Lord!' We

[1] In some varieties of English, other stops can be replaced with glottals including /p/, /k/ and /d/ – but these instances are comparatively very rare.

> would never think of mentioning such trifles were it not that this sort of thing happens to kill the verbal rhythm and is responsible for all kinds of vocal offences besides. Why are singers so afraid to *close* words which have consonant endings? Not one singer in a hundred can sing 'and'. It scares them to death (Roberton, 1963, p. 50).

The quote from Roberton (1963) demonstrates the salience of word-final consonants. He implies that singers are naturally inclined not to 'close' syllables, that is, articulate word-final consonants. As a remedy to this, many choral conductors explicitly promote the use of 'shadow vowels' (epenthetic vowels), as in *lord* realised as [lɔːdᵊ] or [lɔɹdᵊ], to increase the audibility of final consonants (for example, Coward, 1914; Cappadonia, 1962; Moore, 1972; Decker, 1977; LaBouff, 2008; Neuen, 2020). For example, LaBouff writes:

> To eliminate this problem, sing a *shadow vowel*: a short vowel with the release of the final consonant. The preferred vowel to sing would be a short 'ih' vowel [ɪ] rather than a schwa [ə], which makes English start to sound very Italianate (LaBouff, 2008, p. 136).

Neuen gives justification for the use of epenthetic vowels following final consonants, arguing that the 'preceding vowel and/or the accompaniment usually covers them up' (Neuen, 2020, p. 78). While shadow vowels are recommended additions for all phonologically voiced English word-final consonants, there is a special focus on word-final and phrase-final /d/, which needs extra attention to ensure audibility in singing (Henkel, 1965). Johnston writes that one of the pitfalls for learning to sing in English is the voicing of final voiced consonants:

> This is a challenge for German native speakers (hand [hænd] vs. Hand [hant]), especially in words borrowed from German. However, this error is rampant among English native speakers as well, and often is a result of simple carelessness or anticipating the formation of the next word (Johnston, 2016, p. 139).

However, Johnston advocates against using shadow vowels: 'As in German, English consonants should always be merged without the occurrence of an intrusive vowel (a.k.a. shadow vowel), resulting from a drop or movement of the articulators. Moreover, the expressive doubling of certain consonants is highly encouraged as a means of word-painting' (2016, p. 131). It appears, therefore, that there are different schools of thought within the classical singing literature about when consonants should be released or unreleased and whether shadow vowels should be used between consonants across words–or phrase-finally.

In interviews with adolescent choristers in Trinidad, (Wilson, 2014) finds that consonant clusters [nd] and [st] are particularly salient. The choristers thought their directors preferred the canonical pronunciations [land] and [best] over the local accent pronunciations [lan] and [bes], which they sometimes produced in singing. Some of the choristers indicated that [lan] could be avoided by adding an epenthetic schwa, as in [landᵊ] (Wilson, 2014, pp. 141–2). This indicates that the realisation of word-final /d/ may be sociolinguistically salient to listeners. Furthermore, as choirs are typically 'sight-reading' from sheet music, and in the previous chapter on /r/, I found possible evidence of the attention to speech model at work, word-final /d/ may be doubly salient in choral singing. I will now outline how stops, the family of consonants that /d/ belongs to, are produced.

9.2.1 What are stops?

Stops, also known as plosives, are a family of consonants produced with the same manner of articulation, usually described as having three phases: closure, hold, and release. Stops require a complete closure of the oral vocal tract, allowing air pressure to build up behind the obstruction. After some time, the articulators part and the pressure is released as a small burst or puff of air (Catford, 2002). Plosives are stops produced with a complete closure of the oral tract with the velum raised (Ogden, 2009).

The location of the closure (place of articulation) can vary. For example, in English stops, the closure can take place at the lips (as in /p/ *pear*), at the alveolar ridge (as in /t/ *tear*) or at the velum (as in /k/ *care*). At each place of articulation, the consonant produced can either be phonologically voiced or voiceless (for example, /p/ as in *pear* vs /b/ as in *bear*). However, as we shall see, whether a consonant is voiced or voiceless is determined by a complex bundle of cues.

In English, stops can appear in word-initial, word-medial or word-final positions (e.g. *dart* /dɑːt/ *darting* /dɑːtɪŋ/). They can also appear in clusters (e.g. *drink*, *cards*). Both word position and surrounding phonetic context can affect the realisation of the stop. This chapter focuses on the voiced alveolar plosive /d/ in word-final position. This position was selected partly to limit the scope of the research, but it is also theoretically motivated, from both musicological (Roberton, 1963) and linguistic perspectives, as word-final stops may be more salient than in other contexts; Davidson (2011) writes:

> Since word-final position is presumably more perceptually salient than word-internal or phrase-medial positions, it is more likely that speakers would implement a stylistic use of release in this position than in pre-consonantal positions (Davidson, 2011, p. 1050).

9.2.2 Phonological stop voicing

In some languages, for example, Hungarian, phonological voicing contrasts (e.g. /p – b/) are simple in that they map directly onto phonetic voicing. That is, whether there is phonetic voicing or vibration produced by the vocal folds ('buzzing noise').[2] For example, In Hungarian, the phonological contrast /p – b/ maps directly onto the phonetic contrast [p] (voiceless, −buzzing) – [b] (voiced, +buzzing). However, there is no direct relationship in English between phonological and phonetic voicing, as English 'voiced' stops are often phonetically voiceless – produced with little or no vocal fold vibration during the closure phase. If it is not phonetic voicing that makes a stop phonologically 'voiced' or 'voiceless' in English, then what does? As we shall see, there are, in fact, a multiplicity of cues that affect the perception of stop voicing in English, and these can vary by phonetic context.

9.2.3 Cues to phonological stop voicing in word-initial position

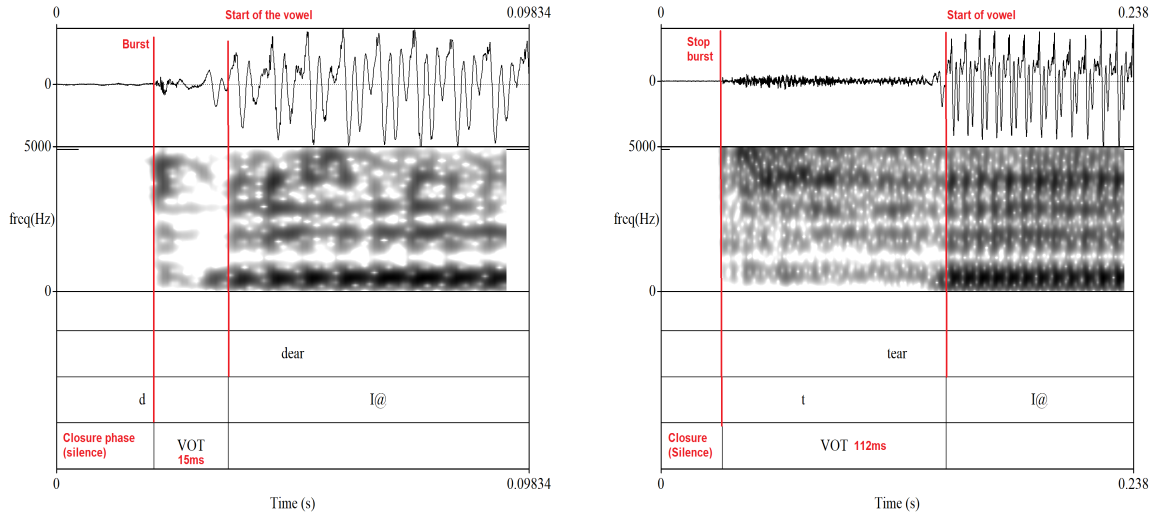
Voice Onset Time

In a study of isolated words in 11 languages, Voice Onset Time (VOT) was found to be the principal cue distinguishing voiced and voiceless stops in word-initial position (Lisker & Abramson, 1964). As shown in Figure 9.1, VOT is the period of time between the stop burst and the onset of voicing. In English, voiced stops tend to have a short positive VOT (in Figure 9.1, /d/ in *dear* has a VOT of 15 ms), whereas their voiceless counterparts (in Figure 9.1, /t/ in *tear* has a VOT of 112 ms) tend to have a much longer VOT. In other languages, for example French, the onset of voicing precedes the stop burst leading to negative VOT.

VOT correlates with other dimensions, including phonetic voicing (vibration or buzzing produced in the larynx) and aspiration (rush of air passing through the vocal tract, similar to glottal fricative [h]). As noted by Lisker & Abramson (1964), in English long VOT equates to a longer period after stop release, or aspiration, and aspirated stops, so /p t k/ are phonetically [p^h t^h k^h]. In contrast, short VOT, equates to no or little aspiration, typical of English /b d g/, and English speakers hear them as 'voiced stops', even though there is often very little vocal fold vibration.

In connected speech, there is some overlap between the VOT distributions of voiced and voiceless stops (Lisker & Abramson, 1967). Initial voiceless stops in

[2] Vocal fold vibration can be felt by placing your hand on your larynx (Adam's apple) and comparing the sensation when speaking and whispering.



(a) Dear (b) Tear

Figure 9.1: An example of Voice Onset Time (VOT) in English. *dear* (VOT 15 ms) and *tear* (VOT 112 ms) produced by the researcher.

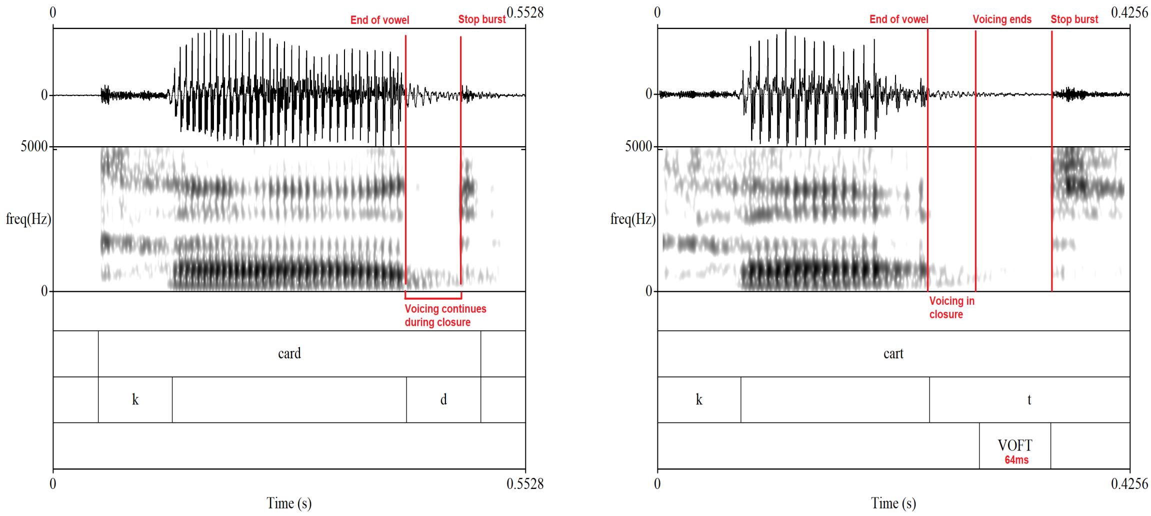
stressed syllables have longer VOT than in unstressed syllables (Lisker & Abramson, 1967). Pre-voicing–lead voicing in voiced stops /b, d, g/ tends to only be found in careful rather than casual speech. This is potentially important, since in choral singing, attention to speech production is high, particularly relating to consonants. In a study of American English stops, five professional male singers produced significantly longer VOT for voiceless stops in speech compared to five male non-singers; VOT was found to be longer in singing for voiceless stops than in speech overall (McCrea & Morris, 2005). However, this effect was not replicated in further studies with more singers and female singers (McCrea & Morris, 2007b; McCrea & Morris, 2007a).

9.2.4 Cues to phonological stop voicing in word-final position

Voice Offset Time

For voiced stops in coda position (e.g. *good*), there is no measurable Voice Onset Time (Lisker & Abramson, 1967). To quantify voicing in word-final stops, Hillenbrand et al. (1984) posited a ‘voice offset time’. This is the period of time between the end of the preceding voiced segment and the stop burst, as shown in Figure 9.2.

Hillenbrand et al. (1984) found that in stop-vowel-stop sequences, voicing in voiceless stops ceases when the closure is complete, whereas in voiced stops voicing continues for some time into the closure. However, it can be difficult to locate the exact point of closure. Research using VOFT is often ‘limited in scope due to the inherent difficulty in the extraction of VOFT’ (Singh et al., 2016).



(a) Card (b) Cart

Figure 9.2: An example of Voice Offset Time (VOFT) in English. *card* (VOFT 0 ms) and *cart* (VOFT 64 ms) produced by the researcher.

Docherty (1992) investigated the phonation of obstruents in Southern British English, finding that voiced stops in word-initial position were completely devoiced in isolation and when preceded by a voiceless consonant. In contrast, final stops showed partial or full voicing in all contexts. Davidson (2016) investigates the degree of phonation in phonologically voiced obstruents in American English, finding that the proportion of voiced stops partially or fully voiced is, in word-initial position 0.25, in word-medial position 0.8, and word-final position 0.57. Davidson finds that 'obstruents that are preceded by a stressed vowel are fully voiced significantly more often' (Davidson, 2016). However, as noted in Chapter 7, the relationship between sung syllables and stress is complex. Importantly, Davidson finds that adjacent obstruents are likely to cause devoicing even when they are voiced (e.g. *good boy*).

Hillenbrand et al. (1984) find that voicing during closure is not essential to perceiving a 'voiced' stop. They write that 'it appears as though the tendency of speakers to devoice is supported by perceptual strategies on the part of listeners that do not rely on the presence versus absence of closure voicing' (Hillenbrand et al., 1984, p. 24). If voicing during closure is not essential to the stop voicing distinction, what factors help listeners distinguish between *back* /bak/ and *bag* /bag/?

Vowel duration

Vowel duration has been noted as a cue to syllable-final consonant voicing identity (Chen, 1970). In a perceptual experiment based on synthetic stimuli, vowel duration was a sufficient cue to stop voicing identity, with phonetic voicing attributed less weight (Raphael, 1972). However, pertinent to the present research, 'expanding vowel durations of naturally produced syllables ending in voiceless stops does not result in voiced stop judgements' (Hillenbrand et al., 1984, p. 19). Fisher writes that:

> substitution of musical features for speech prosodic features such as tempo, rhythm, intonation, accent, and duration results in the removal of various cues critical for accurate language perception (Fisher, 1991, p. 272).

What are the salient acoustic differences between syllable-final voiced and voiceless stops when the music (at least partly) dictates vowel duration? In addition, from my experience, closure duration, voicing during the closure, and burst amplitude are variables that choir conductors attempt to unify within a group of singers. Cues to consonant identity may be different and/or weighted differently in singing than they are in speech.

F1 transition

In addition to vowel duration: F1 transition and characteristics of the burst also play a role in determining the phonological voicing identity of syllable-final voiced stops (Wolf, 1978). Wolf concludes that these, together with phonetic voicing, all affect the amount of low-frequency energy in the signal, which is greater for voiced stops than for voiceless stops. Olive et al. write that 'the factor which most contributes to the correct perception and identification of any voiced stop is the transition or formant movement toward the stop in the sound coming into the closure, and movement away from the stop immediately following the burst' (1993, p. 88). Voiceless stops tend to have a higher burst amplitude, and display F1 'cutback' – a reduced amplitude in the F1 region at the start of the following vowel (Liberman et al., 1958). Perhaps, therefore, F1 cutback is an important factor in distinguishing voiced and voiceless stops in singing, as it may not be prescribed by the music in the same way that duration may be.

9.2.5 Variation in the realisation of word-final stop burst

In addition to voicing, there are a number of features of stops which can vary, including aspects relating to the release (or burst). This section will briefly outline how word-final stop releases can manifest. Stops can be articulated, or deleted. For example, the word-final /d/ in *confounded* /kənˈfaʊndɪd/ could be articulated [kənˈfaʊndɪd] or deleted [kənˈfaʊndɪ∅]. Deletion is promoted in word-final unstressed syllables. Stops that are articulated (i.e. not deleted) can be released or unreleased. For example, *good* /gʊd/ can be released, as in [gʊd], or unreleased as in [gʊd̚], which means that there is a normal closure and hold phase, but there is no burst. Unreleased tokens are more common in word-final contexts (Lisker & Abramson, 1967), or when preceding another stop, for example, *good boy* = [gʊd̚bɔɪ]. Tokens of /d/ that are both articulated and released can differ in various aspects of the release. The loudness of the stop burst can vary. For example, voiceless stops have a higher burst amplitude (create more displacement, heard as loudness) than voiced stops. Of particular relevance to this study is affrication. When the articulators part to produce the stop burst, they can stay close together, such that when the air passes through it creates a friction that we associate with sibilants, such as /s/ *sue*, or /ʃ/ *shoe*. I will now go into some of these issues in more depth.

Coarticulation and Assimilation

Surrounding phonetic context can affect voicing and burst characteristics. For example, assimilation in consonant clusters can cause devoicing of voiced phonemes or voicing of voiceless phonemes such that clusters are made up of all voiced or voiceless consonants (Olive et al., 1993, p. 36). Stops in word-final position are more likely to be unreleased (Lisker & Abramson, 1967). Byrd (1993) reports 880 cases of utterance-final alveolar stops, of which 57% were released. Davidson (2011) investigates the factors affecting stop release in consonant clusters in spontaneous speech. Stop clusters can occur within word (e.g. *chipmunk*, *bookmark*, *rugby*), or across word-boundary (e.g. *pig pen*, *sack bag*). Davidson also investigates stops in pre-pausal contexts (e.g. *I look up*, *I go out*). Contrary to linguistic received knowledge, 25% of stops followed by another stop were released, but this was conditioned by the place of articulation of the initial stop and the manner of articulation of the following stop (Davidson, 2011). Alveolar stops [t] and [d] are more likely to be glottalised or deleted than stops produced at other places of articulation (Davidson, 2011).

Davidson (2011) notes that 'increased prevalence of stop release may be a hallmark of a more careful or formal speech register, such as read speech' (Davidson, 2011, p. 1056). Perhaps we can expect to find more released stops in choral singing, as it is analogous to a more formal speech register. There are also stylistic considerations relating to double consonant realisation in singing. There is some disagreement in the choral community and it is partly a matter of taste – and/or depends on individual cases and the tempo of the music. For example, Neuen (2020) writes:

> In classical music, double consonants such as T's or D's should both be slightly articulated: 'Night to', 'God did.' In pop, country and other music in which we emphasize a natural speaking style (as opposed to a bel canto singing style), we would employ the stop-consonant, which is

> a very brief staccato/stop on the first word: ‘night’ immediately followed by ‘to’ = ‘nigh-to’, as though it were one word (Neuen, 2020, p. 79).

Note that, in the quote above, I interpret Neuen’s use of the term ‘stop consonant’ to refer to no audible release. However, it is clear that the realisation of double consonants may differ between genres of singing.

Coarticulation tends to be viewed negatively in the singing literature. For example, Fisher writes, ‘coarticulation which is common to spoken language has no practical purpose in sung language where textual elements are subject to the tempo and rhythm of the musical piece (except in rare situations where the tempo of the piece is 120 beats/minute or above and approaching a tempo similar to that of common speech)’ (Fisher, 1986, p. 17). Similarly, LaBouff comments on the realisation of $< tr >$ and $< dr >$ clusters which, in speech, ‘are often mispronounced colloquially as [t͡ʃɹ] or [d͡ʒɹ]. This pronunciation, though incorrect, does project better over an orchestra and takes less air to produce’ (LaBouff, 2008, p. 125). LaBouff once again demonstrates the prescriptive language ideologies embedded in the singing pedagogical literature through the use of terms such as ‘incorrect’ or ‘mispronounced’ (see Chapter 2 Section 2.2.4).

Affrication

Stops can be released into a period of frication. It is very common in English for /t/ to be realised as [t^{s}] and can also occur for /d/, being realised as [d^{z}] (Lindsey, 2019, p. 56). Stops can be affricated in both Southern Standard British English (Cruttenden, 2014; Lindsey, 2019; Ogden, 2009) and Scottish Standard English (Chirrey, 1999). Most recently, Dodsworth & Mielke (2022) have found that pre-pausal tokens of /t/ and /d/ from Raleigh, North Carolina are increasingly affricated.

There is debate in the linguistic literature about whether stop affrication represents lenition (i.e. weakening) or fortition (strengthening). In a study of /t/ affrication in RP, Buizza & Plug (2012) find that affricated variants of /t/ have a significantly longer duration, as well as having a higher mean amplitude in the release phase than other variants of /t/. Affricated variants comprise 10% of their /t/ data; For adjacent /t/ and /d/, they find that the first /t/ in /t t/ sequences, where both consonants are realised, is often affricated (Buizza & Plug, 2012). Their conclusion that stop-affrication represents strengthening (fortition), rather than weakening (lenition), complements the singing literature, which recommends ‘wet t/d’ (stop-affrication) for audibility. For example, LaBouff (2008) writes:

> With thick accompaniment or orchestration, use a wet t/d to project. A wet t/d has a forward-placed vowel released with it. Release final t's with a whispered [i] vowel following it. A final d is released with an [ɪ] vowel following it.
> E.g. night [naɪt$^{(\text{ɪ})}$]
> This final wet t sounds similar to the percussion instrument, the high hat (LaBouff, 2008, p. 124).

Musicologist Williams (2019) writes that diction, pronunciation, and speed altered at King's, under the direction of David Willcocks, noting that 'Willcocks himself attributes this shift to the requirements of singing with orchestral instruments as well as the organ' (Williams, 2019, p. 58). Taken together with LaBouff's comments, we might predict that affrication of /t/ and /d/ increased under Willcocks' tenure due to the new constraint of performing with orchestral accompaniment (see Chapter 3 Section 3.6.3).

Stop affrication has also been noted in studies of popular singing. Simpson (1999) reports affrication of word-initial voiced and voiceless alveolar stops (/t/, /d/) in the singing of Liam Gallagher, lead singer of the Manchester rock band, Oasis. Simpson interprets this as the influence of the culturally prominent Liverpool band, the Beatles (as affricated stops are a feature of Liverpool English speech). While this is possible, it does not provide an explanation for why affricated variants may be present in Western classical singing. Increasing affrication may be part of a larger change in progress in global English and also goes hand-in-hand with singing pedagogy.

9.2.6 Regional variation in the realisation of stops

Received Pronunciation was less aspirated than Southern Standard British English, with a generally shorter voice onset time regardless of word stress; Affrication was also less frequent in RP than in SSBE (Lindsey, 2019, pp. 55–56).

Scottish English voiceless plosives (/p, t, k/) were reported to be less aspirated than in other varieties of British English (Catford, 2002; Masuya, 1988; Wells, 1982a). More recently, Stuart-Smith et al. (2015) find that VOT in both voiceless and voiced stops lengthens over time in recordings of Glasgow vernacular English. Averaging over all variables, including time, the model estimates reported are 46.5 ms for voiceless stops and 15.5 ms for voiced stops. Docherty et al. (2011) finds that /p, t, k/ have 10 ms shorter VOT on the Scottish side of the border (Eyemouth) compared to north-east England (Berwick-upon-Tweed). They also report a significant effect of age group such that younger speakers no longer pre-voice.

The stop voicing contrast in Scottish English has shifted over time from being cued by phonetic voicing to being cued mainly by VOT (aspiration) (Stuart-Smith et al., 2015). Sonderegger et al. (2020) demonstrates this change in cue prominence in Scottish spontaneous speech over the twentieth century finding an increase in the use of VOT, compared to phonetic voicing during the closure, perhaps showing an increasing alignment with the Anglo-English stop voicing contrast.

9.2.7 Phonetic variants of /d/

In word-final pre-vocalic position (e.g. *and again*) /d/ is most often realised as a voiced normally-released [d]. In word-final pre-pausal or pre-consonantal position in English speech, stops are often unreleased, meaning there is no audible burst [d˺]. As we have seen, in singing, to improve audibility, shadow vowels are prescribed, for example, [d^{ə}] as in [land^{ə}]. Both normally-released and shadow vowel realisations can also be affricated, for example, [d^{z}], or [d^{z}ə].

Where there is no shadow vowel, there is an increased likelihood of devoicing as phonetic voicing is variable at the end of utterances in spoken English (Davidson, 2016). Voiceless variants in this study are classed into two categories [t] (unaspirated/unaffricated) and [t^{s}] (aspirated/affricated). It is also possible to have no auditory percept of /d/ at all (deletion), particularly before fricatives (for example, *and saw*). Thus there is a final category [∅].

9.3 Predictions for word-final /d/ analyses

In Chapters 5, 6, and 7, I found evidence of shared accent features of British classical choral singing in the vowel inventory. In Chapter 8, I reported regional variation in rhoticity. In the present chapter, the realisation of word-final /d/ is investigated with respect to all research questions, which are restated here as follows: 1) Are there regional differences in the realisation of word-final /d/ between Glasgow and Cambridge? 2) Does realisation of word-final /d/ provide evidence of a common choral accent between these regions? 3a–c) Is there evidence of change over time in the realisation of word-final /d/, and if there is change, can that change be attributed to changes in spoken language, choral aesthetic, or individual choir directors?

9.3.1 /d/ voicing

In this chapter, I analyse auditory coded realisation of word-final /d/. For the independent variable /d/ voicing, the phonetic categories are grouped into two factor levels 'Voiced' and 'Voiceless'. Based on Day (2018)'s comments about David Willcocks' style ('ent they shell stent'), we might expect more voiceless and/or affricated realisations of /d/ under David Willcocks than previously. Based on phonetic research, we might expect recordings of the Glasgow choirs to have more voiced variants overall and less aspiration (Wells, 1982a; Masuya, 1988; Catford, 2002), though these differences to Southern Standard British English may have lessened over time (Stuart-Smith et al., 2015).

9.3.2 /d/ affrication

For the dependent variable /d/ affrication, the phonetic categories are grouped into two factor levels ‘Affricated’ and ‘Not affricated’. In the singing literature, affricated realisations of stops are prescribed when the singer is required to project in a large acoustic or over orchestral accompaniment (LaBouff, 2008). It has been noted that there was a change to the King’s sound under the direction of David Willcocks, which he himself attributed to more frequent singing with orchestral accompaniment (Day, 2000; Williams, 2019). Perhaps, therefore, we could expect more affricated tokens under David Willcocks than under his predecessor Boris Ord. Similarly, the Orpheus and Phoenix choirs rarely sang with accompaniment, and when they did, mainly with piano and organ. Consequently, we might expect fewer affricated stops in the Glasgow corpus than in the King’s corpus. An increase in affrication over time in the King’s data would also be supported by change over time from RP to SSBE (Lindsey, 2019). There is also evidence of an increase in affrication in SSE over time (Chirrey, 1999), so it would be unsurprising to find increasing affrication in the Glasgow corpus.

9.3.3 /d/ variants

For the multinomial (or Softmax) /d/ variants analysis, the phonetic categories are grouped into four factor levels: the reference level ‘d’ = [d]; ‘D’ = [dᵊ], ‘u’ = [d̚], ‘t’ = [d̥]. Specific questions that can be answered using this approach include: is there a difference in the relative frequency of unreleased tokens [d̚] or shadow vowel tokens [dᵊ] between the corpora? Are there particular types of realisation, beyond the macro binary categories of voicing and affrication, which can be said to characterise the individual choirs’ sounds?

9.4 Method

As laid out in Chapter 4, all vowel and consonant phonemes were annotated using the CELEX-English dictionary and automatically segmented and aligned using the HTK forced aligner. This allowed me to search for all word-final tokens of the voiced alveolar plosive /d/. I searched the orthography layer using the regex ‘.*d’ (searching for words that end in $< d >$). As I was listening to the /d/ tokens, I conducted further hand-correction at the phone level; however, in choral singing data, it is not possible to accurately segment the phases of the stop due to the coordination problem. This means that we cannot calculate VOT and analyse VOT as a cue to voicing in choral singing, and this is largely why I adopted an auditory approach.

9.4.1 Auditory coding of word-final /d/

For an overview of the auditory coding method, see Chapter 4 Section 4.4. As with the previous chapter on rhoticity, this analysis will be conducted on auditory-coded data. I systematically listened to the audio files in conjunction with a visual inspection of the spectrogram and waveform. I carried out a phonetic transcription, which resulted in the following fine-grained phonetic categories:

- [d^{ə}] – hyper voiced (with shadow vowel/epenthetic schwa)
- [d^{zə}] – hyper voiced + affricated/aspirated
- [d] – 'normal' (audible burst, usually elided with following syllable)
- [d^{z}] – 'normal' + affricated/aspirated
- [d̚] – unreleased (no audible burst)
- [t] – voiceless unaspirated/unaffricated
- [t^{h}] – hyper voiceless (aspirated/affricated)
- [Ø] – zero (no audible percept of /d/)

Differentiating Affricated realisations from Aspirated realisations auditorily was non-trivial, so these instances were combined. The affricated/aspirated tokens are visible in spectrograms as clouds of high-frequency energy in the 6–10 kHz range, which more closely resemble fricatives in nature than aspiration which occurs at lower frequency (Buizza & Plug, 2012). As shown in Figure 9.3, affricated realisations of /d/ are often indistinguishable from the typically aspirated realisations of /t/.

9.4.2 Word-final /d/ phonetic contexts

For the analyses reported in this chapter, /d/ is always postvocalic, that is, following a vowel (for example, *good*). The preceding vowels are almost always

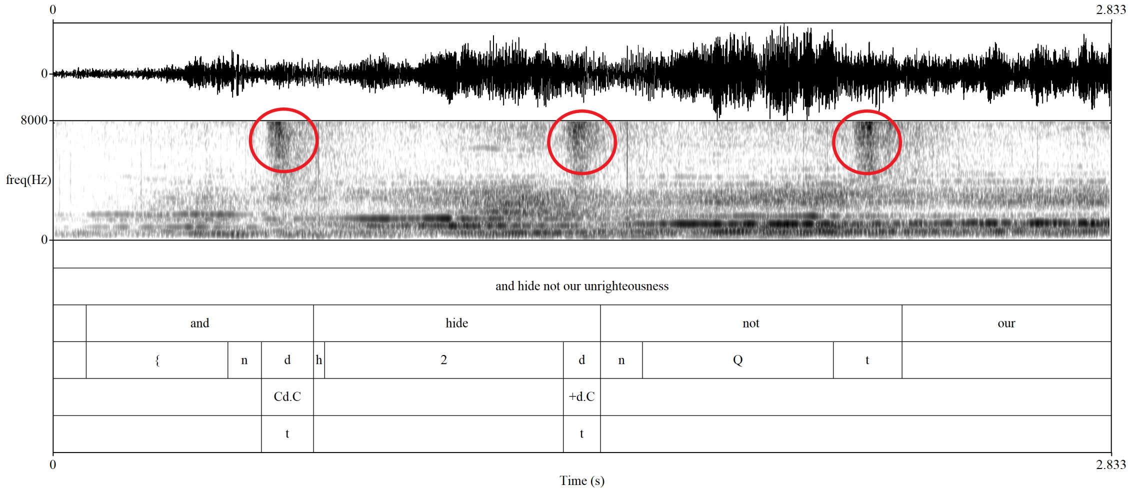


Figure 9.3: Waveform spectrogram of affricated realisations of /d/ with /t/ for comparison. Example from *Hide not Thou Thy face from us* from the LP 'Evensong for Ash Wednesday (1964)'. Recording by the Choir of King's College Cambridge, directed by David Willcocks.

stressed (as we have seen, vowels in singing are more often stressed than in speech), so the preceding context is controlled for and not explicitly included in the model. However, any effect of stress will also be partially accounted for by the varying effects structure, which includes intercepts for Word, and by Corpus or by Time/Director slopes for Word.

The following phonetic context has been shown to affect the realisation of word-final /d/. For example, a following pause increases the likelihood that /d/ is unreleased (Davidson, 2011). Therefore, following context is explicitly included in the model. Optimally, I would include following segment (with a level for each type of following consonant, vowel, or pause); however, as there are fewer tokens of /d/ than for the vowel analyses, I decided to collapse to a three-level factor Context with the levels: 'd.V' following vowel (e.g. *good apple*, *and again*); 'd.C' following consonant (e.g. *good boy*, *and saw*); and, 'd#' following pause.

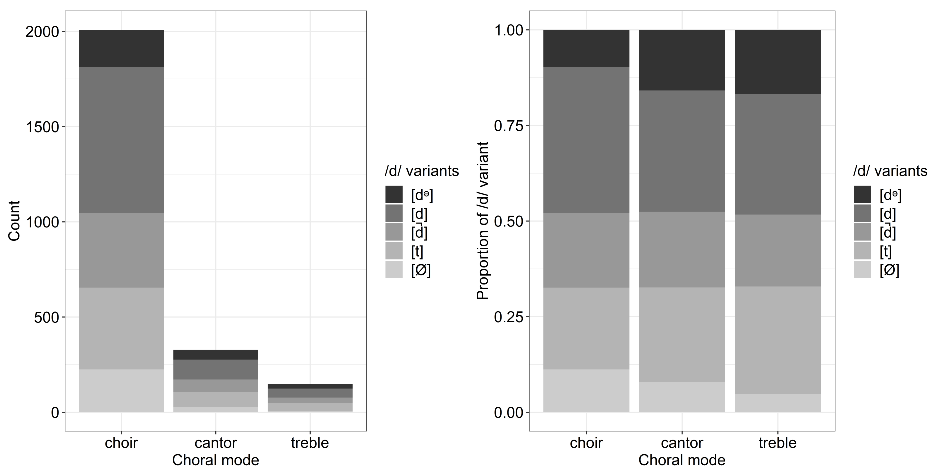
9.4.3 Exclusions

Davidson (2011) excludes the function word *and* due to extreme reduction. However, in the data reported in this chapter, *and* is not reduced to the extent found in speech – apart from in some rare cases. Following Gibson & Bell (2012), I decided to include function words where they were not reduced. Additionally, Davidson (2016) excludes /d/ before /t, d, ð/ 'since /d/ was never released in this environment and therefore could not be distinguished from the following sound' (Davidson, 2016, p. 36). However, in these corpora, the realisation is variable; as Neuen (2020) notes, double consonants are usually articulated in classical choral singing.

As with the vowels analysis, any tokens where multiple different words were being sung at once were excluded. Any instances of audible noise that were visible in spectrograms, such as clicks that were artefacts of the recording or digitisation process, were discarded. There were 3,755 tokens coded. 169 tokens were excluded, leaving 3,586 tokens. Of these, 373 tokens were deletions. These were also removed, leaving 3,213 tokens for analysis.

9.4.4 King's choral mode

Individual variation in solo excerpts might affect the distribution of variants in the King's corpus. There are substantial amounts of cantor singing in recordings of Choral Evensong and solo treble singing, for example, in recordings of *Once in Royal David's City* (which occurs 16 times in the King's corpus). As word-final consonants are particularly salient and subject to individual variation, I decided to explore the effect of choral mode in the King's data prior to analysis. I coded the data into three categories, Cantor (solo adult male singer, leading worship), Treble (solo boy singer), and Choir (full choir/section of the choir). Figure 9.4 shows count and proportion data for the distribution of word-final /d/ variants for the choral modes: 'choir', 'cantor', and 'treble'.



(a) Count (b) Proportion

Figure 9.4: King's /d/ variants by choral mode

As the categories 'cantor' and 'treble' constitute only ∼20% of the total data, and the distribution of /d/ variants across the three choral modes is roughly equal, I decided to collapse the levels and analyse all tokens together. There are no solo excerpts in the Glasgow corpus, and few examples of one section of the choir singing at a time (e.g. soprano, alto, tenor, or bass), so I did not code choral mode for the Glasgow corpus. The effect of choral mode was not considered an issue in the vowels analyses, as it will have had a more limited impact on the formant means.

9.4.5 Summary of word-final /d/ analyses

In the next section, I present the results of three analyses. First, a binary analysis of Voicing – whether a token is 'voiced' or 'voiceless'. Second, a binary analysis of Affrication – whether a token is affricated/aspirated or not. Thirdly, a variant analysis within each corpus. These analyses are exploratory, not confirmatory. For example, there is no published data on the affrication of word-final stops in choral singing, nor, as far as I am aware, anything published on the stop voicing contrast in singing. I do not have specific hypotheses based on existing data. As I am working with corpus data rather than experimental data, I am not able to manipulate specific elements in order to test hypotheses. There are tendencies that we expect based on speech data, singing handbooks, musicological descriptions of choral singing, and arising from listening to the recordings during the auditory coding. As detailed below, this results section features nine models, which form three groups.

9.4.6 Modelling realisation of word-final /d/

The data were analysed with Bayesian binomial logistic mixed models and Bayesian multinomial mixed models using `brms` (Bürkener, 2018) [version 2.18.0] in R (R Core Team, 2021) [version 4.1.2]. Tables were produced with `xtable` (Dahl et al., 2019) [version 1.8-4] and `BayesPostEst` (Karreth et al., 2021) [version 0.3.2]. The model structures were:

/d/ voicing

```
Combined_binary_d_voicing ~ Corpus + Context + Corpus:Context +
(1|Album) + (1|Song) + (1|Corpus:Word)

Glasgow_binary_d_voicing ~ Time/Director + Context +
Time/Director:Context +
(1|Album) + (1|Song) + (1|Time/Director:Word)

Kings_binary_d_voicing ~ Time/Director + Context +
Time/Director:Context +
(1|Album)+ (1|Song) + (1|Time/Director:Word)
```

/d/ affrication

```
Combined_binary_d_affrication ~ Corpus + Context + Corpus:Context +
(1|Album) + (1|Song) + (1|Corpus:Word)

Glasgow_binary_d_affrication ~ Time/Director + Context +
```

```
Time/Director:Context +
(1|Album) + (1|Song) + (1|Time/Director:Word)

Kings_binary_d_affrication ~ Time/Director + Context +
Time/Director:Context +
(1|Album)+ (1|Song) + (1|Time/Director:Word)
```

/d/ variants

These are multinomial/categorical models. For the Corpus comparison model, the dependent variable is a categorical variable with 4 levels ('D' = [də], [d^zə]; 'd' = [d], [d^z]); 'u' = [d˺]; 't' = [t], [t^s]). Deleted tokens [Ø] were removed from this analysis. The variant 'd' was selected as the reference level as it is the most frequent overall. The model structure that I report for the combined corpus model is:

```
d_variants ~ Corpus + Context + Corpus:Context +
(1|ID1|Album) + (1|ID2|Song) +
(1|ID3|Word) + (1|ID4|Corpus:Word)
```

I then ran separate models to investigate change over time within each corpus:

```
Glasgow_d_variants ~ Time/Director + Context +
Time/Director:Context + (1|ID1|Album) + (1|ID2|Song) +
(1|ID3|Word) + (1|ID4|Time/Director:Word)

Kings_d_variants ~ Time/Director + Context +
Time/Director:Context + (1|ID1|Album) + (1|ID2|Song) +
(1|ID3|Word) + (1|ID4|Time/Director:Word)
```

9.5 Results

The raw data, code and models reported in this chapter can be found on the OSF at osf.io/8xgwk. Table 9.1 summarises the distribution of /d/ variants by Corpus. Table 9.2 breaks this down by the following Context.

Table 9.1: Distribution of /d/ variant by Corpus. Percentage rounded to 1 decimal place.

Corpus	Variant	N	(%)
Glasgow	[d^{ə}]	207	18.8%
Glasgow	[d^{zə}]	34	3%
Glasgow	[d]	277	25.2%
Glasgow	[d^{z}]	134	12.2%
Glasgow	[d̚]	183	16.6%
Glasgow	[t]	134	12.2%
Glasgow	[t^{s}]	17	1.5%
Glasgow	[Ø]	115	10.5%
Cambridge	[d^{ə}]	168	6.8%
Cambridge	[d^{zə}]	103	4.1%
Cambridge	[d]	385	15.5%
Cambridge	[d^{z}]	535	21.5%
Cambridge	[d̚]	484	19.5%
Cambridge	[t]	196	7.9%
Cambridge	[t^{s}]	356	14.3%
Cambridge	[Ø]	258	10.4%

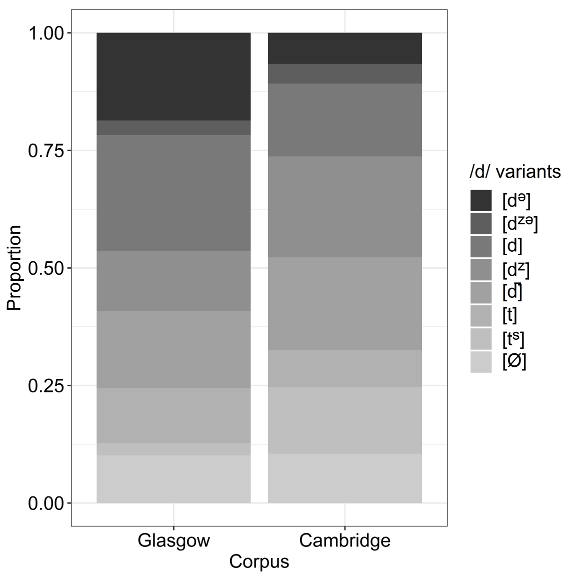


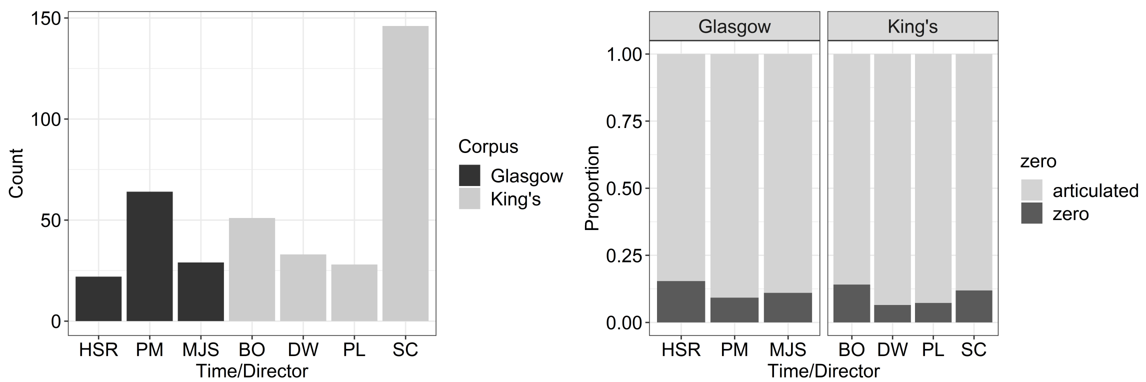
Figure 9.5: Proportion of word-final /d/ realisations by Corpus

Table 9.2: Distribution of /d/ variants by Corpus and Context. 'd.V' = following vowel, 'd.C' = following consonant, 'dp' = following pause. Percentage rounded to 1 decimal place.

Corpus	Context	Variant	N	(%)
Glasgow	d.V	[d]	181	76.4%
Glasgow	d.V	[dᶻ]	32	13.5%
Glasgow	d.V	[d̚]	15	6.3%
Glasgow	d.V	[t]	5	2.1%
Glasgow	d.V	[Ø]	4	1.7%
Glasgow	d.C	[dᵊ]	122	20.8%
Glasgow	d.C	[dᶻᵊ]	15	2.6%
Glasgow	d.C	[d]	85	14.5%
Glasgow	d.C	[dᶻ]	71	12.1%
Glasgow	d.C	[d̚]	124	21.1%
Glasgow	d.C	[t]	52	8.9%
Glasgow	d.C	[tˢ]	9	1.5%
Glasgow	d.C	[Ø]	109	18.6%
Glasgow	dp	[dᵊ]	85	30.7%
Glasgow	dp	[dᶻᵊ]	19	6.9%
Glasgow	dp	[d]	11	4%
Glasgow	dp	[dᶻ]	31	11.2%
Glasgow	dp	[d̚]	44	15.9%
Glasgow	dp	[t]	77	27.8%
Glasgow	dp	[tˢ]	8	2.9%
Glasgow	dp	[Ø]	2	0.7%
Cambridge	d.V	[dᵊ]	1	0.2%
Cambridge	d.V	[d]	256	48.1%
Cambridge	d.V	[dᶻ]	130	24.4%
Cambridge	d.V	[d̚]	104	19.6%
Cambridge	d.V	[t]	12	2.3%
Cambridge	d.V	[tˢ]	20	3.8%
Cambridge	d.V	[Ø]	9	1.7%
Cambridge	d.C	[dᵊ]	51	3.3%
Cambridge	d.C	[dᶻᵊ]	38	2.4%
Cambridge	d.C	[d]	116	7.4%
Cambridge	d.C	[dᶻ]	360	23%
Cambridge	d.C	[d̚]	313	20%
Cambridge	d.C	[t]	122	7.8%
Cambridge	d.C	[tˢ]	322	20.6%
Cambridge	d.C	[Ø]	241	15.4%
Cambridge	dp	[dᵊ]	116	29.7%
Cambridge	dp	[dᶻᵊ]	65	16.7%
Cambridge	dp	[d]	13	3.3%
Cambridge	dp	[dᶻ]	45	11.5%
Cambridge	dp	[d̚]	67	17.2%
Cambridge	dp	[t]	62	15.9%
Cambridge	dp	[tˢ]	14	3.6%
Cambridge	dp	[Ø]	8	2%

9.5.1 Zero

There were 373 tokens of deletion in these corpora, comprising 10.4% of tokens. 93.8% of deletions occurred before a following consonant (e.g. *and saw*, *good boy*). The most common words which featured deletion were *and* (270 tokens), *God* (14 tokens), and *Lord* (12 tokens), with the remaining tokens spread over 65 other words. This is perhaps unsurprising as *and* (1,232 tokens), *Lord* (351 tokens), *God* (294 tokens), *world* (87 tokens), *did* (63 tokens), and *had* (48 tokens) were the most frequent words in the corpus. Figure 9.6 shows the number of deletions by Time/Director; Deletion appears to be more frequent for Stephen Cleobury than any other Time/Director, but if we look at the relative proportion of deletions, the number of deletions seems relatively stable over time and across corpora.

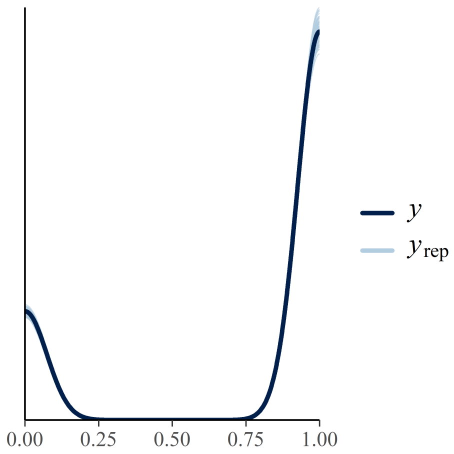


(a) Deletions by Time/Director (Count) (b) Deletions by Time/Director (Proportion)

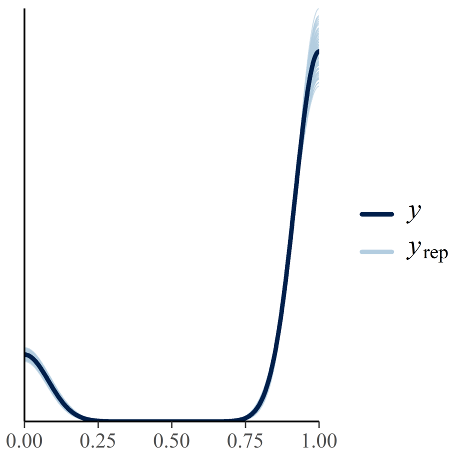
Figure 9.6: Deleted realisations of word-final /d/ by Time/Director. N = 373. HSR = Hugh S. Roberton (1925–1951); PM = Peter Mooney (1959–1975); MJS = Marilyn J. Smith (1987–2016); BO = Boris Ord (1945–1958); DW = David Willcocks (1959–1974); PL = Philip Ledger (1976–1982); SC = Stephen Cleobury (1984–2019).

9.5.2 Binary Voicing analysis

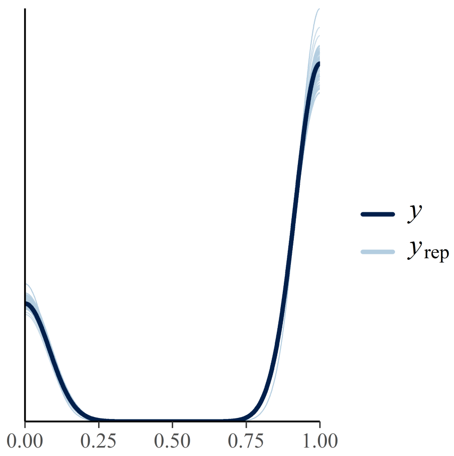
This section and the following three models reported investigate the effect of Corpus and Context, or Time/Director and Context, on whether a token of word-final /d/ is Voiced or Voiceless. As mentioned above, the category Voiced includes the variants: [d^{ə}], [d^{zə}], [d], [d^{z}], [d$^{˺}$]; the category Voiceless includes variants: [t], [t^{s}]. Zero is excluded from this analysis. For these models, Voiced = 1 and Voiceless = 0, such that the greater the proportion/percentage, the more likely a token is to be Voiced. For the following six models, as in the previous chapter on rhoticity, the estimates reported in the model summaries are on the log-odds scale. In the text, these will be converted to probabilities.



(a) Combined Corpus Voicing model



(b) Glasgow Voicing model



(c) King's Voicing model

Figure 9.7: Posterior predictive checks for Combined, Glasgow, and King's corpora word-final /d/ Voicing models

Posterior predictive checks for binary Voicing analyses

Posterior predictive checks are visualised in Figure 9.7. Model chains were visually inspected for convergence, Rhat was 1 for all coefficients, and there were no divergent transitions after warmup. The minimum effective sample size for all coefficients was greater than 100 $\times$ the number of chains. I was satisfied that the models converged successfully and that the posterior summaries were amenable to interpretation.

Contrast coding

For the combined models, reported in Tables 9.3, 9.6, and 9.9, Corpus two-level factor variable was sum coded ('King's' vs 'Glasgow': -0.5, 0.5) such that the main effect reported in the model summary table is the difference between the two corpora (not to the grand mean). This also affects the interpretation of the interaction term. For all models, all other factor variables are sum coded, meaning each level reported in the model summary is compared to the grand mean for that factor.

Corpus comparison Voicing model

The model reported in this section asks whether there is a difference in the likelihood of a token being Voiced or Voiceless by Corpus. Is word-final /d/ more likely to be Voiced in the Glasgow corpus or the King's corpus? Also, does Voicing vary by Context (following vowel, consonant, or pause), and is there an interaction between Corpus and Context?

Table 9.3: Combined: word-final /d/ Voicing posterior summary

	Estimate	95% CI	
Intercept	**2.23**	**1.92**	**2.56**
CorpusGlasgow	0.43	−0.19	1.04
Context_d.C	**−0.59**	**−0.82**	**−0.38**
Context_dp	**−0.85**	**−1.10**	**−0.63**
CorpusGlasgow:Context_d.C	**0.71**	**0.25**	**1.13**
CorpusGlasgow:Context_dp	**−1.19**	**−1.67**	**−0.74**

Point estimate displayed: median

Results are given on the log odds ratio (not the response) scale.

Bold type indicates 0 outside 95% credible interval.

The Intercept is strongly positive (logit: 2.23, CI $[1.92; 2.56]$), meaning that the predicted probability of word-final /d/ being perceived as Voiced by the researcher is 0.9 (or 90%). There is no evidence of a main effect of Corpus. There is a main effect of Context with the context 'd.C' (*and saw*, *good boy*) substantially less likely to be voiced than the grand mean for Context, with a predicted probability of 0.83 (logit difference -0.59, CI [-0.82; -0.38]). The pre-pausal Context 'dp' (*good#*) is the least likely to be Voiced overall with a predicted probability of 0.79 (logit difference -0.85, CI [-1.10; -0.63]). The model supports the interaction of Corpus and Context. Final /d/ tokens in the Glasgow Corpus are more likely to be Voiced in 'd.C' (*good boy*) Contexts with a predicted probability of 0.94 (logit difference 0.71, CI [0.25; 1.13]), whereas they are far less likely to be Voiced pre-pausally with a predicted probability of 0.64 (logit difference -1.19, CI [-1.67; -0.74]). The interaction of Corpus by Context for the binary voicing model is visualised in Figure 9.8.

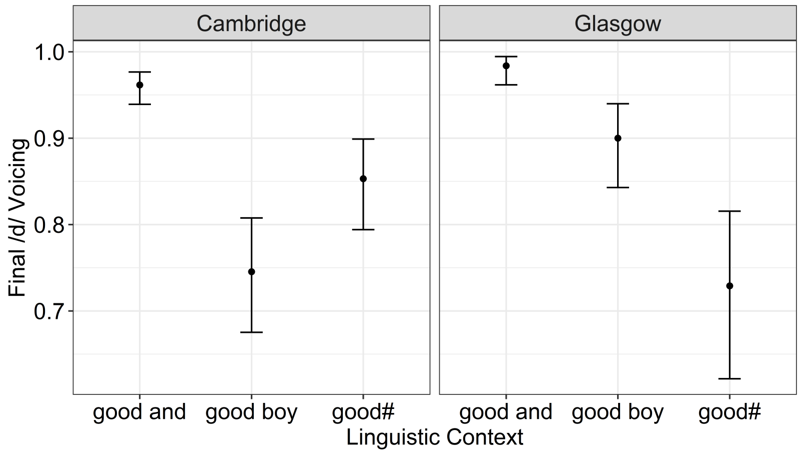


Figure 9.8: Combined Corpora word-final /d/ Voicing Corpus by Context interaction

Figure 9.8 shows that word-final /d/ before consonants (*and saw*, *good boy*) are more likely to be Voiced in the Glasgow corpus than in the King's corpus. However, the pattern is reversed for pre-pausal tokens as King's is more likely to produce a Voiced /d/ pre-pausally than pre-consonantally. In contrast, Voiced /d/ in pre-pausal contexts is less likely to be produced in the Glasgow corpus. I will now report the results of the Glasgow corpus diachronic Voicing model.

Glasgow diachronic Voicing model

The model reported in this section asks whether there is evidence of change over time in the Glasgow corpus. That is, do tokens of word-final /d/ in recordings made under different directors have different likelihoods of being Voiced or Voiceless? Also, does Voicing vary by Context (following vowel, consonant, or pause), and is there an interaction between Time/Director and Context?

Note how the Intercept is even more strongly positive than for the combined model with a predicted probability of being Voiced of 0.98 (logit: 3.90, CI [2.85; 5.35]). There is little evidence supporting change over time overall. However, Time/Director PM is less likely to produce a Voiced /d/ with a predicted probability of 0.93 (logit difference -1.16, CI [-2.57; -0.09]). There is evidence of

Table 9.4: Glasgow: /d/ Voicing posterior summary

	Estimate	95% CI	
Intercept	**3.90**	**2.85**	**5.35**
DirectorPM (1959–1975)	**−1.16**	**−2.57**	**−0.09**
DirectorMJS (1987–2016)	−0.74	−2.25	1.23
Context_d.C	−0.87	−2.20	0.24
Context_dp	−0.78	−2.18	1.19
DirectorPM:Context_d.C	0.50	−0.64	1.86
DirectorMJS:Context_d.C	−0.65	−2.69	0.86
DirectorPM:Context_dp	−0.48	−2.42	0.98
DirectorMJS:Context_dp	**−2.86**	**−5.34**	**−1.19**

Point estimate displayed: median

Results are given on the log odds ratio (not the response) scale.

Bold type indicates 0 outside 95% credible interval.

an interaction of Time/Director by Context as tokens of final /d/ produced under Marilyn J. Smith are substantially less likely to be Voiced in pre-pausal Contexts (predicted probability 0.4; logit difference -2.86, CI [-5.34; -1.19]). The interaction is visualised in Fig. 9.9.

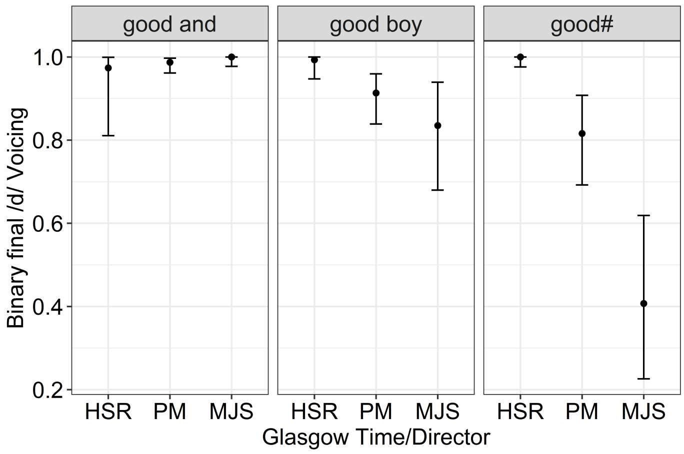


Figure 9.9: Glasgow corpus word-final /d/ Voicing model interaction of Time/Director by Context. HSR = Hugh S. Roberton (1925–1951); PM = Peter Mooney (1959–1975); MJS = Marilyn J. Smith (1987–2016).

King's diachronic Voicing model

The model reported in this subsubsection asks whether there is evidence of change over time in the King's corpus. That is, do tokens of word-final /d/ in recordings made under different directors have different likelihoods of being Voiced or Voiceless? Also, does Voicing vary by Context (following vowel, consonant, or pause), and is there an interaction between Time/Director and Context?

Similarly, the Intercept for the King's binary Voicing model is strongly positive with a predicted probability of /d/ tokens being Voiced of 0.87 (logit: 1.93, CI

Table 9.5: King's: /d/ Voicing posterior summary

	Estimate	95% CI	
Intercept	**1.93**	**1.59**	**2.29**
DirectorDW (1959–1974)	−0.07	−0.60	0.50
DirectorPL (1976–1982)	−0.35	−0.98	0.25
DirectorSC (1984–2019)	0.25	−0.20	0.71
Context_d.C	**−0.83**	**−1.03**	**−0.63**
Context_dp	**−0.45**	**−0.71**	**−0.19**
DirectorDW:Context_d.C	−0.11	−0.45	0.21
DirectorPL:Context_d.C	0.01	−0.35	0.36
DirectorSC:Context_d.C	**−0.39**	**−0.67**	**−0.10**
DirectorDW:Context_dp	0.13	−0.28	0.55
DirectorPL:Context_dp	0.21	−0.27	0.68
DirectorSC:Context_dp	**0.49**	**0.12**	**0.87**

Point estimate displayed: median

Results are given on the log odds ratio (not the response) scale.

Bold type indicates 0 outside 95% credible interval.

$[1.59; 2.29]$). The model does not provide evidence for a main effect of Time/Director. There is evidence for a main effect of Context with pre-consonantal tokens less likely to be Voiced (predicted probability 0.75; logit difference -0.83, CI $[-1.03; -0.63]$). Pre-pausal tokens are also less likely to be Voiced (predicted probability 0.81; logit difference -0.45, CI $[-0.71; -0.19]$). There is an interaction of Time/Director by Context with tokens of final /d/ produced under Stephen Cleobury less likely to be voiced in pre-consonantal contexts (predicted probability 0.72; logit difference -0.39, CI $[-0.67; -0.10]$) and more likely to be Voiced before a pause (predicted probability 0.90; logit difference 0.49, CI $[0.12; 0.87]$). The interaction of Time/Director by Context is visualised in Figure 9.10.

Binary Voicing analysis summary

In summary, the priors, models, and data do not support a main effect of Corpus – there is no difference between Glasgow and King's for Voicing overall. However, there is a main effect of Context, and the interaction of Corpus and Context with /d/ in Glasgow more likely to be Voiced before a consonant (as in *good boy*) and less likely to be Voiced before a pause.

The Glasgow Voicing model revealed a main effect of Time/Director with final /d/ tokens under Peter Mooney less likely to be Voiced. There was also an interaction of Time/Director and Context with tokens produced under Marilyn J. Smith far less likely to be Voiced before a pause.

The King's Voicing model does not support a main effect of Time/Director. There

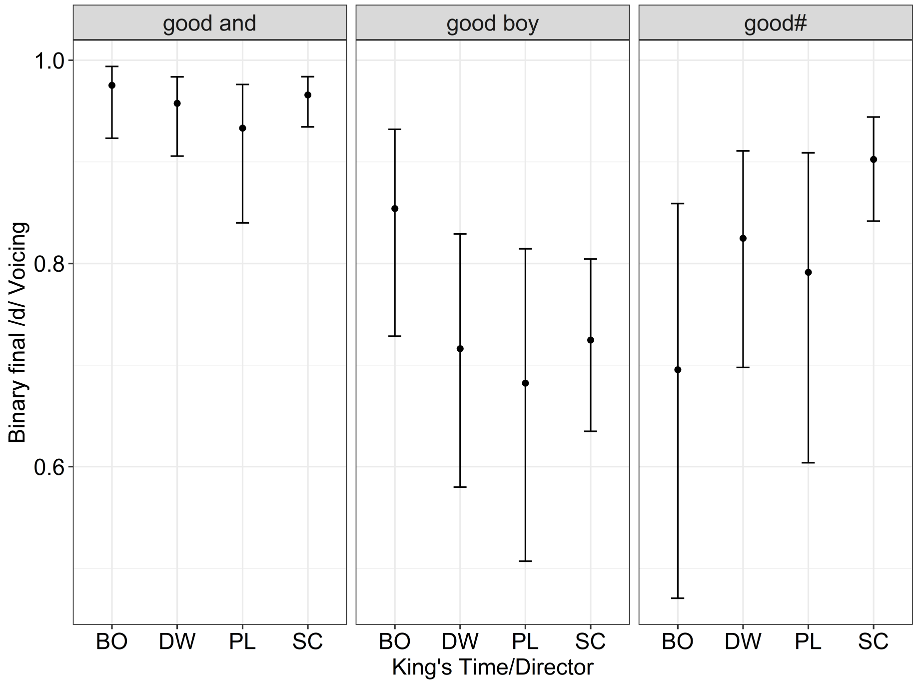


Figure 9.10: King's corpus word-final /d/ Voicing model interaction of Time/Director by Context. BO = Boris Ord (1945–1958); DW = David Willcocks (1959–1974); PL = Philip Ledger (1976–1982); SC = Stephen Cleobury (1984–2019).

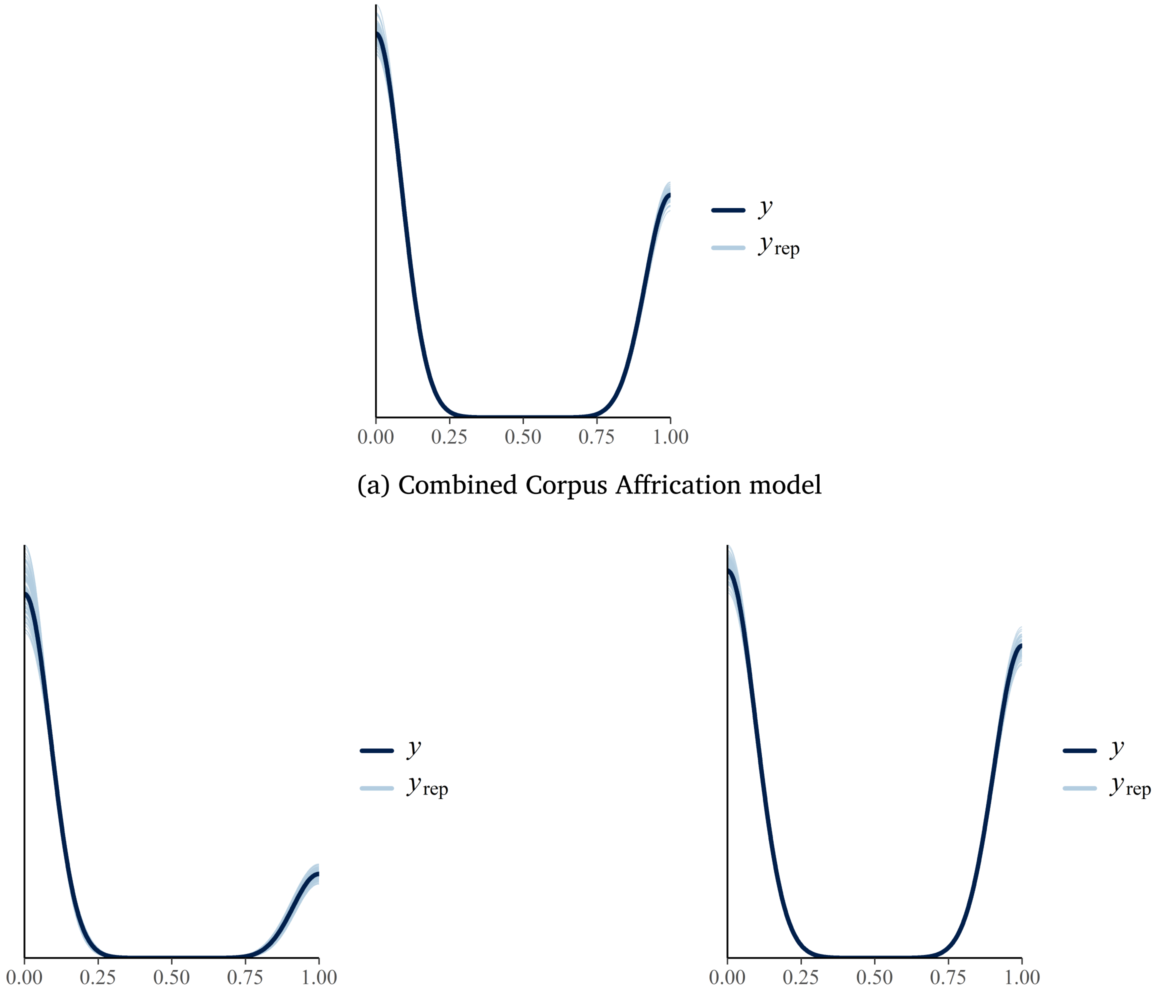
is evidence of a main effect of Context with both pre-consonantal and pre-pausal contexts less likely to be Voiced. There is also evidence of an interaction of Time/Director and Context; pre-consonantal tokens of /d/ produced under Stephen Cleobury are less likely to be Voiced, whereas pre-pausal tokens are more likely to be Voiced. I will now proceed to outline the results of the binary Affrication models.

9.5.3 Binary Affrication analysis

The following three models reported investigate the effect of Corpus and Context, or Time/Director and Context on whether a token of word-final /d/ is Affricated or Not Affricated. As mentioned above, the category Affricated includes the variants: [d^{zə}] [d^{z}], and [t^{s}]; the category Not Affricated includes variants: [d^{ə}], [d], [d$^{˺}$], and [t]. Zero is excluded from this analysis. For these models, Affricated = 1 and Not Affricated = 0, such that the greater the proportion/percentage, the more likely a token is to be Affricated.

Posterior predictive checks for Affrication models

Posterior predictive checks are visualised in Figure 9.11. Model chains were visually inspected for convergence, rhat was 1 for all coefficients and there were no divergent transitions after warmup. The minimum effective sample size for beta coefficients was greater than 400 (100 $\times$ the number of chains). I was satisfied that the models converged successfully and that the posterior summaries are amenable to interpretation.



(a) Combined Corpus Affrication model

(b) Glasgow Affrication model

(c) King's Affrication model

Figure 9.11: Posterior predictive checks for Combined, Glasgow, and King's corpora word-final /d/ Affrication models

Corpus comparison Affrication model

This model asks whether the probability of word-final /d/ Affrication varies by Corpus.

The Intercept for the combined Affrication model is negative with a predicted probability of /d/ being produced with Affrication of 0.2 (logit: -1.36, CI [-1.64; -1.11]). The model supports a main effect of Corpus with Glasgow being less likely to produce Affrication (predicted probability 0.076; logit difference -1.13, CI[-1.65; -0.63]). There is also a main effect of Context with pre-consonantal tokens more likely to be Affricated (predicted probability 0.27; logit difference 0.37, CI [0.22; 0.53]). There is an interaction of Corpus by Context, with final /d/ in the Glasgow corpus in pre-consonantal contexts less likely to be Affricated (predicted probability 0.065; logit difference -0.53, CI [-0.83; -0.23]). The

Table 9.6: Combined: /d/ Affrication posterior summary

	Estimate	95% CI	
Intercept	**−1.36**	**−1.64**	**−1.11**
CorpusGlasgow	**−1.13**	**−1.65**	**−0.63**
Context_d.C	**0.37**	**0.22**	**0.53**
Context_dp	0.05	−0.13	0.24
CorpusGlasgow:Context_d.C	**−0.53**	**−0.83**	**−0.23**
CorpusGlasgow:Context_dp	0.36	−0.00	0.73

Point estimate displayed: median

Results are given on the log odds ratio (not the response) scale.

Bold type indicates 0 outside 95% credible interval.

interaction of Corpus by Context is visualised in Figure 9.12.

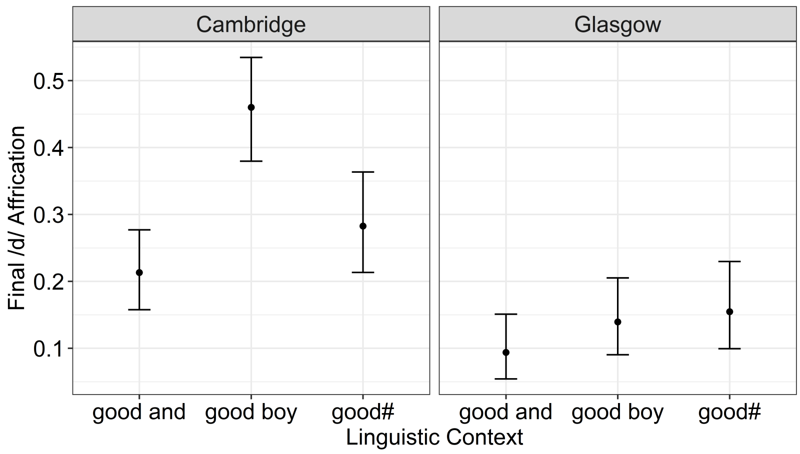


Figure 9.12: Combined Corpora /d/ Affrication model Corpus by Context interaction

Glasgow diachronic Affrication model

The following model asks whether the probability of word-final /d/ Affrication changes over time in the Glasgow Corpus.

The model intercept is strongly negative with a predicted probability of Affrication of 0.048 (logit: -2.9, CI [-4.23; -2.07]). The model supports a main effect of Time/Director whereby /d/ becomes more likely to be Affricated over time; Tokens produced under Peter Mooney (1959–1975) are more likely to be Affricated than the grand mean with a predicted probability of 0.135 (logit difference 1.05, CI [0.21; 2.40]). The same pattern is strengthened under Marilyn J. Smith (1987–2016) with a predicted probability of 0.19; logit difference 1.45, CI [0.59; 2.81]. The model also supports a main effect of Context with pre-pausal tokens more likely to be Affricated (predicted probability 0.14; logit difference 1.10, CI [0.33; 2.42]). There is an interaction of Time/Director by Context. Due to the positive main effect of Time/Director, there is a slight negative adjustment for

Table 9.7: Glasgow: /d/ Affrication posterior summary

	Estimate	95% CI	
Intercept	**−2.90**	**−4.23**	**−2.07**
DirectorPM (1959–1975)	**1.05**	**0.21**	**2.40**
DirectorMJS (1987–2016)	**1.45**	**0.59**	**2.81**
Context_d.C	0.37	−0.56	1.72
Context_dp	**1.10**	**0.33**	**2.42**
DirectorPM:Context_d.C	−0.39	−1.75	0.57
DirectorMJS:Context_d.C	0.11	−1.26	1.09
DirectorPM:Context_dp	**−0.81**	**−2.14**	**−0.00**
DirectorMJS:Context_dp	**−1.10**	**−2.45**	**−0.25**

Point estimate displayed: median

Results are given on the log odds ratio (not the response) scale.

Bold type indicates 0 outside 95% credible interval.

pre-pausal tokens for both Peter Mooney (predicted probability 0.17; logit difference -0.81, CI [-2.14; -0.00]) and Marilyn J. Smith (predicted probability 0.19; logit difference -1.10, CI [-2.45; -0.25]). The interaction of Time/Director by Context is visualised in Figure 9.13.

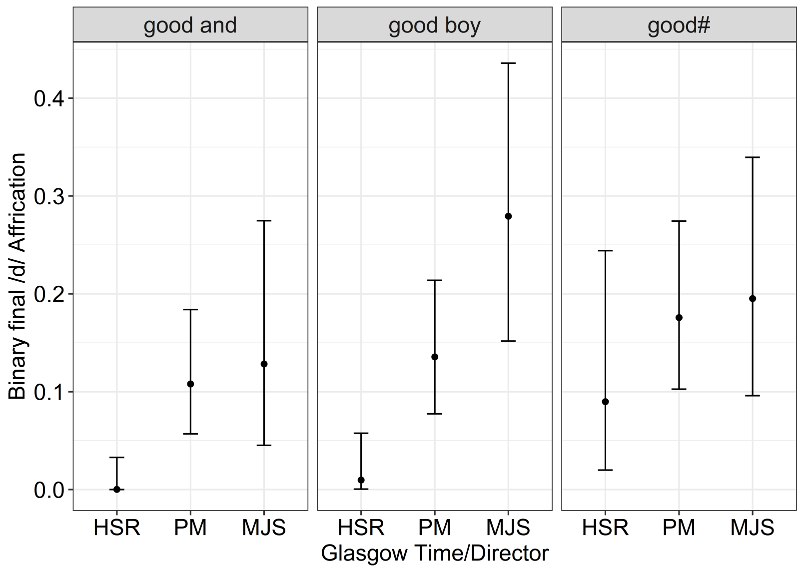


Figure 9.13: Glasgow corpus final /d/ Affrication model interaction of Time/Director by Context. HSR = Hugh S. Roberton (1925–1951); PM = Peter Mooney (1959–1975); MJS = Marilyn J. Smith (1987–2016).

King's diachronic Affrication model

The final model in this section asks whether the probability of Affrication of word-final /d/ changes over time in the King's corpus.

The Intercept for the model is negative with a predicted probability of Affrication of 0.29 when all other effects are kept constant. The model supports a main effect

Table 9.8: King's: /d/ Affrication posterior summary

	Estimate	95% CI	
Intercept	**−0.89**	**−1.23**	**−0.56**
DirectorDW (1959–1974)	−0.08	−0.59	0.42
DirectorPL (1976–1982)	**0.78**	**0.23**	**1.33**
DirectorSC (1984–2019)	0.19	−0.21	0.60
Context_d.C	**0.54**	**0.37**	**0.72**
Context_dp	−0.13	−0.40	0.12
DirectorDW:Context_d.C	0.08	−0.19	0.36
DirectorPL:Context_d.C	**−0.54**	**−0.85**	**−0.24**
DirectorSC:Context_d.C	**0.37**	**0.13**	**0.59**
DirectorDW:Context_dp	0.04	−0.33	0.43
DirectorPL:Context_dp	0.36	−0.06	0.79
DirectorSC:Context_dp	−0.07	−0.40	0.26

Point estimate displayed: median

Results are given on the log odds ratio (not the response) scale.

Bold type indicates 0 outside 95% credible interval.

of Time/Director with tokens of /d/ produced under Philip Ledger (1976–1982) more likely to be Affricated (predicted probability 0.47; logit difference 0.78, CI [0.23; 1.33]). There is also a main effect of Context with pre-consonantal tokens more likely to be Affricated (predicted probability 0.41; logit difference 0.54, CI [0.37; 0.72]). There is an interaction of Time/Director by Context with tokens more likely to be Affricated in pre-consonantal contexts under the direction of Stephen Cleobury (predicted probability 0.55; logit difference 0.37, CI [0.13; 0.59]). In contrast, pre-consonantal tokens are less likely to be Affricated under Philip Ledger compared to the mean effect of Philip Ledger (predicted probability 0.47; logit difference -0.54, CI [-0.85; -0.24]). The interaction of Time/Director by Context for the king's /d/ Affrication model is visualised in Figure 9.14.

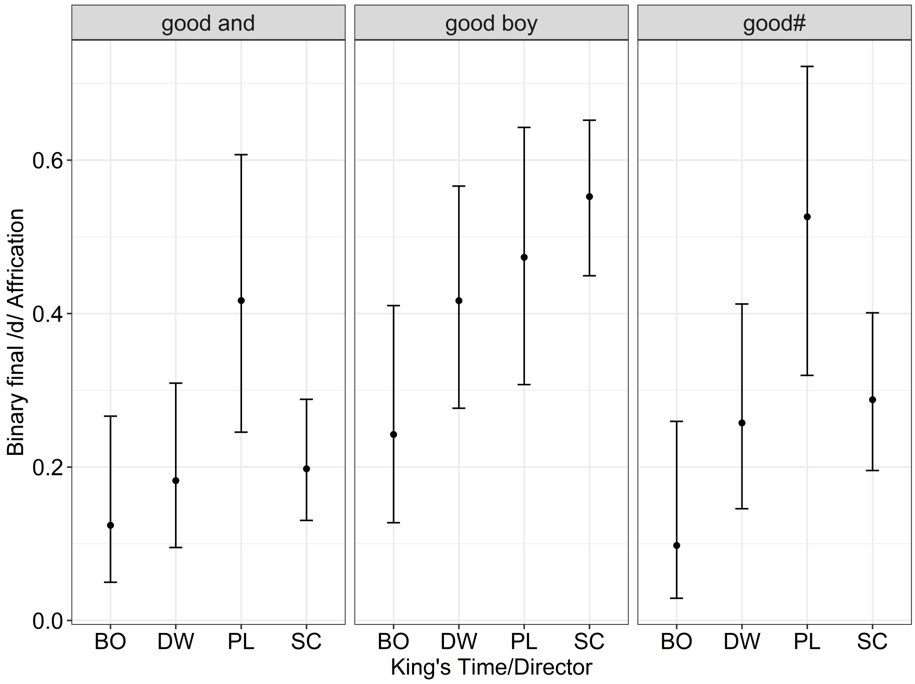


Figure 9.14: King's word-final /d/ Affrication model interaction of Time/Director by Context. BO = Boris Ord (1945–1958); DW = David Willcocks (1959–1974); PL = Philip Ledger (1976–1982); SC = Stephen Cleobury (1984–2019).

9.5.4 /d/ variants multinomial analysis

In this section, I report the results of three multinomial logistic regression models. For each model, the dependent variable is a categorical variable with four levels: 'D' = [d^{ə}], [d^{zə}]; 'd' = [d], [d^{z}]; 'u' = [d˺]; 't' = [t], [t^{s}]. Deleted tokens [∅] were removed from this analysis. The variant 'd' was selected as the reference level as it is the most frequent overall.

Independence of Irrelevant Alternatives

A key assumption of multinomial logistic regression is the independence of irrelevant alternatives (IIA). This states that, if presented with a list of choices, removing or adding an option will not change the ratio of the other options.

To give a hypothetical scenario, in a survey of people's favourite ice cream, with the options vanilla, chocolate, and strawberry, we found that one third of participants surveyed preferred each of the flavours (33% vanilla, 33% chocolate, 33% strawberry). If we introduced a fourth flavour, coconut, this should not alter the ratio between vanilla, chocolate and strawberry. So, if 50% of people preferred coconut when the option is added, the distribution should be 50% coconut, 16.6% each for vanilla, chocolate, or strawberry. If adding the flavour coconut caused more people to vote for vanilla than chocolate or strawberry, then these data would violate the IIA assumption. Tactical voting in elections is a real-life example of violating the IIA assumption.

I do not believe that it is theoretically possible for these data to violate the IIA assumption. As I was conducting the auditory coding, I coded exhaustively, meaning I coded in as much detail as I could and then collapsed levels to form the remaining categories – were we to remove the level 'D', for example, it should not affect the ratio between the remaining levels ('d', 'u', and 't').

Contrasts

The contrast coding was kept the same as for the binary Voicing and Affrication analyses.

Priors

As the multinomial/categorical model is a special case of logistic regression, the priors used are the same as for the binomial logistic regression models: Cauchy(0, 10) for Intercepts, Cauchy(0, 2.5) for varying effects, and normal(0, 2.5) for fixed effects.

Posterior predictive checks for /d/ variants analyses

Posterior predictive checks for the variants analyses are visualised in Figures 9.15, 9.16, and 9.17. Model chains were visually inspected for convergence, Rhat was 1 for all coefficients and there were no divergent transitions after warmup. The minimum effective sample size for all coefficients was greater than 400 (100 $\times$ the number of chains). I was satisfied that the models converged successfully and that the posterior summaries are amenable to interpretation.

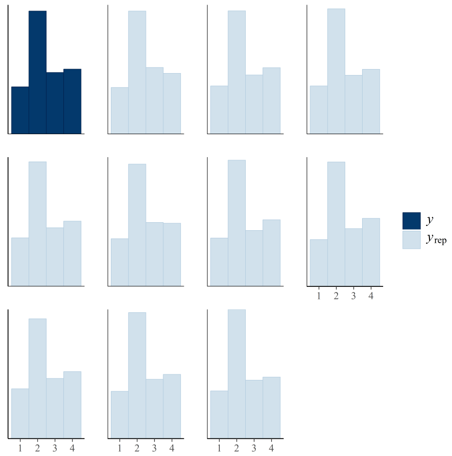


Figure 9.15: Combined Corpora multinomial model posterior predictive check

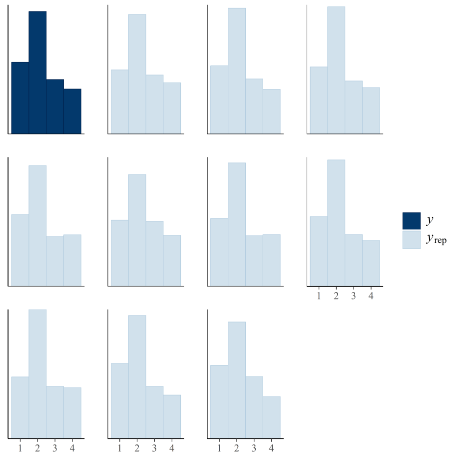


Figure 9.16: Glasgow: /d/ multinomial model posterior predictive check

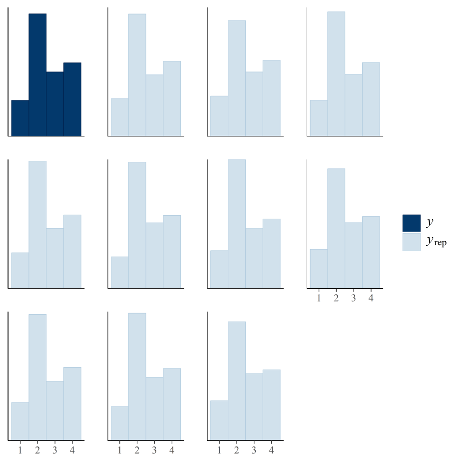


Figure 9.17: King's: /d/ multinomial model posterior predictive check

Combined corpora /d/ variants multinomial model

The combined-corpora multinomial model reported in Table 9.9, seeks to ask whether the distribution of variants differs between the two corpora. In multinomial logistic regression, each category of the dependent variable is compared to the reference level. 'd' ([d], [dᶻ]) was selected as the reference level for each model as it is the most frequent variant overall. This means there are multiple logistic models where 'D' ([dᵊ],[dᶻᵊ]), 'u' ([d̚]) and 't' ([t], [tˢ]) are compared to 'd'. For example, the intercepts for 'D', 'u' and 't' are all negative compared to the reference level 'd' because they are lower frequency overall. Each level of the categorical dependent variable included in the model is labelled mu, so we have mu_D, mu_u, and mu_t.

Table 9.9: Combined: Word-final /d/ multinomial model posterior summary

	Estimate	95% CI	
mu_D_Intercept	**−3.31**	**−4.45**	**−2.52**
mu_u_Intercept	**−0.86**	**−1.19**	**−0.54**
mu_t_Intercept	**−1.26**	**−1.56**	**−0.98**
mu_D_CorpusGlasgow	−0.54	−2.44	0.93
mu_D_Context_d.C	**0.91**	**0.24**	**2.01**
mu_D_Context_dp	**4.36**	**3.62**	**5.48**
mu_D_CorpusGlasgow:Context_d.C	**1.42**	**0.03**	**3.30**
mu_D_CorpusGlasgow:Context_dp	0.26	−1.19	2.18
mu_u_CorpusGlasgow	−0.41	−0.98	0.18
mu_u_Context_d.C	**0.66**	**0.46**	**0.88**
mu_u_Context_dp	**0.74**	**0.47**	**1.01**
mu_u_CorpusGlasgow:Context_d.C	**0.82**	**0.41**	**1.23**
mu_u_CorpusGlasgow:Context_dp	0.38	−0.13	0.89
mu_t_CorpusGlasgow	−0.50	−1.06	0.04
mu_t_Context_d.C	**0.52**	**0.29**	**0.76**
mu_t_Context_dp	**1.58**	**1.32**	**1.85**
mu_t_CorpusGlasgow:Context_d.C	−0.39	−0.83	0.08
mu_t_CorpusGlasgow:Context_dp	**1.06**	**0.57**	**1.60**

Point estimate displayed: median

Results are given on the log odds ratio (not the response) scale.

Bold type indicates 0 outside 95% credible interval.

For mu_D, the model tells us that compared to the reference level 'd' (= [d], [dᶻ]), 'D' (+ shadow vowel = [dᵊ], [dᶻᵊ]) is considerably less likely overall (logit difference -3.31, CI [-4.45; -2.52]). There is no main effect of Corpus for 'D' compared to the reference level. The model supports a main effect of Context with 'D' variants in pre-pausal 'dp' contexts more likely than 'd' (logit difference 4.36, CI [3.62; 5.48]). We can see that 'D' variants are more likely in pre-pausal contexts by adding the intercept for mu_D and the coefficient for pre-pausal Context mu_D_Context_dp ($-3.31 + 4.36 = 1.05$), which results in a positive log-odds of 1.05. This means that the model predicts a greater probability for hyper-voiced ([$d^{ə}$], [$d^{zə}$]) variants in pre-pausal contexts compared to normal voiced ([d], [d^{z}]) variants.

The model supports an increase in the probability of 'D' in pre-consonantal contexts ('d.C') compared to 'd' (logit difference 0.91, CI [0.24; 2.01]). Note that if we add the intercept for mu_D and the coefficient for pre-consonantal context the log-odds remain negative ($-3.31 + 0.91 = -2.4$), meaning that overall 'd' variants are still more likely than 'D' in pre-consonantal contexts, but there has been an increase in the relative probability of 'D'. Furthermore, there is an interaction of Context and Corpus, with an increase in the probability of 'D' compared to 'd' in pre-consonantal Contexts in Glasgow compared to King's (logit difference 1.42, CI [0.03; 3.30]).

For mu_u (unreleased [d̚]), there is a negative intercept meaning that 'u' is less likely than 'd' overall (logit difference -0.86, CI [-1.19; -0.54]). The model supports a main effect of Context such that the relative probability of 'u' increases in pre-consonantal 'd.C' contexts compared to 'd' (logit difference 0.66, CI [0.46; 0.88]). Likewise, the probability of 'u' increases in pre-pausal 'dp' contexts (logit difference 0.74, CI [0.47; 1.01]) compared to the reference level. There is also an interaction of Corpus by Context such that, compared to 'd', 'u' is more likely in Glasgow pre-consonantal contexts (logit difference 0.82, CI [0.41; 1.23]). If we add up the coefficients $-0.86 - 0.41 + 0.66 + 0.82 = 0.21$ we can see that in Glasgow there is no difference between 'd' and 'u' in pre-consonantal contexts, compared to King's where 'd' is more frequent (interaction visualised in Figure 9.18).

Lastly, for mu_t (voiceless [t], [t^{s}]), there is a negative intercept, meaning that 't' variants are less likely than 'd' variants overall (logit difference -1.26, CI [-1.56; -0.98]). There is a main effect of Context for mu_t compared to 'd', with the probability of 't' increasing in pre-consonantal 'd.C' contexts (logit difference 0.52, CI [0.29; 0.76]) and pre-pausal contexts 'dp' (logit difference 1.58, CI [1.32; 1.85]). If we add up the estimates for mu_t_Intercept and mu_t_Context_dp $-1.26 + 1.58 = 0.32$, we can see that voiceless 't' variants are more likely than voiced 'd' variants in pre-pausal 'dp' context. The model supports an interaction of Corpus by Context such that there is an increase in the likelihood of 't' variants in pre-pausal contexts in the Glasgow corpus (logit difference 1.06, CI [0.57; 1.60]). If we sum the coefficients `mu_t_Intercept + mu_t_CorpusGlasgow + mu_t_Context_dp + mu_t_CorpusGlasgow:Context_dp` ($-1.26 - 0.50 + 1.58 + 1.06 = 0.88$) we can see that the resulting log-odds are positive meaning that voiceless 't' variants are more likely than 'd' variants in pre-pausal contexts in the Glasgow corpus compared to the King's corpus.

The interactions are more easily understood and visualised in Figure 9.18. 'D' variants are slightly more likely for Glasgow pre-consonantal contexts compared to King's, compared to 'd' where there is no difference between the corpora. Voiceless variants 't' are more likely compared to 'd' for Glasgow pre-pausal contexts, whereas for King's, there is no difference between 't' and 'd' in pre-pausal contexts.

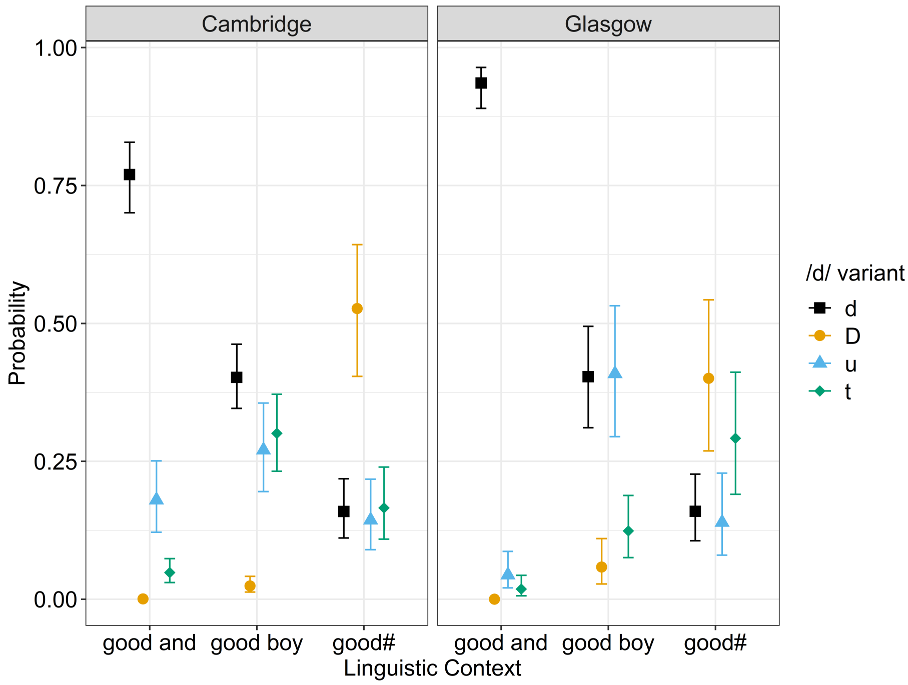


Figure 9.18: Combined Corpora multinomial model: Corpus by Context interaction.
Context: good and = 'd.V'; good boy = 'd.C'; good# = 'dp'.
Variants: 'd' = [d]; 'D' = [də], [dᶻə]; 'u' = [d̚]; 't' = [t], [tˢ].

Glasgow diachronic multinomial model

Table 9.10: Glasgow: Word-final /d/ multinomial model posterior summary

	Estimate	95% CI	
mu_D_Intercept	**−4.23**	**−6.38**	**−2.70**
mu_u_Intercept	**−1.15**	**−1.96**	**−0.46**
mu_t_Intercept	**−2.88**	**−4.32**	**−1.81**
mu_D_DirectorPM (1959–1975)	−0.02	−2.04	1.83
mu_D_DirectorMJS (1987–2016)	−0.66	−2.83	1.23
mu_D_Context_d.C	**2.11**	**0.72**	**4.19**
mu_D_Context_dp	**4.83**	**3.38**	**6.94**
mu_D_DirectorPM:Context_d.C	−0.33	−2.17	1.68
mu_D_DirectorMJS:Context_d.C	−0.66	−2.57	1.52
mu_D_DirectorPM:Context_dp	0.83	−1.06	2.90
mu_D_DirectorMJS:Context_dp	−0.29	−2.20	1.90
mu_u_DirectorPM (1959–1975)	**−0.86**	**−1.68**	**−0.09**
mu_u_DirectorMJS (1987–2016)	0.08	−0.79	0.90
mu_u_Context_d.C	**1.45**	**0.88**	**2.13**
mu_u_Context_dp	**0.87**	**0.27**	**1.53**
mu_u_DirectorPM:Context_d.C	−0.23	−0.91	0.39
mu_u_DirectorMJS:Context_d.C	−0.15	−0.89	0.55
mu_u_DirectorPM:Context_dp	0.47	−0.22	1.18
mu_u_DirectorMJS:Context_dp	−0.66	−1.47	0.11
mu_t_DirectorPM (1959–1975)	**1.15**	**0.10**	**2.57**
mu_t_DirectorMJS (1987–2016)	0.53	−1.46	2.03
mu_t_Context_d.C	**1.14**	**0.04**	**2.49**
mu_t_Context_dp	1.29	−0.68	2.74
mu_t_DirectorPM:Context_d.C	−0.84	−2.21	0.30
mu_t_DirectorMJS:Context_d.C	0.49	−1.00	2.51
mu_t_DirectorPM:Context_dp	0.77	−0.66	2.75
mu_t_DirectorMJS:Context_dp	**2.70**	**0.98**	**5.21**

Point estimate displayed: median

Results are given on the log odds ratio (not the response) scale.

Bold type indicates 0 outside 95% credible interval.

The Glasgow diachronic multinomial model, reported in Table 9.10, seeks to investigate whether the distribution of variants in the Glasgow corpus has changed over time. Similarly to the combined model, all variant intercepts (‘D’, ‘u’, ‘t’) are negative as they are less frequent than ‘d’. For mu_D (+ shadow vowel [dᵊ], [dᶻᵊ]), the model supports a main effect of Context, with the relative probability of ‘D’ increasing compared to ‘d’ in pre-consonantal ‘d.C’ contexts (logit difference 2.11, CI [0.72; 4.19]). Likewise, the probability of ‘D’ variants increases in pre-pausal ‘dp’ contexts compared to ‘d’ (logit difference 4.83, CI [3.38; 6.94]). Summing the coefficients mu_D_Intercept and mu_D_Context_dp ($-4.23 + 4.83 = 0.6$) results in positive log-odds, meaning that for pre-pausal contexts, ‘D’ (+ shadow vowel) variants are more likely than ‘d’. The model does not support a main effect of Time/Director or an interaction of Time/Director by Context for mu_D compared to the reference level ‘d’.

For mu_u (unreleased [d̚]), there is evidence of a main effect of Context, with ‘u’ variants more likely to appear in pre-consonantal context ‘d.C’ (logit difference 1.45, CI [0.88; 2.13]) and pre-pausal context ‘dp’ (logit difference 0.87, CI [0.27; 1.53]) compared to the reference level ‘d’. In fact, for pre-consonantal contexts, ‘u’ (no audible burst) variants are more likely than ‘d’ (mu_u_Intercept + mu_u_Context_d.C $-1.15 + 1.45 = 0.3$). For mu_u, there is a main effect of Time/Director for Peter Mooney (1959–1975), where ‘u’ variants are less likely to occur compared to the reference level ‘d’ (logit difference -0.86, CI [-1.68; -0.09]). There is no evidence of an interaction of Time/Director by Context for mu_u compared to ‘d’.

For mu_t (voiceless [t], [tˢ]), there is evidence of a main effect of Context, with an increase in the likelihood of ‘t’ variants in pre-consonantal ‘d.C’ contexts compared to the reference level ‘d’ (logit difference 1.14, CI [0.04; 2.49]). There is also evidence of a main effect of Time/Director for Peter Mooney (1959–1975) with the likelihood of ‘t’ variants increasing compared to the reference level ‘d’ (logit difference 1.15, CI [0.10; 2.57]). The model supports an interaction of Time/Director by Context with the probability of voiceless ‘t’ variants compared to ‘d’ increasing for the Time/Director Marilyn J. Smith (1987–2016) in pre-pausal ‘dp’ contexts (logit difference 2.70, CI [0.98; 5.21]). Summing the coefficients `mu_t_Intercept + mu_t_Director_MJS + mu_t_Context_dp + mu_t_Director_MJS:Context_dp` $-2.88 + 0.53 + 1.29 + 2.7 = 1.64$ results in a positive log-odds of 1.64 meaning that voiceless ‘t’ variants are more likely than voiced ‘d’ variants in pre-pausal ‘dp’ Contexts under Marilyn J. Smith. The interaction is visualised in Figure 9.19, which shows voiceless realisations of /d/ in pre-pausal ‘good#’ contexts increase incrementally over time from close to zero in the early time period under Hugh S. Roberton (1925–1951) to approximately 60% under Marilyn J. Smith (1987–2016).

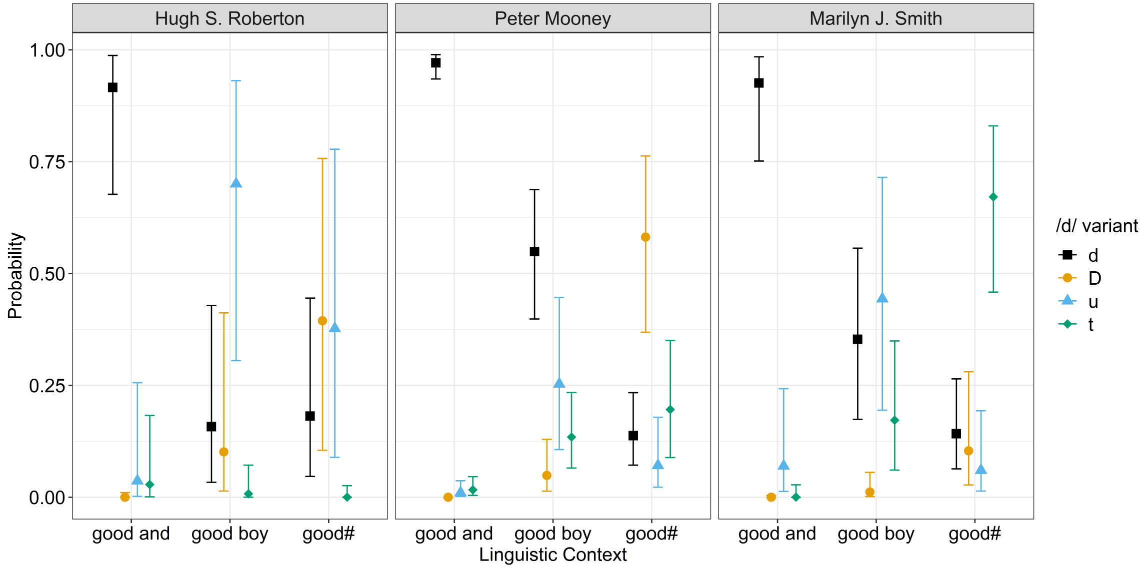


Figure 9.19: Glasgow diachronic multinomial model Time/Director by Context interaction.
y-axis: probability of each variant.
Hugh S. Roberton (1925–1951); Peter Mooney (1959–1975); Marilyn J. Smith (1987–2016).
Context: good and = 'd.V'; good boy = 'd.C'; good# = 'dp'.
Variants: 'd' = [d]; 'D' = [d^{ə}], [d^{zə}]; 'u' = [d$^{˺}$]; 't' = [t], [t^{s}].

King's diachronic multinomial model

Table 9.11: King's: Word-final /d/ multinomial model posterior summary

	Estimate	95% CI	
mu_D_Intercept	**−3.85**	**−5.40**	**−2.77**
mu_u_Intercept	**−0.96**	**−1.39**	**−0.57**
mu_t_Intercept	**−1.03**	**−1.38**	**−0.72**
mu_D_DirectorDW (1959–1974)	−0.44	−2.58	1.29
mu_D_DirectorPL (1976–1982)	−0.25	−2.40	1.47
mu_D_DirectorSC (1984–2019)	**1.60**	**0.36**	**3.16**
mu_D_Context_d.C	0.82	−0.21	2.31
mu_D_Context_dp	**4.85**	**3.79**	**6.36**
mu_D_DirectorDW:Context_d.C	−0.29	−2.00	1.91
mu_D_DirectorPL:Context_d.C	−0.23	−1.95	1.96
mu_D_DirectorSC:Context_d.C	−0.63	−2.15	0.58
mu_D_DirectorDW:Context_dp	0.12	−1.61	2.28
mu_D_DirectorPL:Context_dp	0.29	−1.44	2.46
mu_D_DirectorSC:Context_dp	−0.91	−2.44	0.34
mu_u_DirectorDW (1959–1974)	−0.12	−0.67	0.41
mu_u_DirectorPL (1976–1982)	**−0.97**	**−1.71**	**−0.27**
mu_u_DirectorSC (1984–2019)	**0.86**	**0.44**	**1.30**
mu_u_Context_d.C	**0.60**	**0.33**	**0.87**
mu_u_Context_dp	**0.54**	**0.16**	**0.92**
mu_u_DirectorDW:Context_d.C	0.14	−0.26	0.55
mu_u_DirectorPL:Context_d.C	**0.86**	**0.33**	**1.48**
mu_u_DirectorSC:Context_d.C	**−0.71**	**−1.03**	**−0.39**
mu_u_DirectorDW:Context_dp	−0.22	−0.79	0.33
mu_u_DirectorPL:Context_dp	0.10	−0.70	0.88
mu_u_DirectorSC:Context_dp	0.15	−0.30	0.61
mu_t_DirectorDW (1959–1974)	−0.03	−0.52	0.45
mu_t_DirectorPL (1976–1982)	0.18	−0.35	0.73
mu_t_DirectorSC (1984–2019)	0.03	−0.38	0.45
mu_t_Context_d.C	**0.62**	**0.39**	**0.85**
mu_t_Context_dp	**1.20**	**0.89**	**1.53**
mu_t_directorDW:Context_d.C	0.19	−0.16	0.54
mu_t_directorPL:Context_d.C	0.05	−0.34	0.45
mu_t_directorSC:Context_d.C	0.26	−0.06	0.58
mu_t_directorDW:Context_dp	−0.28	−0.75	0.20
mu_t_directorPL:Context_dp	−0.18	−0.74	0.39
mu_t_directorSC:Context_dp	−0.29	−0.75	0.16

Point estimate displayed: median

Results are given on the log odds ratio (not the response) scale.

Bold type indicates 0 outside 95% credible interval.

The King's diachronic multinomial model reported in Table 9.11 investigates whether there is evidence of change over time in the distribution of /d/ variants in the King's corpus. Similarly to the previous two models, intercepts for 'D', 't', and 'u' are all negative, reflecting their relative infrequency compared to the reference level 'd'.

For mu_D, there is evidence of a main effect of Context with 'D' (+ shadow vowel [d^{ə}], [d^{zə}]) in pre-pausal 'dp' contexts more likely than the reference level 'd' (logit difference 4.85, CI [3.79; 6.36]). The model also supports a main effect of Time/Director for mu_D compared to 'd' with Stephen Cleobury (1984–2019) showing a relative increase in the use of 'D' variants overall compared to the grand mean for Time/Director (logit difference 1.60, CI [0.36; 3.16]). The model does not support an interaction of Time/Director by Context for mu_D. At King's, 'D' variants (+ epenthetic vowel) appear to become more frequent over time in pre-pausal 'dp' contexts.

For mu_u (unreleased [d̚]), there is a main effect of Context with an increase in the relative probability of 'u' variants compared to 'd' for pre-consonantal 'd.C' contexts (logit difference 0.60, CI [0.33; 0.87]) and pre-pausal 'dp' contexts (logit difference 0.54, CI [0.16; 0.92]). There is a main effect of Time/Director with Philip Ledger (1976–1982) relatively less likely to produce 'u' variants compared to 'd' compared to the grand mean for Time/Director (logit difference -0.97, CI [-1.71; -0.27]). Stephen Cleobury (1984–2019) is relatively more likely to produce 'u' variants compared to 'd' than the grand mean (logit difference 0.86, CI [0.44; 1.30]). The model also supports an interaction of Time/Director by Context. For Time/Director Philip Ledger (1976–1982), as 'u' is less likely compared to the grand mean for Time/Director, 'PL' is relatively more likely to produce 'u' variants in pre-consonantal 'd.C' contexts compared to 'd' (logit difference 0.86, CI [0.33; 1.48]). While Stephen Cleobury (1984–2019) is more likely to produce 'u' variants overall compared to the reference level, 'u' is relatively less likely for 'SC' in pre-consonantal 'd.C' Contexts (logit difference -0.71, CI [-1.03; -0.39]). The interaction is visualised in Figure 9.20.

For mu_t (voiceless [t], [t^{s}]), the model supports a main effect of Context, with 't' variants relatively more likely compared to 'd' in both pre-consonantal 'd.C' contexts (logit difference 0.62, CI [0.39; 0.85]), and pre-pausal 'dp' contexts (logit difference 1.20, CI [0.89; 1.53]). Voiceless 't' variants are more likely than 'd' variants overall in pre-pausal contexts (mu_t_Intercept + mu_t_Context_dp $-1.03 + 1.20 = 0.17$). The model does not support a main effect of Time/Director for mu_t, nor an interaction of Time/Director and Context.

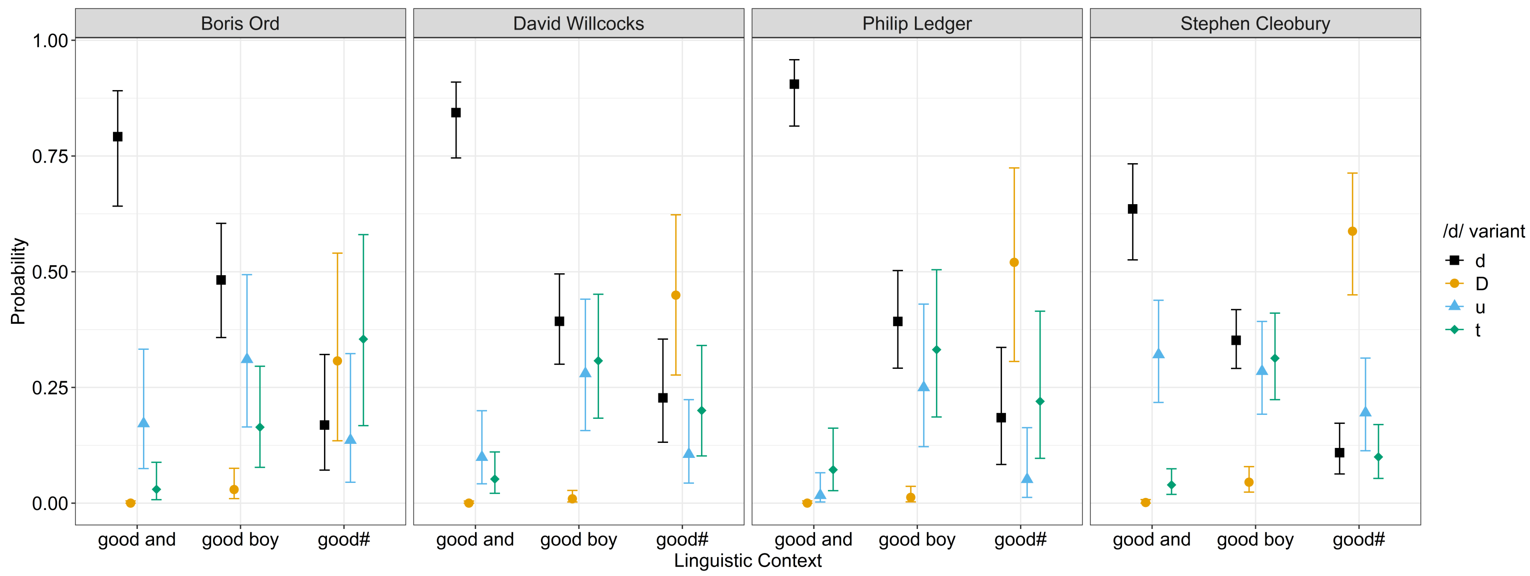


Figure 9.20: King's diachronic multinomial model Time/Director by Context interaction.
y-axis: probability of each variant.
Boris Ord (1945–1958); David Willcocks (1959–1974); Philip Ledger (1976–1982); Stephen Cleobury (1984–2019).
Context: good and = 'd.V'; good boy = 'd.C'; good# = 'dp'.
Variants: 'd' = [d]; 'D' = [də], [d^{z}ə]; 'u' = [d˺]; 't' = [t], [t^{s}].

9.6 Discussion

In this chapter, I have reported three quantitative analyses of word-final /d/ in choral singing from choirs in Glasgow and Cambridge over time. I will now provide a summary of findings where I discuss each analysis in turn, followed by a more general discussion.

9.6.1 Summary of key findings

Binary Voicing Analysis

In this analysis /d/ variants were collapsed into categories Voiced ([dᵊ], [dᶻᵊ], [d], [dᶻ], and [d̚]) and Voiceless ([t], [tˢ]). Overall, the predicted probability of tokens to be perceived as Voiced by the researcher was 0.90. /d/ tokens were less likely to be Voiced pre-consonantally (0.83) and pre-pausally (0.79). Pre-consonantal tokens were more likely to be Voiced in the Glasgow corpus than in the King's corpus. Conversely, pre-pausal tokens were more likely to be Voiceless in the Glasgow corpus than in the King's corpus. In the Glasgow corpus, I found that /d/ is substantially more likely to be Voiceless in pre-pausal contexts for Time/Director Marilyn J. Smith (1987–2016), and there is a trend of Voicing decreasing over time in both pre-pausal and pre-consonantal contexts. In the King's corpus, I found that /d/ is less likely to be Voiced in pre-consonantal contexts for Time/Director Stephen Cleobury (1984–2019) and more likely to be voiced in pre-pausal contexts. For King's, there is a trend of increasing Voicelessness in pre-consonantal contexts and increasing Voicing in pre-pausal contexts.

Binary Affrication Analysis

In this analysis /d/ variants were collapsed into the categories Affricated ([dᶻᵊ], [dᶻ], [tˢ]) and Unaffricated ([dᵊ], [d], [d̚], [t]). The overall predicted probability of Affrication was 0.20. In the combined model, Affrication was more likely pre-consonantally than in other Contexts. Affrication was quite rare overall in the Glasgow corpus, but there was an increase over time. There was also an increase of Affrication over time in the King's corpus in pre-consonantal Contexts, increasing from approximately 20% for Boris Ord (1945–1958) to around 50% for Stephen Cleobury (1984–2019). For King's, word-final /d/ is least likely to be Affricated in the context of a following vowel and most likely to be Affricated when followed by a consonant.

Multinomial /d/ Variants Analysis

The variants of /d/ selected for modelling are: normally-released 'd' ([d], [dᶻ]), + shadow vowel 'D' ([dᵊ], [dᶻᵊ]), 'imploded' no audible release 'u' ([d̚]), and voiceless ‘t’ ([t], [tˢ]). ‘D’, ‘u’, and ‘t’ are less frequent than ‘d’ overall. Shadow vowel ‘D’ variants are more likely before a pause and more likely pre-consonantally (‘d.C’ contexts) in the Glasgow corpus than in the King’s corpus.

Unreleased ‘u’ variants [d̚] are more common in pre-consonantal ‘d.C’ contexts, and more common in the Glasgow corpus than the King’s corpus. At King’s, unreleased tokens are more common across contexts for Time/Director Stephen Cleobury (1984–2019).

Voiceless ‘t’ variants ([t], [tˢ]) are much more common pre-pausally in the Glasgow corpus than in the King’s corpus; at King’s, shadow vowel) are the most common before a pause.

9.6.2 How does the realisation of word-final /d/ contribute to a choir’s aesthetic?

The realisation of word-final /d/ was selected for investigation as it is salient to the overall aesthetic of a choir, and it is particularly associated with Western classical choral singing. Voiceless realisations were more common overall in pre-consonantal contexts, as expected based on findings in speech that adjacent obstruents are likely to promote devoicing regardless of whether they are voiced or voiceless (Davidson, 2016). Likewise, it is consistent with phonetic findings that tokens of /d/ in pre-pausal contexts are less likely to be Voiced than tokens followed by a vowel (Davidson, 2016). However, Davidson (2016) found that for stops in pre-pausal contexts, the predicted probability of partial or full voicing was 0.57 (compared to voiceless). While we cannot directly compare the auditory coding of this work and the acoustic analysis conducted by Davidson (2016), it seems that there is a tendency for more frequent voicing of phonologically voiced stops in pre-pausal contexts in singing than in speech. This would fit with the view that phonation during singing is prioritised more highly than in speech. That is, voiced consonants can be voiced at the pitch of the adjacent vowel to carry the tune (Morrissey, 2008; Johnston, 2016, p. 104). While this tendency is unsurprising, it needs to be empirically tested by recording individual singers producing voiced stops and then using a similar methodology to measure the proportion and shape of voicing distribution during the stop closure.

Shadow vowel variants are more likely before a pause. This is consistent with the Western classical choral singing literature (for example, Coward, 1914; Cappadonia, 1962; Moore, 1972; Decker, 1977; LaBouff, 2008; Neuen, 2020).

The increase in affrication over time in both the Glasgow and King’s corpora may mimic increases in affrication in SSBE (Lindsey, 2019) and SSE (Chirrey, 1999) speech and may reflect a broader change in English globally (Dodsworth & Mielke, 2022). It is also possible that singing pedagogy has played a role in the increase of affrication in these data, as affrication is recommended to help boost the audibility of word-final /d/ when singing with orchestral accompaniments (LaBouff, 2008).

Glasgow word-final /d/

For the Glasgow Orpheus choir under Hugh S. Roberton (1925–1951), /d/ is almost always Voiced in all contexts. The increase in the use of Voiceless variants in the recordings of the Glasgow Phoenix choir could reflect a realisation of word-final /d/ that is more closely aligned to the variant distribution found in spoken Scottish English, which includes ejective allophones of voiced stops (Gordeeva & Scobbie, 2013). Contrary to the attention to speech model interpretation of the categorical realisation of linking /r/ from Chapter 8, phrase-final /d/ is not consistently Voiced in the Glasgow choir singing. This shows that attention to speech does not apply to all variables uniformly, and there may be some variables which are more salient to a particular choir's style than others.

King's word-final /d/

King's sound has consolidated over time, with shadow vowel 'D' variants in pre-pausal contexts becoming the most frequent realisation. At King's, the increase in the use of Voiced variants in pre-pausal contexts over time, and the increase in the consistency of Voiced variants under Stephen Cleobury (1984–2019) particularly, demonstrates how pre-pausal Voiced /d/ has become enregistered as a feature of the style of King's, and perhaps also the style of elite Western classical choral singing more widely.

Affricated variants of /d/ have been incorporated into the King's style, particularly in pre-consonantal contexts. While there has been an increase in the proportion of affricated variants over time in the Glasgow corpus, it remains to be seen whether affricated variants of /d/ have become a feature of a broader British choral aesthetic. Affricated realisations of /d/ were substantially less frequent in the Glasgow corpus compared to the King's corpus. The relatively lower rate of affrication in Glasgow could relate to affrication being associated with SSBE, or perhaps it aligns with our musically-informed predictions that choirs/singers need to affricate /d/ in particular when accompanied by an orchestra or for singing in the acoustic of the chapel of King's College, Cambridge (LaBouff, 2008; Williams, 2019). The choirs were not accompanied in the recordings analysed here; however, it is possible that the habits formed when singing with organ and orchestra – the latter becoming more frequent after the arrival of David Willcocks – were carried over into choral *a cappella* singing, as suggested by Day (2018).

9.6.3 Other explanatory variables for future examination

For the most part, it is impressive that highly trained choirs can produce consonants in a synchronised manner. Having said this, for some /d/ sites, there were up to five (or even more) identifiable bursts spread over 100 ms. Choral directors have suggested that the coordination issue can be reduced in larger choirs by permitting only a subset of the choir to produce the consonant, particularly relating to the sibilant /s/ (e.g. Cappadonia 1962). Due to the coordination issue, particularly with stop consonants, it is impossible to accurately segment the closure, burst, and onset of the following vowel. As such, I decided to continue with auditory coding rather than adopt an acoustic methodology, as with the vowel analyses presented in chapters 2–4. This means that I cannot include duration-based variables which may play a role, including: overall duration of /d/; duration of stop closure; duration of the stop burst; duration of the preceding vowel; Voice Offset Time; and Genre.

Duration of /d/

The segment's duration could not be included in this analysis as segmentation was not fine-grained enough, particularly in the context of following voiced segments where it is difficult to ascertain where /d/ ends and the following segment begins. However, durational aspects of /d/ require investigation in future research. The duration in milliseconds for each variant of /d/ is listed in Table 9.12 and plotted in Figure 9.21.

In addition, the duration of the complete segment is confounded with the macro categories Voicing and Affrication, as well as the more fine-grained Variant. If it were possible to segment the closure phase of the released stops accurately, closure duration could be a cue to phonological voicing that is not confounded. However, as I mentioned previously, segmenting the data at this level is impossible, largely due to the coordination problem. This needs to be explored in future research, perhaps with individual singers.

Sung speech rate

The relative sung speech rate – the number of phones (speech sounds) divided by the duration of a sung phrase – could be used as a proxy for speech rate. We know that /d/ is less likely to be released and more likely to be deleted in faster speech (Lisker & Abramson, 1967; Davidson, 2011). Therefore, it is possible that when

Table 9.12: /d/ variant mean duration and standard deviation by Corpus. % rounded to one decimal place

Corpus	/d/	Mean Duration (ms)	SD	N	(%)
Cambridge	[d^{ə}]	202	99	168	7.5%
Cambridge	[d^{zə}]	204	102	103	4.6%
Cambridge	[d]	120	58	385	17.3%
Cambridge	[d^{z}]	130	55	535	24%
Cambridge	[d̚]	145	89	484	22%
Cambridge	[t]	160	90	196	8.8%
Cambridge	[t^{s}]	127	48	356	16%
Glasgow	[d^{ə}]	232	116	207	21%
Glasgow	[d^{zə}]	256	152	34	3.5%
Glasgow	[d]	182	86	277	28%
Glasgow	[d^{z}]	195	107	134	13.6%
Glasgow	[d̚]	194	113	183	18.6%
Glasgow	[t]	260	129	134	13.6%
Glasgow	[t^{s}]	243	157	17	1.7%

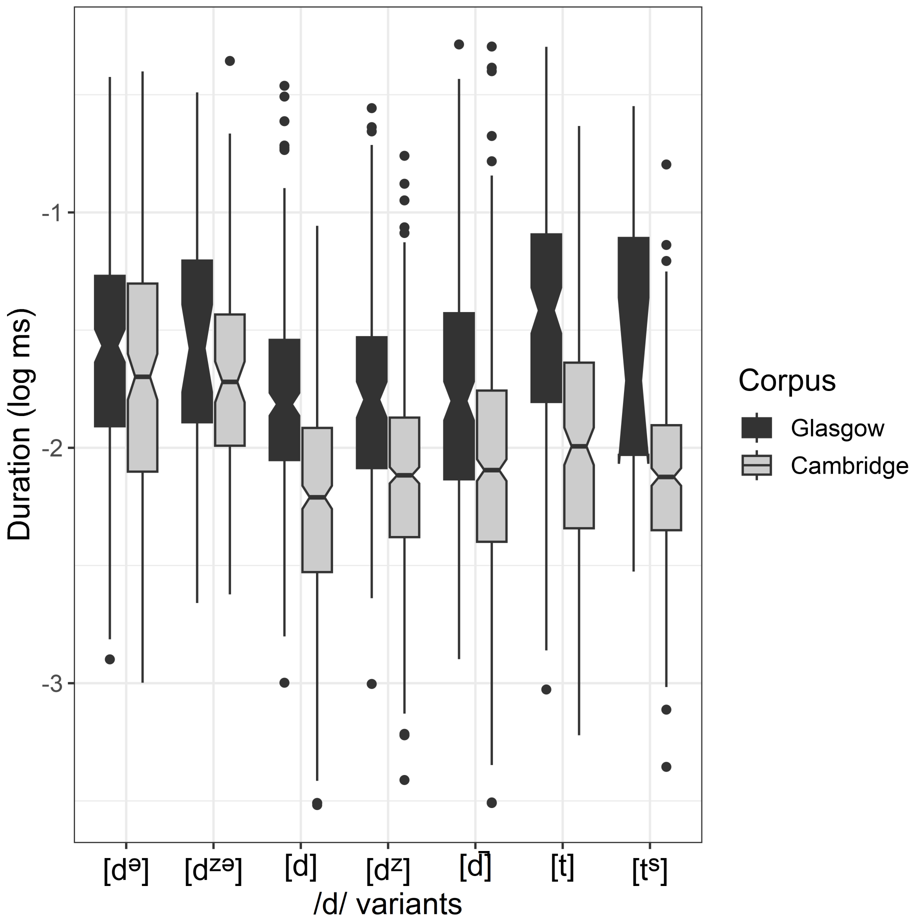


Figure 9.21: Duration (log ms) of word-final /d/ variant by Corpus

the music is faster, /d/ is more likely to be reduced or deleted. This needs to be explored in future work.

Duration of preceding vowel

In some sung contexts, the duration of the preceding vowel may also affect the perception of word-final consonant voicing. I considered using word duration as a proxy for vowel duration. However, word duration is inherently confounded with both Voicing and Affrication. Word-final /d/ realisations with shadow vowels (epenthetic vowels) are longer than realisations without, as an extra sound is added to the sung speech sequence. In addition, affricated /t/ variants in speech are longer than unaffricated variants (Buizza & Plug, 2012), and we might expect a similar pattern for /d/ in singing.

Genre – It's alright [ɪtsaːlɹaɪt̚] (not [ɔːlɹaɪt^{h}])

We have seen from the musical literature (see Section 9.2.5) that there is the belief that double consonants are treated differently within the classical reference style and the popular reference style (e.g. Neuen, 2020; LaBouff, 2008). Given that my corpora do not include singing in popular styles, I decided not to include Genre in this analysis. Genre was omitted partly because the categories are Corpus specific and arise from the data – they do not completely match across corpora – though they are mostly similar. Within the King's corpus, the Genre is mostly constant. For example, although the corpus includes music from different eras, the singing serves an exclusively liturgical purpose – and it has been suggested that the choir does not vary its style when performing different repertories (Sagrans, 2016). The Glasgow corpus shares a large portion of repertoire which contains hymns and metrical psalms (church music). In these data and models, much of the impact of Genre will be soaked up by the varying intercepts for Album and Song, but there will be some unquantifiable impact. In future work, it would be particularly interesting to compare the distribution of variants between choral singing in a genre in the classical reference style with choral singing from within the popular reference style.

Singing pedagogy of popular genres such as jazz favours unreleased or 'imploded' stops in word-final contexts. Spradling & Binek (2015) write that 'Diction requirements in vocal jazz are based on vernacular, not formal, speech patterns … When one uses a "formal" palette of pronunciation in this genre, the delivery of text sounds stilted, stiff, or, as some would say, affected'. They continue: 'Many final consonants are imploded at the ends of words to make the delivery of the text more microphone compatible' (Spradling & Binek, 2015).

In popular styles, therefore, producing released allophones of phrase-final stops can make the singing sound affected. Unreleased variants also occur within the classical reference style. In the data presented here, unreleased variants were more likely in Glasgow than in Cambridge but occurred in both corpora, particularly before following consonants (for example, *good boy*). This may be related to the realisation of double consonants, that is, /t t/ or /d d/ sequences, such as *that tin*, or *good dog*, where the singing literature recommends the first consonant be 'imploded' (unreleased) unless both consonants are released for particular emphasis (Johnston, 2016; LaBouff, 2008). Unreleased variants in classical singing are dispreferred in pre-pausal position, contrary to what we know from speech data and popular singing styles, perhaps due to the formal context and increased attention to speech driven by orthography.

As we have seen, pre-pausal contexts may be particularly salient (Davidson, 2016). Perhaps the realisation of phrase-final consonants is one of the key distinguishing features of the popular and classical reference styles of singing. As Spradling & Binek (2015) remark, the classical reference style is analogous to a careful formal speech style, whereas the popular reference style is closer to casual speech. That is not to say we sing as we speak in either popular or classical styles.

9.6.4 Sung speech rate

One hypothesis suggested by Fisher (1991) is that coarticulation only plays a role in choral singing at faster speeds. For example, double consonants (*good door*) at faster speeds may precipitate cases of no audible release. It would be interesting to record singers producing simple sung phrases at various speeds and see whether an increase in tempo leads to an increase in unreleased realisations of stops across various linguistic contexts.

9.6.5 Musical dynamic (i.e. loudness or softness)

The variant employed by individual singers often needs to match the volume and tone quality of the sung passage. For example, in tender, quiet moments of music, I have heard singers produce unaspirated ejective [t'] realisations of /t/ in phrase-final position, perhaps to increase audibility as ejectives are typically louder than their pulmonic counterparts, and this may serve to enhance the listener's perception of the place of articulation of the plosive (Ogden, 2009, p. 164). Equally, it is possible that in quieter moments, phrase-final shadow vowel [dᵊ] variants are too loud. A singer might opt for an alternative realisation that is less prominent. Johnston writes that 'A plosive [d] will not poke out of the melodic line if the surrounding phonemes are similar in intensity. A consonant must match its environment' (2016, p. 110). Does the dynamic of a sung passage (how loud or soft it is) affect how choirs collectively realise word-final and phrase-final /d/? This hypothesis will need to be explored experimentally in future work.

9.6.6 Syllabification in singing

The voiced normally-released variant [d] is by far the most prevalent in pre-vocalic contexts (for example, *and again*). Voiceless and Affricated variants are least likely in this context. This finding aligns with the singing literature: ‘Avoid over-aspirated medial consonants – use softer attack when medial consonants begin unstressed syllables’ (LaBouff, 2008, p. 124).

Let us recall the first two quotations presented at the start of this chapter from Coward (1914) and Roberton (1963). Interestingly there is some evidence for resyllabification in the examples provided. Coward (1914) gives the example *Hel, Lor* (as opposed to *Help, Lord*). In contrast, Roberton (1963) gives the example *O–hel–pu–slor* for the phrase ‘O help us, Lord!’ Note how Roberton places the final consonant of each word at the start of the next, while Coward does not. These different approaches reflect two different aesthetic approaches in choral literature.

One strategy is to place the final consonant of one word onto the beginning of the next (Henkel, 1965; Decker, 1977). This approach seeks to maintain the legato line by minimising the gaps between syllables and maintaining phonation as much as possible. This approach cannot be uniformly applied as, on occasion, it can lead to misinterpretation of the sung text. One such example from the corpus is an early recording of the Glasgow Phoenix Choir singing ‘and earth’; as there is no gap between the final /d/ and the onset of ‘earth’, the phrase is perceived as ‘an dearth’.

In the alternative approach, Neuen (2020) writes that the most important thing choirs can do when singing in English or German is to place a ‘slight glottal attack on most words that begin with a vowel’. He gives examples: ‘Come all,’ not ‘cuh–mall’, ‘God of our,’ not ‘Gaw–duh–vour’. Neuen shows a preference for placing the final consonant of a syllable together with the previous syllable rather than at the start of the next – when it is across a word boundary.

Thus we are presented with conflicting ideologies of intelligibility vs legato and whether to prioritise one over the other. Many choral conductors would disagree with Neuen, since when you place a glottal at the start of the word, even a slight one, you effectively stop the sound or the line. There is a trade-off between these differing views. I imagine it will depend on a case-by-case basis whether intelligibility needs to be increased by adding a glottal, or if the legato line (smoothness and continuity of voice) should be prioritised.

There is limited evidence to support either approach from the analyses presented in this chapter. However, the prolific use of [d] variants in word-final pre-vocalic context (for example, *and again*) may be an example of placing the consonant at the start of the following word. Other variants tend to end the first word without carrying on seamlessly into the next. Unreleased [d̚] variants in pre-vocalic contexts may show a different syllabification strategy than [d] variants. As illustrated in Table 9.13, the proportion of [d] variants used in pre-vocalic contexts in the Glasgow corpus is much higher (90%) than at King's (73%), where 20% of the realisations are unreleased [d̚] and 6% voiceless ([t] or [t^{s}]).

Table 9.13: Realisation of word-final /d/ in pre-vocalic position (e.g. *and again*) by Corpus

Corpus	Variant	N	(%)
Glasgow	[d^{ə}], [d^{zə}]	0	0%
Glasgow	[d], [d^{z}]	213	90%
Glasgow	[d̚]	15	6.3%
Glasgow	[t], [t^{s}]	5	2.1%
Glasgow	[∅]	4	1.7%
Cambridge	[d^{ə}], [d^{zə}]	1	0.2%
Cambridge	[d], [d^{z}]	386	73%
Cambridge	[d̚]	104	20%
Cambridge	[t], [t^{s}]	32	6%
Cambridge	[∅]	9	1.7%

Voiceless or unreleased variants may separate the following vowel onset by creating a region of lower amplitude at the end of the preceding word with an unreleased stop, allowing the vowel to protrude slightly, or by separating the following vowel onset with a burst of aspiration from the preceding voiceless stop. A perceptual experiment could be designed to test whether either of these variants facilitates intelligibility or represents random variation in the realisation of /d/.

9.6.7 Making meaning with word-final /d/

Fully-voiced realisations of phrase-final /d/ appear to be a stylistic feature of the King's sound that cannot be related to a speech accent. Could this be part of a wider non-dialect-related referee for Western classical choral singing? I am wary of adopting this position, given Wilson's (2014) assertion that devoiced variants of /d/ are part of the choral referee. I think that it is more likely that hyper-voiced variants of /d/ have become enregistered as part of the sound of elite choral singing, such as the singing of the Choir of King's College, Cambridge. By producing these hyper-voiced realisations accurately, which are difficult for other singers to produce, elite choristers are setting themselves apart from other forms of classical choral singing. It is also possible that hyper-voiced variants are a style marker of the liturgical genre in which King's specialises. Variation in the realisation of word-final /d/ may provide evidence of the attention to speech model at work. Singers are encouraged to produce phonetically hyper-voiced variants of /d/ for each orthographic representation of /d/, particularly in phrase-final position, to contrast with the phonetically voiceless /t/.

9.7 Conclusion

This chapter has demonstrated how the realisation of word-final /d/ can contribute to a choir's sound/accent. The sound of King's, in particular, has developed a preference for phrase-final shadow vowel realisations, and affricated variants in pre-consonantal contexts. In contrast, in the Glasgow corpus, voiceless realisations in word-final contexts have become more in common which may relate to the spoken voicing contrast of Scottish English. The realisation of /d/ is constrained by Context, with Voiced variants favoured in following vowel contexts. The realisation of word-final /d/ in pre-vocalic contexts may be affected by whether the choir director and singers prioritise intelligibility or legato line. It is unclear whether the realisation of word-final /d/ is influenced by a choral referee, but it seems likely that it is a style marker of liturgical music and elite Western classical choral singing more generally. In the following chapter, Chapter 10, I will present a general discussion of the findings of this thesis and suggest directions for future research.

Chapter 10

General Discussion

This thesis aims to establish whether choirs have accents. That is, whether the accent of choral singing varies by dialect area, presumably conditioned by the accent of the singers and/or their choir director. I also sought to explore whether the accent of choral singing in these corpora showed linguistic variation and change over time. After building the first Corpus to assess change over time in the vowel quality of choirs from Glasgow, the results showed that front vowels had acoustically lowered over time (as reported in Chapter 5). I built the second corpus, containing recordings of the Choir of King's College, Cambridge, to confirm the findings of the first, and to explore the impact of Choir Director on the choral signal, finding that David Willcocks substantially raised the acoustic vowel quality, followed by lowering (see Chapter 6). I then presented a combined analysis of vowel quality across the corpora which supported a shared front vowel phonology which seemed to be based on Standard Southern British English, particularly with distinct TRAP and BATH phonemes in both the Cambridge and Glasgow corpora. The back vowels showed a different pattern, with differences in the phonetic realisation of GOOSE, with the Glasgow choirs producing a markedly backed realisation. This could be in contrast to the Scottish fronted vernacular spoken form of GOOSE, or perhaps related to singing pedagogy (see Chapter 7).

Cumulatively, the vowel analyses showed that there were similarities between the front vowel phonology and realisation between the choirs reflecting SSBE. At the same time, there were elements of regional vowel phonology that were evidenced in the Glasgow corpus. The vowel contrast LOT–THOUGHT was distinct in quality in the King's corpus, as expected. However, there was no evidence of the LOT–THOUGHT contrast in the Glasgow corpus. Both corpora showed a robust difference in vowel quantity and small differences in vowel quality between FOOT and GOOSE. The lack of distinction in quality could be due to the relative lack of tokens for FOOT, the manual data extraction, or possibly the singing technique employed in classical choral singing.

Chapter 8 demonstrated contrasting consonant phonology, with Glasgow choirs producing postvocalic /r/ and King's only producing postvocalic /r/ in linking /r/ contexts. Rhoticity declined in the Glasgow corpus over time, and the realisation of /r/ has shifted too. Chapter 9 showed that the realisation of word-final /d/ varies between the two choirs. This variable is particularly salient; King's employs more shadow vowel (epenthetic vowel) variants in phrase-final position. In contrast, there are more voiceless variants in the Glasgow corpus for later Time/Directors. The King's corpus also shows affricated variants, and affrication appears to increase over time, perhaps reflecting the influence of orchestral accompaniment, which became more common under the direction of David Willcocks (see Chapter 3 Section 3.6.3).

The discussion is structured as follows. First, I will address the primary research questions in turn. Then I will discuss the evidence for the impacts of spoken accents, choir director and choral singing pedagogy on choir accents. Then I will discuss what models may tell us about how choral singers know how to sing, including Referee Design (Bell, 1984) and the Attention-to-speech model (Labov, 1966). Following this I will discuss methodological reflections relating to the current research, followed by potential avenues for future research.

10.1 Research questions

This thesis sought to answer the following research questions:

1. Is there evidence of regional differences between Glasgow and Cambridge, in the phonology of vowels, rhoticity, and word-final /d/?

2. Is there evidence of a common choral accent uniting Glasgow and Cambridge in the phonology of vowels, rhoticity, and word-final /d/?

3. What changes have taken place in the phonology of choral singing over time?

    (a) Are the changes linked with changes in spoken phonology over the relevant time period?

    (b) Are the changes linked with changes in aesthetic coventions of choral singing?

    (c) Are the changes linked with individual properties of the choir directors?

10.1.1 What is British classical choral singing like in terms of phonology?

In this section I will address research questions 1 and 2. The data reported in this thesis broadly support a shared British choral (classical choral) accent, as found in Chapter 7.

Front vowels

In both choirs FLEECE, KIT, DRESS and TRAP are equidistant with FLEECE being high, and TRAP being very low. TRAP and BATH are statistically distinct in the backness dimension (F2), which indicates that the front vowel phonology is modelled on a prestigious variety which makes that distinction (for example, RP, M/K or SSBE). For the more recent Glasgow singers, the TRAP–BATH split is likely not present in their spoken accents (Standard Scottish English), but it persists in the sung accent.

Back vowels

For the King's corpus, there is a clear separation between BATH, LOT, and THOUGHT with the distribution as expected for a southern British prestige variety like SSBE. STRUT tends to be higher and fronter than BATH, though there is no clear separation between the two phonemes. The data do not support a contrast between GOOSE and FOOT, but this may relate to the number of tokens of FOOT.

For the Glasgow corpus, there is no evidence of a distinction between LOT and THOUGHT. STRUT tends to be higher and backer than BATH for the Glasgow choirs. GOOSE is higher than FOOT recordings of the Glasgow Phoenix Choir produced under the direction of Peter Mooney and Marilyn J. Smith.

Rhoticity

The Glasgow choirs are more likely to produce rhoticity than King's in all phonetic contexts and this is not related to Scottish repertoire. Linking /r/ (*car and*) is categorically produced in Glasgow, whereas, in the King's data, linking /r/ is produced approximately 60% of the time. Rhoticity in pre-pausal contexts, and pre-consonantal contexts (within-word and across word boundary), has reduced over time in the Glasgow corpus. This is particularly noticeable in pre-pausal contexts where rhoticity occurs approximately 75% of the time for recordings made under Hugh S. Roberton, but close to zero for recordings produced under Marilyn J. Smith. In the King's data, postvocalic /r/ is rarely articulated, which reflects my expectations about the connection between the choral accent and a non-rhotic spoken accent.

Word-final /d/

In the recordings of choral singing analysed here, word-final /d/ is articulated 90% of the time. Articulated /d/ is realised as [d], [d^{ə}], [d^{z}], [d^{zə}], [d˺], [t], and [t^{s}], and the distribution of variants differed between the choirs. In phrase-final position hyper-voiced [d^{ə}] tokens increased over time at King's, and affricated variants [d^{z}] became more common phrase-medially. In Glasgow, affrication has increased slightly over time. However, voiceless variants have become the most common in phrase-final contexts under Marilyn J. Smith.

10.1.2 Is there evidence of variation and change in British choral singing over time (RQ 3a)?

The front vowels KIT, DRESS, and TRAP have lowered, and KIT and TRAP retracted over time in both the Glasgow and King's corpora (see Chapter 7). Similarly, BATH, STRUT, LOT, and THOUGHT lowered over time in both corpora. BATH has retracted more for Glasgow, and THOUGHT has fronted, meaning that Glasgow and King's seem to have become more similar in back vowel F2 over time. As reported in Chapter 8, rhoticity has decreased over time in all contexts apart from linking /r/ in Glasgow (*car and*), which may be evidence of a shift towards a non-rhotic Anglo-English norm for choral singing.

10.1.3 Is there evidence of aesthetically-driven differences between choirs (RQ 3b)?

The realisation of word-final /d/ varies by Corpus and Time/Director (see Chapter 9). The Glasgow choirs are more likely to produce voiced variants of /d/ in pre-consonantal contexts (e.g. *and can*). Voiced variants in pre-pausal contexts increase over time at King's, driven by an increase in shadow vowel (epenthetic vowel) realisations. Voiceless variants increase over time in pre-pausal contexts in the Glasgow corpus. There is a marked difference in style between the choirs, and it is possible that shadow vowel variants may index elite and/or liturgical styles (see Chapter 9).

10.2 What is the accent of British classical choral singing based on?

There are three major sources of variation in accent features that this study has considered:

- the spoken accent of a regional dialect area.

- the impact of a particular choir director.
- Western classical choral pedagogy and/or singing technique.

Each of these sources has been found to contribute to the overall choral sound.

10.2.1 Influence of spoken accent

This study investigated the impact of spoken accents on the choral sung signal. The Glasgow choirs investigated were the Glasgow Orpheus and Glasgow Phoenix which were presumed to have a Scottish Standard English (SSE) phonology. The Choir of King's College, Cambridge is from a Southern Standard British English (SSBE) dialect area. The spoken dialect of the area where the choirs are based was predicted to have an effect on their pronunciation.

For vowels produced by the Glasgow choirs, based on Standard Scottish English phonology and realisation, I expected TRAP to be more central than in SSBE, and for DRESS to be more raised (Wells, 1982b). What I found is that TRAP has retracted for both King's and the Orpheus and Pheonix choirs and that there is no difference between the two choirs in the late time periods (Marilyn J. Smith, Glasgow, and Stephen Cleobury, King's). Unexpectedly, there is a statistical difference for DRESS with King's producing a more raised quality. Overall, however, TRAP and DRESS have converged in F1 over time in the choir corpora. FLEECE, KIT, and TRAP have converged in F2 over time in the choir corpora.

If the singing in Glasgow was completely based on SSBE phonology we would expect separate TRAP–BATH, LOT–THOUGHT, and FOOT–GOOSE phonemes, and if it was based entirely on SSE we would expect TRAP–BATH, LOT–THOUGHT, and FOOT–GOOSE to be merged. There is a more nuanced picture emerging. The front vowel and low vowel quality seem to have converged between the Glasgow and King's corpora over time. However, the back vowels remain different. The accent of choral singing in the Glasgow corpus is a hybrid containing SSE and SSBE elements. The particularly salient TRAP–BATH distinction of SSBE is incorporated alongside a single-target LOT–THOUGHT phoneme of SSE. In contrast, the phonology of King's is mostly SSBE-like with distinct BATH, LOT and THOUGHT phonemes.

In terms of rhoticity, I expected the Glasgow choirs to articulate postvocalic /r/ variably in all contexts, based on SSE phonology, and for King's to not articulate postvocalic /r/ apart from in linking /r/ contexts (e.g. *car and*), based on SSBE phonology. These expectations were largely met, however, there was a noticeable decrease in rhoticity over time in the Glasgow corpus, potentially suggesting that they have shifted towards an SSBE model, or reflecting derhoticisation of working-class SSE. The realisation of word-final /d/ was not impacted by dialect features, rather conditioned by the classical choral aesthetic and directorial input.

Is there a British choral accent based on a spoken prestige accent?

Musicologists have suggested that the accent of classical choral singing is based on the High form of the language, or RP (e.g. Potter, 1998), and particularly of King's (Day, 2018). What does the evidence say?

TRAP–BATH Firstly, I found distinct TRAP–BATH lexical sets in both the Glasgow and King's recordings, which supports the impact of SSBE phonology on choral singing. This finding is surprising as it relates to an accent that is different to the spoken accent of the Glasgow singers. The realisation of TRAP in both Glasgow and King's has shifted from a high front realisation like [æ], or even [ɛ], to [a]. This mirrors a shift in TRAP vowel height and backness in Received Pronunciation (Wells, 1982a; Harrington et al., 2000; Hawkins & Midgley, 2005; Fabricius, 2007; Cruttenden, 2014; Bjelaković, 2017). It seems that as the singers' speech has changed over time at King's, so has the sung vowel realisation – though it is possible that this is also driven by other factors, for example, the choir directors.

Rhoticity The realisation of postvocalic /r/ too seems to relate to the non-rhotic accent SSBE, as singers in Glasgow have become less rhotic over time, apart from in the SSBE-licensed linking /r/ context. This perhaps indicates that the choirs are orienting towards a non-rhotic SSBE accent. However, this is where the evidence for a non-regional accent of British classical choral singing ends.

LOT–THOUGHT In the recordings of King's there are clearly separated LOT–THOUGHT phonemes, as we would expect if the singing is based on an SSBE phonology (Wells, 1982a). However, in the recordings of Glasgow choirs, there is no evidence of a contrast between the lexical sets LOT–THOUGHT which is consistent with SSE phonology (Abercrombie, 1979; Wells, 1982b; Stuart-Smith, 2003; Stuart-Smith, 2008)

GOOSE To further complicate matters, the GOOSE vowel of King's, while more central than the Glasgow realisation, is still more peripheral than we would expect if based on SSBE speech (for example, see Chapter 4 Figure 4.6a). The GOOSE vowel of the Glasgow choirs is extremely backed like [u], which cannot be explained by reference to either SSE or SSBE. The GOOSE vowel of contemporary urban Scotland is closer to a front or central mid vowel (Scobbie et al., 2012).

In summary, there are features of both the Glasgow corpus and the King's corpus that can be attributed to the spoken accent of the region where the choir is situated. However, there are also some features, such as the realisation of GOOSE, that cannot be explained by the spoken accents SSE, SSBE, or RP. I will now discuss the impact of the choral director on choral accent.

10.2.2 Influence of the choir director (RQ 3c)

Thus far, I have discussed the evidence for the impact of spoken accents on the accent of choral singing. There are a number of possible factors which might influence variation and change in choral accents, and which warrant further discussion, including: the accent of the choir director, or the director's artistic vision. For example, do singers imitate their director's realisations, or do they do as they are told? Wilson (2014) finds that choir leaders correct accent features in addition to musical features. Recent research has investigated what singers want from their conductors (Cronie, 2021), and found that the artistic vision of the director was one of a set of expectations of the choir members. How might artistic vision relate to linguistic variation and change?

Evidence of Choir Director impact from Glasgow corpus

I found that the Glasgow Orpheus Choir, under the direction of Hugh S. Roberton, developed a uniquely Scottish sonic identity (see Chapter 8 Section 8.6.5). The evidence shows that the sound was crafted towards a 'High form' of Scottish Standard English, like the Kelvinside/Morningside accents of upper-middle-class Glasgow and Edinburgh (Johnston, 1985). This interpretation is supported by the combination of a particularly high front vowel realisation, separation of TRAP and BATH, the prevalence of word-initial alveolar trill realisations of /r/, frequent articulation of postvocalic /r/ in all contexts, and evidence of a single target for the lexical sets LOT–THOUGHT. While careful not to imply the superiority of Scottish choirs, Roberton himself was of the belief that 'in Scottish singing at its best there is a note, essentially Scottish, which does not always strike a responsive chord in a mind attuned to a different type of expression' (Roberton, 1963, pp. 108–109). This was a sound that he intended to foster in the Glasgow Orpheus Choir.

Many of the Orpheus' stylistic features were carried over in recordings produced by Peter Mooney (1959–1975). This may be partly because the Glasgow Phoenix Choir was founded by members of the Orpheus that wanted to continue singing. While some features were carried over, the sound began to evolve. The front vowels began to lower and retract; alveolar trills were much less frequent. Perhaps following the decline of the Kelvinside/Morningside accent, there was a need for a new model for Scottish choral singing. At the same time, there is a desire to disassociate the form from hackneyed ‘tartan’ stereotypes.

I have found that, under the direction of Marilyn J. Smith (1987–2016) there was a shift from the upper-middle-class Scottish accent to a hybrid British accent that incorporated more Southern Standard British English features. While the alveolar trill had already fallen out of fashion under Peter Mooney, under Marilyn J. Smith, the Phoenix Choir no longer produced rhoticity in pre-pausal contexts and much less frequently in pre-consonantal contexts. However, in the SSBE-licensed postvocalic /r/ contexts, the Scottish singers produce linking /r/ categorically – more consistently than in the King’s corpus. The vowel contrast LOT–THOUGHT was previously only distinct in duration, but under Marilyn J. Smith LOT–THOUGHT became distinguished by vowel height. In addition, there is a significant decrease in vowel duration under Marilyn J. Smith, showing a departure from the luxuriant expansive favoured by Hugh S. Roberton and Peter Mooney.

Overall, the Scottish choirs show evidence of a shift from a High Scottish prestige accent, present in recordings of the Glasgow Orpheus Choir under Hugh S. Roberton (1925–1951), towards a Southern Standard British English accent under Marilyn J. Smith (1987–2016). The Choir Director may play a role in selecting a target accent and orientating the choir towards the chosen accent through modelling and/or correcting accent features in the choral rehearsal (Wilson, 2014).

Evidence of Choir Director’s impact from King’s corpus

The Choir of King’s College, Cambridge, under Boris Ord (1945–1958) appears to have adopted an SSBE-like accent. As we saw in Chapter 7, there are few differences in front vowel height between recordings made under Boris Ord and more recent recordings made under Stephen Cleobury. There are differences in front vowel F2 as KIT fronts and TRAP retracts over time.

David Willcocks orientated the accent of King’s towards a conservative-RP accent with which he was familiar from his time as a chorister at Westminster Abbey in the 1930s (Day, 2018). This is evident in the overall shift in vowel height, amounting to a change in the habitual articulatory settings of the choir. This shift in height is particularly noticeable for DRESS and TRAP, which sound like [e] and [ɛ], respectively. There was also a significant retraction of the back vowels BATH, STRUT, LOT, FOOT and GOOSE. GOOSE shifted from the typical SSBE realisation [ʉ] back towards a more conservative-RP-like [u]. These changes were picked up on by critics who wrote of the ‘preciousness’ of the sound. Day writes that:

> ‘Preciousness’ was not an infrequently made charge against the singing. If the critics meant that the style was affected, that it was artificially

> cultivated in some sense by Willcocks, they were wrong. The singing style was 'in the King's tradition'. It was also emphatically Willcocks's own style (Day, 2018, p. 174).

The evidence supports the notion that David Willcocks, amongst other musical aspects, shifted the choral referee from an SSBE accent to a conservative-RP accent (see Chapter 6). Whether this means that the style was 'artificially cultivated' is not a question that I can answer, but it seems to have become established under Willcocks's direction. Day reports that Willcocks himself believed that the sound had evolved due to more frequent singing with orchestral accompaniment, which began under his tenure in the 1960s (Day, 2018, p. 173). As we saw in Chapter 9, the data support this belief, as affrication of word-final /d/ increased significantly in recordings made under David Willcocks, and continued on this upwards trajectory under recordings of Philip Ledger and Stephen Cleobury, becoming a stable feature of the King's sound.

Similarly to the transition from the Glasgow Orpheus Choir to the Glasgow Phoenix Choir under Peter Mooney, due to the strength of the character of King's sound curated under David Willcocks, recordings of Philip Ledger show modest differences. The overall vowel space begins to lower. FOOT–GOOSE return to the more front realisation of recordings made under Boris Ord. Recordings of King's under Stephen Cleobury show almost a complete reversal to the vowel quality cultivated under Boris Ord. That is, the choir returned to an SSBE-like accent, as Day writes, 'King's at the beginning of the twenty-first century was certainly not such a dominating exemplar as it had been fifty years earlier' (Day, 2018, p. 240). This is not the only change, however, as phrase-final /d/ is much more likely to be fully voiced or hyper-voiced [dᵊ] under Stephen Cleobury.

Impact of the Choir Director's' own spoken accent

In Chapter 8, I suggested the possibility of the impact of the Choir Director's spoken accent. While this requires examination in future work, it is consistent with my findings that the singing of the Orpheus Choir was highly rhotic under the direction of Hugh S. Roberton, who had a rhotic accent. There is a decline in rhoticity over time, which advances quickly under Marilyn J. Smith who is a speaker of SSBE – a non-rhotic accent (see Chapter 8).

The director's aesthetic or artistic vision

David Willcocks' shifted the King's sound towards a conservative-RP sound that he was familiar with from his time as a chorister at Westminster Abbey in the 1930s (Day, 2018). It is unclear whether this was his own accent, or if Willcocks' artistic vision is based on the accent of a third party (Referee Design). Either way it was distinctive. It is possible that the fronter realisation of FLEECE under Stephen Cleobury could be attributed to encouraging the choir to sing with a 'bright forward tone', but it's unclear whether this is related to singing with Italian vowel sounds. The question of Italianate quality aside, this analysis supports the view that the vowel quality of the Choir of King's College, Cambridge evolved over time. Under Cleobury's tenure the realisation of word-final /d/ has become more consistently hyper-voiced.

> ...Cleobury was sure, the articulation of consonants must be clear and incisive. While it was very easy to over-emphasize 't's and 'd's in the Chapel's acoustic – which quickly began to sound pedantic and ridiculous – it was necessary to work very hard to ensure 'f's and 'p's emerged distinctly (Day, 2018, p. 262).

In the next section, I will discuss some of the ways that Western classical choral pedagogy may have impacted the accent of the choirs.

10.2.3 Influence of Western classical singing pedagogy (RQ 3b)

There are two types of musical pedagogy that are relevant. Firstly, Western classical choral pedagogy relates to literature from choir directors including 'how-to' guides for choral singing, and choral direction (for example, Coward, 1914; Decker, 1977; Emmons & Chase, 2006; Hollins & Vango, 2022). There is also Western classical singing pedagogy (for example, Adams, 2008; LaBouff, 2008; Johnston,2016), which relates to literature on singing targeted at the individual vocal student or voice teacher. While these sound similar, and there is a good deal of overlap in technique, they do not always go hand in hand. The solo voice pedagogy tends to prioritise the aesthetic of the voice, that is, legato line and vocal tone colour, over intelligibility. In contrast, in Western classical choral pedagogy, 'intelligibility' is often a primary aim, and as we saw in Chapter 9, at King's, hyper-articulated consonants became a feature of the style. For the rest of the discussion I am going to use the term 'singing pedagogy' to relate to both choral and solo voice pedagogy, apart from where specified in text.

There are a number of ways that concerns surrounding vocal production can impact the accent of singing. For example, Morrissey (2008) raised the issue of 'singability', discussing a hierarchy of sonority where speech sounds are arranged by how sonorous they are – with the idea that more sonorous speech sounds are preferred in singing. There are various ways that speech sounds are modified for singing. For example, Gibson & Bell (2012), in a study of three New Zealand pop artists, find that the singers tend to have more open vowels in singing than in speech. One of the singers, Andrew, was found to have a similar F1 for all open vowels, which the authors interpret as a reflection of his classical singing background. Do the data reported in this thesis support these findings?

Vowel modification

Western classical singing pedagogy advocates for vowel modification depending on voice type and fundamental frequency (Emmons & Chase, 2006). It is not clear whether the same degree of vowel modification goes on in choral contexts as in solo singing. However, the results of this study may also evidence the impact of a choral singing pedagogy on the sung accent. The pattern of increasing F1 reflecting overall lowering of acoustic vowel quality may reflect a change in referee for choral singing from Received Pronunciation to Southern Standard British English. However, it could also reflect a change in Western classical choral singing practices more widely. That is, lowering the jaw to produce a broader, louder sound could also produce a similar acoustic impact. Day notes that at King's, choristers began having individual vocal tuition when Stephen Cleobury became Director, with one choral scholar commenting in 1992 that they 'projected' better creating a slightly louder, more robust sound (2018, pp. 260–261).

There are other glimpses of the acoustic manifestations of singing pedagogy at work in the vowel results. For example, I find that increasing duration causes KIT to raise and front toward FLEECE. Likewise, TRAP tends towards BATH as duration increases (see Chapters 5, 6, and 7). The acoustic backing of TRAP (decreasing F2) might be caused by articulatory retraction, but it could also be caused by increased lip-rounding. Regardless of the articulatory configuration used, its source may have musical-aesthetic roots. LaBouff (2008) notes that the 'English' TRAP vowel is not found in sung German, French or Italian. Perhaps the slightly rounded or backer realisation of TRAP is closer to the Italianate vowel preferred for singing. These influences are not linguistic in nature but relate to singing technique.

Consonant modification

Rhoticity As we saw from the writing of choral pedagogues, attitudes towards rhoticity in choral singing varies. A British choralist at the end of the nineteenth century writes that 'a provincial rustic "burr" must be eliminated.' (Martin, 1892, p. 12 in Day, 2018, p. 83). Decker writes:

> For those who believe that American English should be sung without a British accent, a touch of the 'r' is essential. When 'r' occurs at the end of a word or at the end of a prominent syllable, the vowel preceding it should be elongated as much as possible with only the thought of an 'r' added at the very end (1977).

Emmons & Chase write:

> There are times in choral literature when the American [r] is mandated. However, care should be taken that the American [r] be softened, sometimes to the omission of [r] as in the British 'dahling.' The director's ear is the guide (2006, p. 81).

I include these two quotes from American choral singing pedagogues as General American English is typically rhotic (Wells, 1982a). Therefore, these sentiments about the appropriateness and realisation of rhoticity in American choral singing may transfer to the Scottish context; if the accent of Scottish choral singing is based on a variety of Scottish English speech, it should be rhotic. The results of Chapter 8 show that rhoticity is produced consistently in recordings of the Glasgow Orpheus Choir under Hugh S. Roberton (1925–1951). However, rhoticity starts to decline under recordings of Peter Mooney (1959–1975) and is far less frequent in recordings under Marilyn J. Smith (1987–2016). It is possible that choral singing pedagogy contributed to the shift from the highly-rhotic, tangibly Scottish, sound of the Orpheus Choir to a British non-rhotic choral accent. At King's there is no evidence of rhoticity, as expected, meaning that the choral accent reflects the SSBE non-rhotic spoken accent.

word-final /d/ In contrast, the realisation of word-final /d/ shows a potential influence of singing pedagogy on consonant realisation at King's, as word-final hyper-voiced variants (e.g. *lord* = [lɔːdᵊ]) increase over time, becoming most frequent in the recordings of Stephen Cleobury (1984–2019). In addition, affrication of word-final /d/ increases in King's recordings over time, perhaps reflecting the shift to singing with orchestral accompaniment under David Willcocks from 1960 onwards (Day, 2018). The changes may reflect the impact of singing pedagogy, as affrication is recommended when singing with orchestral accompaniment (for example, LaBouff, 2008, p. 124). The recordings of the Glasgow Phoenix Choir show a reduction of voiced variants in favour of voiceless variants in phrase-final position. Voiceless realisations of /d/ in word-final phrase-final contexts are not consistent with choral pedagogy as they may affect intelligibility. However, other phonetic features could be cues to the perceived phonological voicing identity, for example, the duration aspects of the stop or the centre of gravity of the stop burst. Equally, as we have seen, Wilson (2014) suggests devoicing of final /d/ as a feature of a 'neutral' (that is, not accent-related) Western classical choral singing style. Therefore, it remains unclear where phrase-final stop voicing fits into the stylistic constraints of Western classical choral singing.

10.3 How do choirs know how to sing?

Thus far, I have discussed the separate impacts of spoken accent, choir director, and singing pedagogy on a choir's sound. I have shown how there are shared accent features in the singing of choirs in Glasgow and Cambridge, particularly the TRAP–BATH contrast which is not native to Scottish English. How did the well-established TRAP–BATH split arrive in choral singing in Scotland?

There have been a number of theories to account for why people sing the way they do. In popular solo singing, there are two main theories: Le Page & Tabouret-Keller's (1985) *Acts of Identity* framework, and Bell's (1984) Audience Design, specifically, Referee Design. Trudgill (1983) suggested that British rock and pop artists adopting mid-Atlantic accent features constituted Acts of Identity, in the sense that singers adopted the features of the audience they wanted to appeal to – in this case, Americans. More recently, Bell & Gibson (2011) find that the default accent of popular music as a genre is mid-Atlantic, with General American norms and singing-aesthetic and technique factored in. In the case of pop, therefore, the American-ish accent has become 'institutionalised' and functions as the default. In other genres such as indie, where a perceived authenticity is important to audiences (Beal, 2009), singers are freer to channel local identities using local features (Krause & Smith, 2017) (see Chapter 3).

What about the more 'rigid' genre of Western classical choral singing? Wilson's (2014) study on language ideologies in choirs in Trinidad found that there were norms associated with classical choral singing, which at some points are said to be based on Standard British English, and others are representative of a neutral (i.e. non-national) style of Western classical choral singing based on the demands of the sung form itself. Is there evidence of a supralocal accent associated with Western classical choral singing? As we have seen, both musicologists and singing pedagogues believe that Western classical singing pronunciation is based on the 'High form' of the language (Potter, 1998; Emmons & Chase, 2006; LaBouff, 2008; Johnston, 2016; Sagrans, 2016; Day, 2018). Is there evidence of this High form in the recordings of British choral singing from Glasgow and Cambridge?

In Referee Design, speakers orient their linguistic practice towards 'a third party, a reference group, or a model. Referees are third persons not physically present at an interaction but possessing such salience that they influence language choice even in their absence' (Bell, 1992, p. 328). In the popular singing reference style, Morrissey (2008) notes that the singers tend to use a bundle of features that are associated with American accents.

10.3.1 'Institutionalised' Referee Design in British choral singing

The modified front vowel inventory of British classical choral singing is similar to SSBE. There is evidence of change over time from an RP referee to an SSBE referee in both corpora. The TRAP–BATH split of Southern Standard British English has become 'institutionalised' in the Referee Design of British classical choral singing, as this contrast is preserved for all choirs and Time/Directors, even when the speakers of those choirs most likely do not have the contrast in their spoken phonology. While this finding will be unsurprising to singers, it is surprising to sociolinguists, as Milroy (2004) writes:

> It is clear also that the target phonological system(s) of careful speakers in Glasgow, Edinburgh, and Belfast were rarely oriented to RP. Indeed, the phonologies of these Celtic fringe dialects could not be mapped directly onto RP, as is shown by the example of the low vowel /a/ in both Glasgow and Belfast. RP and many Anglo-English dialects are characterized by a clear phonological distinction between short high front and long back variants of this vowel in pairs like Sam: psalm and have: halve. Variation in length and quality in Scotland and Northern Ireland, however, is allophonic rather than phonologically distinctive. A very few careful middle-class speakers in Glasgow – and indeed in Belfast – display an orientation to an RP type of norm with respect to /a/. (Milroy, 2004, p. 164)

Only a very few careful middle-class speakers distinguish between TRAP–BATH in a way that is consistent with RP or SSBE phonology. Consequently, it is highly unlikely that the singers of the Glasgow Orpheus or Phoenix Choirs had or have the contrast in their spoken language. This element certainly supports the Referee Design interpretation of Western classical choral singing in a British context.

GOOSE

However, this is not the full picture. SSBE as a referee for choral singing is not supported by an analysis of the back vowels. For example, GOOSE in Glasgow has a particularly backed phonetic realisation that is peripheral and cardinal-like in quality (close back rounded vowel [u]), whereas, for the most part, King's produces a more central realisation akin to contemporary SSBE (close central rounded vowel [ʉ]), but still more peripheral than in speech. The backed [u] realisation of GOOSE in Glasgow may be evidence of an act of identity (Le Page & Tabouret-Keller, 1985). As previously mentioned, GOOSE fronting is particularly salient in Glasgow with typical realisations akin to [ʉ], which, at face value, does not appear different to the SSBE GOOSE-fronting in RP over time (for example, Jansen & Mompean, 2023).

The degree of lip rounding and lip protrusion may also affect F2. Lawson et al. (2019) write that 'Scottish speakers tended to have smaller degrees of lip protrusion for GOOSE, perhaps confirming the persistence of exolabial lip rounding in GOOSE, as described in McAllister's articulatory-phonetic account of Central Scottish English (McAllister, 1938)' (Lawson et al., 2019). This means that similar values for F2 can be produced with very different articulatory configurations. For example, Lawson et al. (2019) find that speakers in the Central Belt of Scotland produce GOOSE with a lower tongue-body position. The point is that we do not know what articulatory feature is producing this acoustically backed phonetic realisation of /u/ reported in this study. It could be created by a more retracted tongue position, by a high degree of lip-rounding, or a combination of the two.

In terms of the social salience of GOOSE in Glasgow, the backed realisation of GOOSE in classical choral singing perhaps represents an 'act of identity' that seems to say 'now we are performing classical music, so we will produce GOOSE = [u]'. Alternatively, it could be viewed as a form of hypercorrection to a perceived Anglo-English norm, as the GOOSE of conservative-RP was much backer than in SSBE, as seen in the recordings of King's produced under the direction of David Willcocks.

In addition to the sociolinguistic aspects of GOOSE, there are impacts of vocal pedagogy at play. High, retracted, hyper-rounded [u] variants tend to be preferred in Western classical singing pedagogy – for example, Emmons & Chase write that [u] should be produced with the 'Tongue tip down, back tongue arched toward soft palate, soft palate in the highest arch of all lip-rounded vowels' (2006, p. 71). This may also be in contrast to singing within the popular reference style, which may prefer fronter, more speech-like variants of /u/. Perhaps then, the phonetically high back realisation of GOOSE could be an element of the accent-neutral style of Western classical choral singing, suggested by Wilson (2014).

LOT–THOUGHT

The Glasgow singers do not merely produce an SSBE template vowel inventory in their choral singing. Nor are all differences driven by singing pedagogy. There are differences in phonology, including a single target for the lexical sets LOT–THOUGHT in the Glasgow singing. Perhaps, LOT–THOUGHT is less salient and therefore flies under the radar. It seems most likely to me that the cause is that there is only one target for LOT–THOUGHT in the singers' speech. Taking the vowel results together shows that it is not simply a question of adopting a Southern Standard British English referee for the performance of choral singing. In the Glasgow choir recordings, there is evidence of a hybrid referee which incorporates features of both SSBE and SSE, as well as the impact of singing pedagogy.

Rhoticity

Where does rhoticity sit in the Referee Design interpretation of classical choral singing? As we saw in Chapter 8, rhoticity was a major feature of earlier recordings of the Glasgow Orpheus choir under Hugh S. Roberton. Rhoticity in recordings of the Glasgow Phoenix choir has decreased over time, particularly in pre-pausal contexts. It seems, therefore, that in Glasgow, the referee has shifted from a SSE referee, with maximal rhoticity under Hugh S. Roberton, to a non-rhotic SSBE-like referee under Marilyn J. Smith. However, there are differences between the later Time/Directors of Glasgow and King's. King's only produces linking /r/ around 60% of the time, whereas, in Glasgow, it is categorical. Furthermore, while there is a reduced incidence, the Glasgow choirs still produce /r/ in pre-consonantal contexts such as *card* and *car could*. Therefore, while there is an overall tendency towards a non-rhotic referee, the implementation of the shift differs across phonetic contexts.

10.3.2 'Reading the dots on the page': Choral singing and the Attention-to-speech model

An alternative and possibly complementary model is the Attention-to-speech model (Labov, 1966). The Attention-to-speech model shows that listeners vary stylistic features depending on context (formal versus informal) and speech style (casual versus careful). In Western classical choral singing, the context of choral rehearsals and performances is typically a formal one, with accepted behavioural norms attached. Elite classical choral singing in the UK relies on a high degree of literacy and sight-reading ability. That is, the ability to reproduce the notes (and words) from a musical score in performance, often with minimal preparation. This means that many British classical choirs, even when singing music they know very well for a CD recording, may be paying a high degree of attention to the orthography. In this way, Western classical choral singing could be considered a (hyper-)careful speech style. Alternatively, the increased cognitive load caused by sight-reading could reduce the attention the singers pay to their sung speech. How do the findings of this research relate to the attention-to-speech model? As we have seen, hyper-articulated consonants became a feature of the King's sound. Potter writes:

> The Ord/Willcocks style of text presentation at King's involved exaggerating consonants and vowels far beyond the demands of clarity … such was the eminence of the choir that these quirks of style and pronunciation became the norm for parish church choirs throughout the land (and generally remain so). The stylised pronunciation was a by-product of the music-as-discipline approach and a striving for an abstract notion of excellence. The pronunciation established criteria by which excellence could be measured, and the

> singing was judged in part by the excellence of its pronunciation rather than by the success or otherwise strategies to put across meaning (Potter, 1998, p. 117).

There are a number of points from the quote from Potter that need to be discussed. King's 'exaggerat[ed] consonants and vowels beyond the demands of clarity' – in the guise of intelligibility – but it appears to be the implementation of a particular style or aesthetic. This is supported by the evidence for word-final /d/, as while hyper-voiced tokens are part of the style that King's established, it is not known whether they aid the listener in distinguishing between phrase-final voiced and voiceless stops (/d/ versus /t/).

The 'music-as-discipline' approach of King's is also touched on by Sagrans (2016) and Day (2018). It seems likely to me that there is a link between the music-as-discipline approach and orthography. The disciplined articulation of orthographic representations suggests the Attention-to-speech model. Finally, 'the pronunciation established criteria by which excellence could be measured' suggests that hyper-articulated consonants became a feature of a standard accent of British classical choral singing.

Rhoticity

The results for postvocalic /r/ support the Attention-to-speech model interpretation. In the recordings of the Glasgow choirs, linking /r/ is categorically produced in all time periods. Almost every orthographic /r/ followed by a vowel is articulated. This suggests that the singers are paying attention to the orthography and reproducing it. At King's, postvocalic /r/ is produced only 60% of the time meaning that there is hiatus in 40% of cases (see Chapter 8).

Word-final /d/

In the case of word-final /d/, the recordings of King's show a tendency to fully-voice or hyper-articulate phrase-final tokens of /d/. Perhaps this finding shows that, in a particularly salient phrase-final context, the singers produce hyper-voiced tokens cued by the orthography, supporting the Attention-to-speech model. There appears to be attention to speech interpretations in the Glasgow and King's corpora, but the variables that are attended to differ between the corpora.

10.4 Towards a unified model of choral singing

In this research, I analysed recordings of British classical choral singing, and showed that the accent of singing has changed over time. In the Glasgow choirs, recordings made under Hugh S. Roberton were orienting towards a Morningside/Kelvinside accent – upper-middle-class Scottish accents which declined in the twentieth century (Johnston, 1985). Peter Mooney retains some of those features but begins to shift. Under Marilyn J. Smith, the choir orients towards an SSBE-like referee, though there are some differences.

At King's, recordings made under Boris Ord already reflected the shift to an SSBE accent. David Willcocks orientated the choir towards the conservative 'upper crust' RP, which he was familiar with from singing as a chorister at Westminster Abbey in the 1930s (Day, 2018). There was largely a continuation of the sound Willcocks cultivated under the direction of Philip Ledger. From this High point of departure, the King's sound evolved considerably under Stephen Cleobury as the referee shifted back to SSBE.

While there are similarities between the accents of the Glasgow Phoenix Choir under Marilyn J. Smith and King's under Stephen Cleobury, there are also differences which are variously driven by singing technique and regional accent features. There does not appear to be a one-size-fits-all referee for British classical choral singing, though there are tendencies that I expect to be found elsewhere. Given that TRAP–BATH were found to be separate phonemes in classical choral singing in Glasgow, I would be surprised if they were found to be merged in any other UK dialect area, and perhaps further afield. This is a feature of the 'institutionalised' Referee Design for Western classical choral singing, which appears to stem from a spoken prestige accent like SSBE. However, not all variation in this study can be explained by the Referee Design model. For example, single target for LOT–THOUGHT in the Glasgow data perhaps shows that not all vowel contrasts are equally salient. Despite consonants having been identified as particularly salient to listeners (Bell, 1992; Wilson, 2014), the consonant variables analysed in this research, rhoticity and the realisation of word-final /d/, do not fit well in the Referee Design explanation of the sung choral accent, instead supporting an Attention-to-speech model interpretation. In Figure 10.1, I attempt to draw together all of the influences I have discussed. There are multiple models at work that need to be accounted for in addition to an outgroup spoken referee like RP, or SSBE.

This study sought to analyse variation and change in British classical choral singing. From this research, I can only speculate about the salience of particular variables to the singers and/or choir directors, as I did not conduct interviews as part of this study. Future research on choral accent needs to employ both quantitative language variation and change approaches, as exemplified in this study, and qualitative survey, interview and ethnographic methods (Wilson,

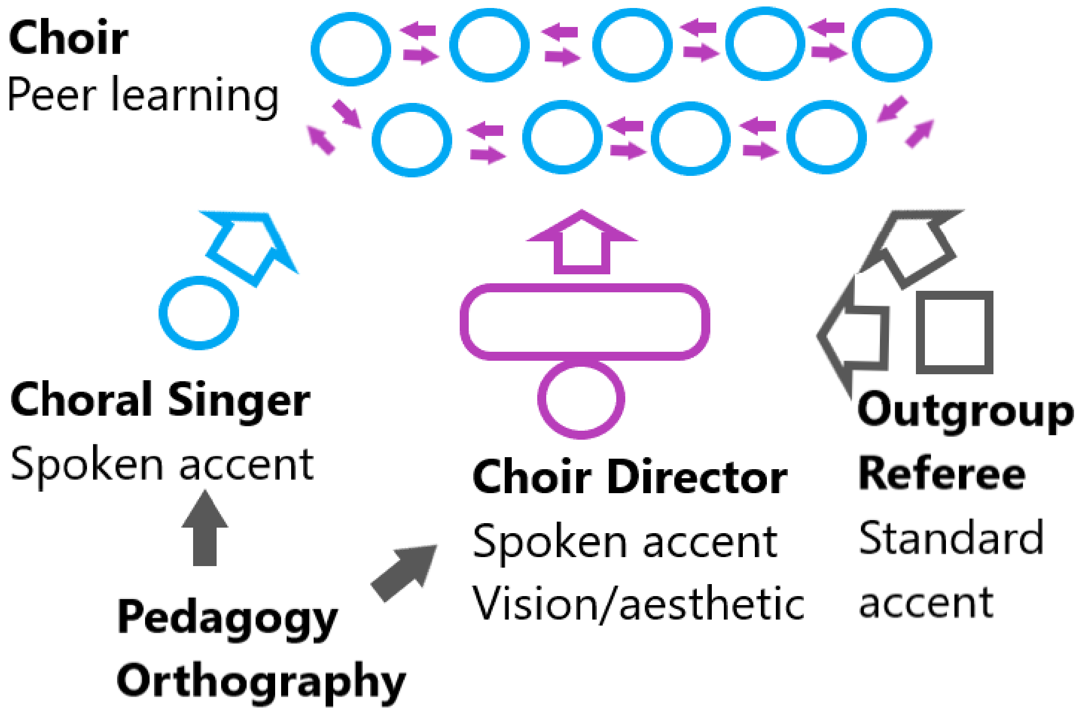


Figure 10.1: Visualising influences on choir accent

2014), so that we can get a more complete understanding of how meaning is made in choral settings.

10.5 Methodological reflections

In this thesis, I conducted an acoustic analysis of choral singing, finding that vowel quality has changed over time. Importantly, the acoustic method has shown that formants can be extracted from choral data. I adapted language variation and change methods in the building of the corpora, and analyses. As the first foray into the acoustic analysis of classical choral singing, there are a number of questions that remain unanswered and which require investigation in future study. In terms of technical analysis, what Praat settings for formant extraction would allow us to characterise the signal best? Whose voices are being heard in this analysis? That is, are the extracted formant data a flat average of all of the values produced by each singer, or is the analysis biased towards a certain voice type and/or gender?

10.5.1 Reflections on acoustic method

One of the major contributions of this study is that it is the first to apply acoustic analysis to recordings of choral singing. It is also one of the few studies of singing to quantitatively analyse sung acoustic vowel quality. It is probably the largest study of acoustic vowel quality in singing yet carried out. There are, however, reasons for this:

There are a number of unknowns associated with the corpora that come with corpus analysis of historical data. For example, it is not known what microphones were used, how many of them, in what configuration, and how close they were to the singers. We also do not know the configuration of the choir – how were the singers arranged for recording purposes? These unknowns certainly contribute to the uncertainty of the estimates or the width of the credible intervals for estimates reported for Vowel and Time/Director.

Furthermore, we do not know what strategies choral singers of different voice types use when blending. They might or might not aim to match formant values. In the acoustic analysis of formants presented in Chapters 5, 6, and 7, it is not known exactly whose formants are being detected and extracted, but presumably, it will be the most prominent peaks at any one given point in time. This may not be particularly intuitive, as it is low voice sections like bass, baritone, and lower tenors which may dominate the formant frequencies when sopranos are singing at high frequencies.

In short, we just do not know what the best practices are for acoustic analysis of the choral signal. Almost certainly the vowel quality of the choir will shift at higher frequencies, or when the frequencies are more dispersed – when high voices are singing particularly high, and low voices particularly low. I was not able to include fundamental frequency in this research due to the inherent difficulty of extracting fundamental frequency from a signal with multiple fundamentals present. Empirical plots showed that the impact of fundamental frequency on vowel formants is likely to have been suppressed by the normalisation and statistical trimming procedure (see Chapter 4 Section 4.3.12).

Multiple people singing together

There are anthropological studies of acts of joint speech, from communal prayer to football chants (e.g. Cummins, 2018); however, as far as I am aware, there are no published acoustic analyses of joint speech. Even if we subtract from the equation that I am interested in choral singing, there are many unknowns that stem from analysing a signal containing the vocalisations of multiple people at once, as noted by Wilson (2014).

Different types of voices

In addition to the joint speech or joint singing problem, there is also the issue of different types of singers singing together. Whether looked at by sex, age, or Western classical voice categorisation (for example, soprano, alto, tenor, or bass), most choirs tend to be comprised of singers of different voice types. For example, the Glasgow Orpheus Choir and Glasgow Phoenix Choir are adult mixed-voice choirs (soprano, alto, tenor, bass) where the age range is unknown but supposedly boasts teenagers to octogenarians. The Choir of King's College, Cambridge, since the 1930s, has been comprised of young-adult male choral scholars and boy trebles. While these choirs differ in make-up, there are also similarities in the spread of pitches covered, with voices from very high to very low.

We know that professional singers of different Western classical voice types sound different, and their sounds are created by using different articulatory strategies. Professional male singers tend to lower the larynx to lower all formants and create the singer's formant in the F4 region to project over orchestras (Sundberg, 1974). Meanwhile professional soprano singers at high frequencies tend to lower the jaw so that F1 tracks the fundamental frequency (Joliveau et al., 2004). Amateur singers do not make use of these techniques (Sundberg & Ternström, 1986). However, it is unclear whether professional choral singers that are not operatically trained use them. In addition, while fundamental frequency will affect the vowel quality used in choral singing, even in the recordings of elite choirs, notes at the edge of possible fundamentals (such as the soprano high C) are rare events. The questions remain, therefore: what are we measuring, or whose voices are we measuring when we analyse the choral signal?

Microphone placement, room acoustic, noise

A recording problem that is specific to Western classical choral singing is that choirs prefer to sing in venues that have natural reverberation, as they are more pleasant to sing in: the room 'gives back'. This is problematic for analysing recordings as there is less silence and more natural reverberation and noise than there would be in lab-recorded speech, contributing to the reduced accuracy of automatic forced alignment. In addition, microphone placement can have a large impact on the recorded sound quality and can have an impact on formant measurements (Hansen & Pharao, 2006). However, the data for exactly where microphones are placed, the type of microphone, or the number used, just does not exist for most recordings. Furthermore, the configuration of the choir – how the singers of different voice types are positioned – can affect the distribution of energy in the spectrum (Morris et al., 2007). Audio compression of the kind used for online streaming, such as YouTube, is reported to have an effect on F3, with a lesser effect on F2, but increasing F1 for high vowels (De Decker & Nycz, 2011).

Praat unknowns

In addition to these factors relating to choral singing itself, there are also Praat-specific questions which I raised in the method outlined above.

1. What is the optimal maximum number of formants for automatic acoustic analysis of singing?

2. What is the appropriate formant ceiling for a group of mixed vocal tract lengths?

3. What are the optimal default settings for pre-emphasis?

What Praat is currently doing with the settings as given above is something of an unknown. The formants tend to be weak when we have multiple singers or speakers. In previous phonetic work these spectra may have been discarded due to the lack of clarity. So, what is Praat picking up on, and how accurate is it?

Regarding FOOT–GOOSE, the issue of poor formant estimation in the low F1/F2 region might have been resolved by changing the Praat settings. Lowering the formant ceiling further might have increased the accuracy in the lower frequency region. However, I opted to take these measurements by hand.

In addition, regardless of what Praat is picking up, whose voices are producing the formants that Praat detects? Is it a flat average of all the values produced by each singer, or is it biased towards a certain voice type, gender, or loudness in the mix? Despite these issues, I remain optimistic that acoustic analysis of choral singing is viable.

Digitisation

To digitise all vinyl and shellac records (LP and EP), I used an ION three-speed turntable with USB output. I played the record with the turntable connected to a laptop. I recorded the input sound using the audio software Audacity (Audacity Team, 2018), recording the whole side of each record at once and separating the tracks later. The recordings were made in a lossless format in Audacity and exported as .wav files.

I recently spoke to a sound engineer specialising in music who told me that best practices for digitising records in Music include playing the record on a gramophone and positioning a microphone in the bell of the gramophone. It is possible that this change in the method could have an impact on the resulting sound quality.

While taking the formant values from the LPC spectra, I found that there sometimes seemed to be an additional small peak between the F2 and F3 regions. This is something that I have not had time to investigate. However, I suspect it has some impact on the choir sound overall. It is a boosted harmonic in the area between F2 and F3, sometimes quite small. Hopefully, I will be able to come back and investigate this at a later point – this may have something to do with soprano high-frequency resonance tuning – which appears in the spectrum as an additional peak between F2 and F3, but this requires investigation.

10.5.2 Auditory method

The auditory coding was carried out primarily by myself. The method consisted of first coding some tokens and developing a protocol, which was discussed with a phonetically-trained supervisor. Then I coded the entire dataset, and discussed difficult items with my supervisor. This applied to the auditory coding of /r/ (Chapter 8) and /d/ (Chapter 9), but also earlier on in the process, impressionistically listening to the vowel qualities analysed (Chapters 5, 6, and 7). Methods to control for single coder reliability include working with more than one coder for all or more realistically a subset sample of the data. Alternatively, single coders can check reliability by returning to their data, recoding, and comparing results.

10.6 Directions for future research on choral singing

This section is structured as follows. First, what additional variables of interest could be explored within the corpora presented in this study? Then alternative proposed samples by style, region, and language.

10.6.1 Other variables of interest within this sample

In this study, I analysed the first and second formants of the monophthongs FLEECE, KIT, DRESS, TRAP, BATH, STRUT, LOT, THOUGHT, FOOT, and GOOSE. I also analysed rhoticity and the realisation of word-final /d/ using auditory coding. Below are some variables that would be particularly interesting to examine within the corpora presented in this thesis.

Sibilants

Sibilants are reported by choir directors to be particularly problematic for choral blend. For example, Decker writes:

> The sibilant 's' is a horror in choral music. Because the sound cuts through any vocal ensemble, an unwanted 's' sung by one careless singer can be heard throughout an auditorium. The 's', of course, should be kept as brief as possible. In multi-syllable words, divisions should be made so that 's' begins syllables rather than ends them. When dealing with separate words the problem is more complex since intelligibility can be distorted when placing a final 's' on the following word as in 'let us spray' for 'let us pray'. The conductor must use his ear to de-emphasize the 's' so that it is not overly prominent yet still understood. Often by asking only a small number of the singers in the ensemble to sing an 's', a more subtly balanced sound can be achieved (Decker, 1977).

I would like to know more about what happens to sibilants in choral singing. The shape and distribution of energy in sibilants can carry sociolinguistic information relating to sex and gender (for example, Stuart-Smith, 2007). It is also clear from Decker's quote above that sibilants are aesthetically prominent and salient to audiences, and are directly addressed by choral directors in rehearsals. So, what happens to /s/ and /ʃ/ in choral singing, particularly in mixed-voice choirs?

Diphthongs

The realisation of diphthongs is both relevant to singing technique and choral aesthetic, and differs in the spoken accents of the regions analysed in this thesis. Emmons & Chase (2006) write that English and German are problematic for singing because of their frequent diphthong realisations of vowels, and specify relative durations for component qualities of diphthongs. For example, Decker writes: 'since most diphthongs consist of a basic vowel with a rapid vanishing vowel, the main vowel is generally held as long as possible while the vanishing vowel is sung just before the conclusion of the compound sound' (1977). In classical choral singing in English, the first quality tends to be elongated and the second very reduced (Decker, 1977; Emmons & Chase, 2006; LaBouff, 2008, Wikan, 2017; Neuen, 2020). However, anecdotally, the realisation of diphthongs can be quite drastically different in other genres of singing, such as folk, where the first quality is reduced and the second lengthened.

GOAT From my extensive listening to the data, I predict that the realisation of the GOAT vowel differs between the corpora. I think that David Willcocks introduced a particularly salient conservative-RP realisation of GOAT akin to [əʊ].

In the Glasgow corpus GOAT is a monophthong and closer to Standard Scottish English [o]. Interestingly, a monophthong realisation of GOAT may be closer to an idealised classical singing technique, which may explain why the feature is preserved in the choral signal.

FACE Similarly, if the Glasgow singing is based on an SSE referee, rather than a SSBE referee, I would expect FACE to be realised as a monophthong, particularly in the earlier recordings, whereas FACE in the King's corpus should be realised as a diphthong and there may be quite salient differences in realisation between recordings made under David Willcocks and Stephen Cleobury.

FLEECE and GOOSE FLEECE and GOOSE are reported to be diphthongal in SSBE (for example, Lindsey, 2019), so it is possible that there are differences in trajectory between the Glasgow and King's data that are hidden in the analysis of the vowel means. With more time, it would be interesting to re-analyse FLEECE and GOOSE using formant trajectories, or auditory coding. If GOOSE is, in fact, a diphthong in the King's data, this might help explain why the F2 Credible Intervals are wide for this vowel.

10.6.2 Other samples of interest

In future research, it would be valuable to investigate how each voice part contributes to the overall spectrum, and how that can change as the voicing of the choir changes (that is, the distribution of pitches within the choir). These questions could be explored in recordings of online choirs that were produced during the COVID-19 pandemic. There are many recordings of choirs that were multi-tracked, layering individual voices. Using this untapped unique source of data, we could compare the distribution of formant frequencies of singers within certain voice parts of a given piece of music, to the overall spectral qualities. We would also be able to get a rough idea of the fundamental of each voice part and the dispersion of the fundamentals. Conducting a formant analysis in the way that I have done in this thesis would then give us an idea of which singers Praat is picking up on, and in what conditions.

Initially, I hoped to extend this study to other collegiate-style choirs which have a comparable history of recordings. However, this was not possible due to time constraints. Investigating other elite British classical choirs with a long history of recording, for example, the Choir of Trinity College, Cambridge, the Choir of St John's College, Cambridge, or the Choir of King's College, London, would help further evidence the role of the choir director in driving changes in the choir sound. It would also help establish whether front vowel lowering and backing within choral singing in the UK more widely, which I suspect may be the case. The spread of the King's style nationally needs to be tested in future research. Can we find evidence of hyper-voicing in phrase-final /d/, or affrication of word-final phrase-medial /d/ increasing in recordings of other British church choirs over time?

This study has focused on British classical choral singing. However, there are now many types of choral singing. We might be able to learn more about the effect of choral singing – that is, the impact of the form: collective singing – by examining other genres of choral singing. Rock Choir, for example, has become a sensation with choirs in all major cities in the UK (Rock Choir, 2023). As British rock and pop artists have been found to sing with a 'mid-Atlantic' accent (e.g. Trudgill, 1983; Simpson, 1999), would we expect to find the institutionalised mid-Atlantic accent in recordings of Rock Choirs? Equally, are there impacts of group singing or choral singing techniques which transcend genre?

Another possible direction for future work concerning change over time in choral sound would be to investigate recordings of German choirs which have a comparable history of recording. There is some indication in this chapter that classical choral singing practice in the UK is tethered to the non-regional accent: SSBE. It is possible there is a similar situation in Germany with *Hochdeutsch* (high German) which is a comparable non-regional accent. Referring to solo singing, Johnston (2016) writes: 'In lyric diction, one strives to sing in the "high form" of each language. For example, in English there is Received Pronunciation (RP) for Great Britain and General American English (GA) for the United States and Canada; in French one uses Parisian French; in German one uses Hochdeutsch' (Johnston, 2016, p. 147). If there are vowel contrasts present in Hochdeutsch that are absent in a certain regional variety, it would be interesting to see if this contrast is found in the singing of speakers from regions which do not have the contrast in speech, as we have found in this research.

10.7 Conclusion

This thesis has presented the first large-scale acoustic and auditory analysis of recordings of choral singing. I investigated the sound of the Glasgow Orpheus and Glasgow Phoenix Choirs and the Choir of King's College, Cambridge. As we have seen, the choirs share a front vowel phonology that is different to the spoken vowel phonology of Standard Scottish English (SSE) and has similarities with Southern Standard British English (SSBE), particularly with a seemingly 'institutionalised' TRAP–BATH split in both recordings from Glasgow and King's. However, the Glasgow choirs, while becoming more similar to the SSBE model over time, do not faithfully produce it, as there is evidence of the single LOT–THOUGHT target of SSE, as well as rhoticity in contexts not permitted in SSBE nor present in the King's data. It seems, therefore, that there are shared elements that may relate to SSBE speech patterns and/or classical choral singing technique, in addition to local phonological features such as the Scottish English single target for LOT–THOUGHT.

The main contributions of this work are as follows. This thesis is the first large-scale quantitative investigation of the accent of choral singing; the first acoustic investigation of Western classical singing using corpus phonetic methods; the first sociolinguistic work to investigate the accent of choral singing in the UK – which is essential if, as suggested by Wynn York (1951) and Wilson (2014), a southern British prestige variety forms the basis of a supralocal standard of choral singing. The present work discovers a shift in overall vowel height in choral singing, which may be caused by a change in a standard accent of speech; finally, this is the first study to show regional variation in the accent of choral singing.

This study has shown that, even in a form described as rigid and conservative – Western classical choral singing (Potter, 1998; Wilson, 2014) – there exists variation and change over time that tracks a well-evidenced shift in front vowel height from RP to SSBE. I have also shown that there are differences in British choral singing that pattern by regional dialect area, as the Glasgow choirs examined show evidence of local phonological features such as rhoticity and a single target for the LOT–THOUGHT lexical sets. This study has also investigated the impact of a choir director on a choir's sound. From the analysis of King's recordings, it appears that the choir director can play a large role in selecting a particular style and encouraging the choir towards it – as evidenced in the recordings made under the direction of David Willcocks.

In conclusion, this thesis has shown that choirs do have accents and these singing accents partly relate to those of spoken language, but partly are independent; they can change over time, and are also shaped by local phonological and phonetic features of the singers and choir directors, and by classical choral singing technique.

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Appendix A

Investigation of prior choice for vowel quality in choral singing

As outlined in Chapter 4, the mean of the posterior distribution is a weighted combination of the mean of the data and the mean of the prior. The priors we specify can have a considerable impact on our analyses. Well-defined priors can give greater certainty in the posterior estimates. Poorly defined priors can be overly informative and override the data by constraining the shape of the posterior too rigidly. What does it mean to set appropriate priors for analysing vowel quality in choral singing?

A.1 Why set priors at all?

To set no priors or uninformative priors could be considered disingenuous. At least from a phonetic perspective, we do know a lot about vowel formants, their distribution in different languages and varieties. The acoustic vowel space is bounded by our physiology. That is, the tongue cannot raise more than a cardinal realisation of FLEECE, before frication is produced, and it is no longer considered a vowel. Likewise, for a cardinal production of the BATH vowel, the tongue cannot retract further before pharyngeal frication is produced. These are established facts. Therefore, the vowel space is limited, and likewise, the acoustic patterns that result are also limited. These facts can be incorporated into the prior specification. However, I decided to go one step further as outlined below.

At the start of the PhD process, I investigated using different sets of priors based on vowel formant data extracted from speech recordings. Three sets of priors were specified based on data from Received Pronunciation (RP), Standard Scottish

English (SSE), and weakly informative priors. These priors were created by obtaining diachronic speech data for RP and SSE from the sources outlined in Table A.2 and Table A.3, respectively.

Raw formant values (Hz) were normalised using the Lobanov method, as described in Chapter 4. Means and standard deviations were calculated and used to form the priors for the Vowel by Time/Director interaction. The Vowel and TimePeriod priors were calculated by averaging over the levels of the other factor. For example, the RP prior for FLEECE was calculated by subsetting the RP FLEECE vowel data and averaging over Time/Director. The prior for each Time/Director was created by averaging over all vowels within a given time period. All other beta coefficients were specified with `normal`$(0, 1)$. All varying effects were specified with `student_t`$(3, 0, 1)$. The dataset analysed and the model structure were kept constant and only the priors were changed. This allowed me to examine the impact of the different priors on the posterior summaries. The sets of priors can be found as follows: Front vowel F1 (RP Table A.4; SSE Table A.6), front vowel F2 (RP Table A.5; SSE Table A.7), back vowel F1 (RP Table A.8; SSE Table A.10), and back vowel F2 (RP Table A.9; SSE Table A.11). The weakly informative priors used in these analyses are shown in Table A.1.

Table A.1: Weakly informative regularizing priors

prior	class	coef	source
`normal`$(0, 1)$	b		user
`student_t`$(3, 0, 1)$	Intercept		user
`student_t`$(3, 0, 1)$	sd		user

The model structure for each model was:

```
vowel formant ~ Time/Director + Vowel + VowelDuration +
FollowingSegment + Genre +
+ Time/Director:Vowel + Vowel:VowelDuration + Vowel:Genre +
Time/Director:VowelDuration +
(1|Album) + (1|Song) + (1|Word) + (1|Album:Song) + (1|Song:Word)
```

Table A.2: RP prior sources

Time/Director	Speakers	Source(s)
Hugh S. Roberton (1925–1951)	John Henderson (b.1920; recorded 1980s) and Walter Prideaux (b.1910; recorded 1980s)	Fabricius, A. H. (2021, February 9). Data source for The Anticlockwise Checked Vowel Shift of modern RP. `https://doi.org/10.17605/OSF.IO/3F4V2`
Peter Mooney (1959–1975)	Speakers 65 + age group recorded in early 2000s and 25 year old speakers recorded in 1960s	Hawkins & Midgley (2005) and Wells (1962)
Marilyn J. Smith (1987–2017)		Modern RP via Spade OSF and data from Bjelaković (2017)

Table A.3: SSE prior sources

Time/Director	Speakers	Source(s)
Hugh S. Roberton (1925–1951)	Young middle-class speakers	Edinburgh Arthur the Rat, SPADE OSF
Peter Mooney (1959–1975)	Young middle-class speakers (recorded 1970s) and middle aged middle class speakers (recorded 1990s)	ICE Scotland, SPADE OSF
Marilyn J. Smith (1987–2017)	Young middle-class Glaswegian speakers (recorded early 2000s)	Sounds of the City, Spade OSF

As seen in Tables A.12 and A.13 for front vowels, and Tables A.14 and A.15 for back vowels, the different sets of priors made negligible difference to the posterior distributions. This is a good thing. It means that the weight of the data is sufficient to overwhelm the information contained in the prior – therefore the priors are not too informative or impacting the posterior more than they should.

Another way of interpreting this finding is that using priors based on formant values from speech data is comparable to using weakly informative priors, perhaps supporting Morrissey's view that 'It is a truism that singing is not speaking and that singing style and speaking style are therefore subject to different parameters' (Morrissey, 2008). Perhaps specifying priors based on sung data would yield a different result. Either way, this is a pleasing finding for this study and I proceed using weakly informative priors for subsequent analyses. The raw data, code and models reported can be found on the OSF at osf.io/tev9h.

Table A.4: RP front vowel F1 priors

prior	class	coef	source
normal$(0, 1)$	b		user
normal$(0.37, 0.68)$	b	vowelDRESS	user
normal$(-0.59, 0.44)$	b	vowelKIT	user
normal$(1.25, 1.08)$	b	vowelTRAP	user
normal$(-0.44, 0.26)$	b	Time/DirectorPM1959–1975:vowelDRESS	user
normal$(0.18, 0.67)$	b	Time/DirectorMJS1987–2016:vowelDRESS	user
normal$(0.05, 0.11)$	b	Time/DirectorPM1959–1975:vowelKIT	user
normal$(0.16, 0.43)$	b	Time/DirectorMJS1987–2016:vowelKIT	user
normal$(-0.07, 0.75)$	b	Time/DirectorPM1959–1975:vowelTRAP	user
normal$(0.16, 1.09)$	b	Time/DirectorMJS1987–2016:vowelTRAP	user
student_t$(3, 0, 1)$	Intercept		user
student_t$(3, 0, 1)$	sd		user

Table A.5: RP front vowel F2 priors

prior	class	coef	source
normal$(0, 1)$	b		user
normal$(-0.37, 0.48)$	b	vowelDRESS	user
normal$(0.15, 0.59)$	b	vowelKIT	user
normal$(-0.6, 0.38)$	b	vowelTRAP	user
normal$(1.45, 0.24)$	b	Time/DirectorPM1959–1975:vowelDRESS	user
normal$(0.36, 0.44)$	b	Time/DirectorMJS1987–2016:vowelDRESS	user
normal$(1.04, 0.22)$	b	Time/DirectorPM1959–1975:vowelKIT	user
normal$(0.39, 0.59)$	b	Time/DirectorMJS1987–2016:vowelKIT	user
normal$(1.16, 0.16)$	b	Time/DirectorPM1959–1975:vowelTRAP	user
normal$(0.38, 0.36)$	b	Time/DirectorMJS1987–2016:vowelTRAP	user
student_t$(3, 0, 1)$	Intercept		user
student_t$(3, 0, 1)$	sd		user

Table A.6: SSE front vowel F1 priors

prior	class	coef	source
`normal`$(0, 1)$	b		user
`normal`$(0.08, 0.6)$	b	vowelDRESS	user
`normal`$(-0.36, 0.74)$	b	vowelKIT	user
`normal`$(1.24, 1.08)$	b	vowelTRAP	user
`normal`$(0.01, 0.57)$	b	Time/DirectorPM1959–1975:vowelDRESS	user
`normal`$(-0.07, 0.59)$	b	Time/DirectorMJS1987–2016:vowelDRESS	user
`normal`$(0.06, 0.69)$	b	Time/DirectorPM1959–1975:vowelKIT	user
`normal`$(0.15, 0.83)$	b	Time/DirectorMJS1987–2016:vowelKIT	user
`normal`$(0.22, 1.23)$	b	Time/DirectorPM1959–1975:vowelTRAP	user
`normal`$(-0.01, 1.01)$	b	Time/DirectorMJS1987–2016:vowelTRAP	user
`student_t`$(3, 0, 1)$	Intercept		user
`student_t`$(3, 0, 1)$	sd		user

Table A.7: SSE front vowel F2 priors

prior	class	coef	source
`normal`$(0, 1)$	b		user
`normal`$(0.09, 0.67)$	b	vowelDRESS	user
`normal`$(0.03, 0.68)$	b	vowelKIT	user
`normal`$(-0.65, 0.58)$	b	vowelTRAP	user
`normal`$(0.51, 0.61)$	b	Time/DirectorPM1959–1975:vowelDRESS	user
`normal`$(0.67, 0.53)$	b	Time/DirectorMJS1987–2016:vowelDRESS	user
`normal`$(0.47, 0.66)$	b	Time/DirectorPM1959–1975:vowelKIT	user
`normal`$(0.41, 0.61)$	b	Time/DirectorMJS1987–2016:vowelKIT	user
`normal`$(0.36, 0.54)$	b	Time/DirectorPM1959–1975:vowelTRAP	user
`normal`$(0.43, 0.56)$	b	Time/DirectorMJS1987–2016:vowelTRAP	user
`student_t`$(3, 0, 1)$	Intercept		user
`student_t`$(3, 0, 1)$	sd		user

Table A.8: RP back vowel F1 priors

prior	class	coef	source
normal$(0, 1)$	b		user
normal$(0.67, 0.83)$	b	vowelBATH	user
normal$(0.3, 0.6)$	b	vowelLOT	user
normal$(-0.4, 0.4)$	b	vowelTHOUGHT	user
normal$(-0.52, 0.33)$	b	vowelFOOT	user
normal$(-0.86, 0.31)$	b	vowelGOOSE	user
normal$(-0.08, 0.22)$	b	Time/DirectorPM1959–1975:vowelBATH	user
normal$(-0.08, 0.82)$	b	Time/DirectorMJS1987–2016:vowelBATH	user
normal$(0.05, 0.32)$	b	Time/DirectorPM1959–1975:vowelLOT	user
normal$(-0.05, 0.61)$	b	Time/DirectorMJS1987–2016:vowelLOT	user
normal$(-0.08, 0.22)$	b	Time/DirectorPM1959–1975:vowelTHOUGHT	user
normal$(-0.05, 0.4)$	b	Time/DirectorMJS1987–2016:vowelTHOUGHT	user
normal$(-0.07, 0.28)$	b	Time/DirectorPM1959–1975:vowelFOOT	user
normal$(0.04, 0.33)$	b	Time/DirectorMJS1987–2016:vowelFOOT	user
normal$(-0.22, 0.42)$	b	Time/DirectorPM1959–1975:vowelGOOSE	user
normal$(-0.02, 0.27)$	b	Time/DirectorMJS1987–2016:vowelGOOSE	user
student_t$(3, 0, 1)$	Intercept		user
student_t$(3, 0, 1)$	sd		user

Table A.9: RP back vowel F2 priors

prior	class	coef	source
normal$(0, 1)$	b		user
normal$(-0.15, 0.57)$	b	vowelBATH	user
normal$(-0.4, 0.41)$	b	vowelLOT	user
normal$(-0.83, 0.37)$	b	vowelTHOUGHT	user
normal$(0.34, 0.47)$	b	vowelFOOT	user
normal$(1.01, 0.74)$	b	vowelGOOSE	user
normal$(-0.37, 0.17)$	b	Time/DirectorPM1959–1975:vowelBATH	user
normal$(-0.64, 0.58)$	b	Time/DirectorMJS1987–2016:vowelBATH	user
normal$(-0.5, 0.13)$	b	Time/DirectorPM1959–1975:vowelLOT	user
normal$(-0.63, 0.41)$	b	Time/DirectorMJS1987–2016:vowelLOT	user
normal$(-0.54, 0.097)$	b	Time/DirectorPM1959–1975:vowelTHOUGHT	user
normal$(-0.63, 0.36)$	b	Time/DirectorMJS1987–2016:vowelTHOUGHT	user
normal$(-1.04, 0.14)$	b	Time/DirectorPM1959–1975:vowelFOOT	user
normal$(-0.57, 0.48)$	b	Time/DirectorMJS1987–2016:vowelFOOT	user
normal$(-1.69, 0.2)$	b	Time/DirectorPM1959–1975:vowelGOOSE	user
normal$(-0.53, 0.64)$	b	Time/DirectorMJS1987–2016:vowelGOOSE	user
student_t$(3, 0, 1)$	Intercept		user
student_t$(3, 0, 1)$	sd		user

Table A.10: SSE back vowel F1 priors

prior	class	coef	source
`normal`$(0, 1)$	b		user
`normal`$(1.16, 1.02)$	b	vowelBATH	user
`normal`$(0.12, 0.62)$	b	vowelLOT	user
`normal`$(-0.01, 0.68)$	b	vowelTHOUGHT	user
`normal`$(-0.82, 0.53)$	b	vowelFOOT	user
`normal`$(-0.97, 0.57)$	b	vowelGOOSE	user
`normal`$(0.06, 1.21)$	b	Time/DirectorPM1959–1975:vowelBATH	user
`normal`$(0.11, 1)$	b	Time/DirectorMJS1987–2016:vowelBATH	user
`normal`$(-0.02, 0.58)$	b	Time/DirectorPM1959–1975:vowelLOT	user
`normal`$(-0.2, 0.69)$	b	Time/DirectorMJS1987–2016:vowelLOT	user
`normal`$(-0.02, 0.65)$	b	Time/DirectorPM1959–1975:vowelTHOUGHT	user
`normal`$(-0.01, 0.78)$	b	Time/DirectorMJS1987–2016:vowelTHOUGHT	user
`normal`$(0.04, 0.57)$	b	Time/DirectorPM1959–1975:vowelFOOT	user
`normal`$(0.06, 0.43)$	b	Time/DirectorMJS1987–2016:vowelFOOT	user
`normal`$(-0.05, 0.6)$	b	Time/DirectorPM1959–1975:vowelGOOSE	user
`normal`$(0.17, 0.61)$	b	Time/DirectorMJS1987–2016:vowelGOOSE	user
`student_t`$(3, 0, 1)$	Intercept		user
`student_t`$(3, 0, 1)$	sd		user

Table A.11: SSE back vowel F2 priors

prior	class	coef	source
`normal`$(0, 1)$	b		user
`normal`$(0.01, 0.55)$	b	vowelBATH	user
`normal`$(-0.45, 0.66)$	b	vowelLOT	user
`normal`$(-0.65, 0.62)$	b	vowelTHOUGHT	user
`normal`$(0.55, 0.66)$	b	vowelFOOT	user
`normal`$(0.65, 0.77)$	b	vowelGOOSE	user
`normal`$(-0.5, 0.54)$	b	Time/DirectorPM1959–1975:vowelBATH	user
`normal`$(-0.45, 0.54)$	b	Time/DirectorMJS1987–2016:vowelBATH	user
`normal`$(-0.54, 0.66)$	b	Time/DirectorPM1959–1975:vowelLOT	user
`normal`$(-0.46, 0.75)$	b	Time/DirectorMJS1987–2016:vowelLOT	user
`normal`$(-0.6, 0.62)$	b	Time/DirectorPM1959–1975:vowelTHOUGHT	user
`normal`$(-0.48, 0.69)$	b	Time/DirectorMJS1987–2016:vowelTHOUGHT	user
`normal`$(-0.15, 0.55)$	b	Time/DirectorPM1959–1975:vowelFOOT	user
`normal`$(-0.2, 0.59)$	b	Time/DirectorMJS1987–2016:vowelFOOT	user
`normal`$(-0.24, 0.56)$	b	Time/DirectorPM1959–1975:vowelGOOSE	user
`normal`$(-0.15, 0.57)$	b	Time/DirectorMJS1987–2016:vowelGOOSE	user
`student_t`$(3, 0, 1)$	Intercept		user
`student_t`$(3, 0, 1)$	sd		user

Table A.12: Front vowel F1 model estimates with different priors
(RP = Received Pronunciation, SSE = Standard Scottish English, weak = weakly informative)

	RP			SSE			Weak		
	Est.	95% CI		Est.	95% CI		Est.	95% CI	
Intercept	**−0.21**	**−0.43**	**0.00**	**−0.22**	**−0.43**	**−0.01**	**−0.22**	**−0.43**	**−0.01**
Time/DirectorPM1959–1975	0.17	−0.03	0.38	0.18	−0.02	0.38	0.18	−0.03	0.39
Time/DirectorMJS1987–2016	**0.41**	**0.19**	**0.64**	**0.42**	**0.20**	**0.64**	**0.42**	**0.20**	**0.65**
vowelKIT	**−0.54**	**−0.64**	**−0.44**	**−0.52**	**−0.63**	**−0.42**	**−0.52**	**−0.62**	**−0.41**
vowelDRESS	**0.56**	**0.41**	**0.71**	**0.53**	**0.39**	**0.68**	**0.54**	**0.39**	**0.69**
vowelTRAP	**0.84**	**0.69**	**0.97**	**0.84**	**0.70**	**0.98**	**0.83**	**0.69**	**0.97**
vowelDur	−0.02	−0.07	0.03	−0.01	−0.07	0.04	−0.02	−0.07	0.04
Time/DirectorPM1959–1975:vowelKIT	−0.01	−0.09	0.07	−0.03	−0.11	0.06	−0.03	−0.11	0.06
Time/DirectorMJS1987–2016:vowelKIT	−0.05	−0.15	0.04	−0.07	−0.16	0.03	−0.07	−0.16	0.03
Time/DirectorPM1959–1975:vowelDRESS	−0.07	−0.19	0.05	−0.04	−0.16	0.08	−0.05	−0.17	0.07
Time/DirectorMJS1987–2016:vowelDRESS	0.07	−0.06	0.20	0.09	−0.04	0.22	0.09	−0.05	0.22
Time/DirectorPM1959–1975:vowelTRAP	−0.05	−0.16	0.05	−0.06	−0.16	0.05	−0.05	−0.16	0.05
Time/DirectorMJS1987–2016:vowelTRAP	**0.13**	**0.02**	**0.25**	**0.13**	**0.01**	**0.25**	**0.13**	**0.02**	**0.25**

Bold type indicates 0 outside 95% credible interval.

Table A.13: Front vowel F2 model estimates with different priors
(RP = Received Pronunciation, SSE = Standard Scottish English, weak = weakly informative)

	RP			SSE			Weak		
	Est.	95% CI		Est.	95% CI		Est.	95% CI	
Intercept	**0.83**	**0.70**	**0.97**	**0.83**	**0.69**	**0.97**	**0.83**	**0.69**	**0.97**
Time/DirectorPM1959–1975	**−0.24**	**−0.39**	**−0.10**	**−0.24**	**−0.39**	**−0.09**	**−0.24**	**−0.38**	**−0.09**
Time/DirectorMJS1987–2016	**−0.29**	**−0.44**	**−0.13**	**−0.28**	**−0.44**	**−0.13**	**−0.28**	**−0.44**	**−0.13**
vowelKIT	**0.23**	**0.17**	**0.30**	**0.23**	**0.17**	**0.30**	**0.23**	**0.17**	**0.30**
vowelDRESS	**−0.24**	**−0.33**	**−0.14**	**−0.23**	**−0.32**	**−0.14**	**−0.23**	**−0.32**	**−0.13**
vowelTRAP	**−0.65**	**−0.74**	**−0.56**	**−0.62**	**−0.71**	**−0.53**	**−0.62**	**−0.71**	**−0.53**
vowelDur	**−0.07**	**−0.10**	**−0.04**	**−0.07**	**−0.10**	**−0.03**	**−0.07**	**−0.10**	**−0.03**
Time/DirectorPM1959–1975:vowelKIT	0.04	−0.02	0.09	0.04	−0.02	0.09	0.04	−0.02	0.09
Time/DirectorMJS1987–2016:vowelKIT	0.01	−0.05	0.07	0.01	−0.05	0.07	0.01	−0.05	0.07
Time/DirectorPM1959–1975:vowelDRESS	−0.06	−0.14	0.01	−0.07	−0.15	0.00	−0.07	−0.15	0.00
Time/DirectorMJS1987–2016:vowelDRESS	**−0.12**	**−0.20**	**−0.04**	**−0.13**	**−0.21**	**−0.04**	**−0.13**	**−0.21**	**−0.04**
Time/DirectorPM1959–1975:vowelTRAP	**0.07**	**0.00**	**0.13**	0.04	−0.03	0.10	0.04	−0.03	0.10
Time/DirectorMJS1987–2016:vowelTRAP	**−0.08**	**−0.15**	**−0.01**	**−0.11**	**−0.18**	**−0.03**	**−0.11**	**−0.18**	**−0.03**

Bold type indicates 0 outside 95% credible interval.

Table A.14: Back vowel F1 model estimates with different priors
(RP = Received Pronunciation, SSE = Standard Scottish English, weak = weakly informative)

	RP			SSE			Weak		
	Est.	95% CI		Est.	95% CI		Est.	95% CI	
Intercept	0.06	−0.20	0.33	0.05	−0.22	0.32	0.05	−0.22	0.32
Time/DirectorPM1959–1975	−0.06	−0.33	0.20	−0.06	−0.33	0.21	−0.06	−0.32	0.21
Time/DirectorMJS1987–2016	0.22	−0.05	0.50	0.22	−0.06	0.51	0.22	−0.06	0.50
vowelBATH	**0.64**	**0.44**	**0.84**	**0.67**	**0.46**	**0.88**	**0.65**	**0.43**	**0.86**
vowelLOT	**0.50**	**0.35**	**0.66**	**0.52**	**0.36**	**0.68**	**0.52**	**0.36**	**0.69**
vowelTHOUGHT	**0.23**	**0.06**	**0.39**	**0.25**	**0.08**	**0.43**	**0.25**	**0.07**	**0.43**
vowelFOOT	**−1.00**	**−1.31**	**−0.70**	**−1.12**	**−1.47**	**−0.76**	**−1.10**	**−1.48**	**−0.71**
vowelGOOSE	**−1.00**	**−1.18**	**−0.83**	**−1.00**	**−1.18**	**−0.81**	**−0.99**	**−1.18**	**−0.80**
vowelDur	−0.02	−0.11	0.06	−0.01	−0.10	0.07	−0.01	−0.10	0.07
Time/DirectorPM1959–1975:vowelBATH	−0.03	−0.19	0.13	−0.04	−0.22	0.13	−0.03	−0.21	0.15
Time/DirectorMJS1987–2016:vowelBATH	0.01	−0.17	0.19	0.00	−0.19	0.19	0.02	−0.18	0.21
Time/DirectorPM1959–1975:vowelLOT	0.03	−0.10	0.16	0.02	−0.12	0.15	0.02	−0.12	0.15
Time/DirectorMJS1987–2016:vowelLOT	0.10	−0.04	0.24	0.09	−0.05	0.23	0.10	−0.05	0.24
Time/DirectorPM1959–1975:vowelTHOUGHT	0.12	−0.01	0.25	0.12	−0.02	0.26	0.12	−0.03	0.26
Time/DirectorMJS1987–2016:vowelTHOUGHT	**0.15**	**0.00**	**0.29**	0.14	−0.01	0.29	**0.15**	**0.00**	**0.30**
Time/DirectorPM1959–1975:vowelFOOT	−0.08	−0.32	0.17	−0.02	−0.32	0.27	−0.04	−0.36	0.28
Time/DirectorMJS1987–2016:vowelFOOT	−0.10	−0.39	0.19	−0.06	−0.39	0.26	−0.09	−0.45	0.27
Time/DirectorPM1959–1975:vowelGOOSE	−0.00	−0.15	0.14	−0.01	−0.16	0.14	−0.01	−0.17	0.14
Time/DirectorMJS1987–2016:vowelGOOSE	−0.16	−0.32	0.00	−0.17	−0.34	0.01	−0.17	−0.35	0.00

Bold type indicates 0 outside 95% credible interval.

Table A.15: Back vowel F2 model estimates with different priors
(RP = Received Pronunciation, SSE = Standard Scottish English, weak = weakly informative)

	RP			SSE			Weak		
	Est.	95% CI		Est.	95% CI		Est.	95% CI	
Intercept	**−0.92**	**−1.06**	**−0.78**	**−0.95**	**−1.08**	**−0.81**	**−0.95**	**−1.09**	**−0.81**
Time/DirectorPM1959–1975	**−0.13**	**−0.27**	**−0.01**	−0.11	−0.24	0.01	−0.11	−0.24	0.02
Time/DirectorMJS1987–2016	−0.08	−0.23	0.06	−0.07	−0.20	0.07	−0.07	−0.20	0.07
vowelBATH	**0.55**	**0.41**	**0.68**	**0.64**	**0.50**	**0.78**	**0.65**	**0.50**	**0.79**
vowelLOT	**0.12**	**0.02**	**0.22**	**0.14**	**0.03**	**0.25**	**0.15**	**0.04**	**0.26**
vowelTHOUGHT	−0.00	−0.11	0.11	−0.04	−0.16	0.08	−0.03	−0.15	0.09
vowelFOOT	**−0.33**	**−0.55**	**−0.10**	**−0.51**	**−0.77**	**−0.26**	**−0.55**	**−0.81**	**−0.28**
vowelGOOSE	**−0.48**	**−0.60**	**−0.36**	**−0.49**	**−0.62**	**−0.37**	**−0.49**	**−0.62**	**−0.36**
vowelDur	**−0.07**	**−0.12**	**−0.01**	**−0.06**	**−0.12**	**−0.01**	**−0.06**	**−0.12**	**−0.00**
Time/DirectorPM1959–1975:vowelBATH	0.06	−0.05	0.17	−0.04	−0.16	0.08	−0.04	−0.16	0.08
Time/DirectorMJS1987–2016:vowelBATH	−0.09	−0.21	0.04	**−0.16**	**−0.29**	**−0.03**	**−0.16**	**−0.29**	**−0.03**
Time/DirectorPM1959–1975:vowelLOT	0.00	−0.08	0.09	−0.02	−0.11	0.07	−0.02	−0.11	0.07
Time/DirectorMJS1987–2016:vowelLOT	−0.06	−0.15	0.04	−0.07	−0.17	0.03	−0.07	−0.17	0.02
Time/DirectorPM1959–1975:vowelTHOUGHT	**0.08**	**0.00**	**0.17**	**0.14**	**0.04**	**0.23**	**0.13**	**0.03**	**0.23**
Time/DirectorMJS1987–2016:vowelTHOUGHT	0.06	−0.03	0.16	**0.11**	**0.00**	**0.21**	0.10	−0.00	0.21
Time/DirectorPM1959–1975:vowelFOOT	**−0.21**	**−0.37**	**−0.04**	−0.02	−0.23	0.19	0.00	−0.22	0.22
Time/DirectorMJS1987–2016:vowelFOOT	−0.16	−0.38	0.05	−0.02	−0.26	0.21	−0.01	−0.25	0.24
Time/DirectorPM1959–1975:vowelGOOSE	−0.04	−0.14	0.06	−0.03	−0.13	0.08	−0.03	−0.13	0.08
Time/DirectorMJS1987–2016:vowelGOOSE	0.10	−0.01	0.21	0.11	−0.00	0.23	0.11	−0.01	0.23

Bold type indicates 0 outside 95% credible interval.

Appendix B

Corpora

B.1 Glasgow Corpus

Table B.1: Glasgow Orpheus Choir Corpus

Album	Song	Recorded	Time/Director	Genre	Format	Released	Master
The Isle of Mull	Cargoes	1925	HSR (1925–1951)	Other Popular	LP	1974	Bb-7056-2
The Isle of Mull	Scots wha hae	1925	HSR (1925–1951)	Scottish Popular	LP	1974	Bb-7055-2
The Isle of Mull	Summer is gone	1925	HSR (1925–1951)	Other Popular	LP	1974	Bb-7054-2
O Light of Life	The laird o'Cockpen	1926	HSR (1925–1951)	Scottish Popular	CD	2007	BR-258-1
The Isle of Mull	The isle of Mull	1927	HSR (1925–1951)	Scottish Popular	LP	1974	CR-1310-1
The Isle of Mull	Corydon arise	1929	HSR (1925–1951)	Other Popular	LP	1974	Bb-16339-1
20 Classic Recordings	All in the April evening	1945	HSR (1925–1951)	Church Music	CD	1992	2EA-10600-2
20 Classic Recordings	By cool Siloam's shady rill	1945	HSR (1925–1951)	Church Music	CD	1992	2EA-10606-1
20 Classic Recordings	Far away	1945	HSR (1925–1951)	Other Popular	CD	1992	2EA-10601-1/2
Crimond	Come let us to the lord...	1945	HSR (1925–1951)	Church Music	CD	2002	OEA-10597-2
O Light of Life	In silent night	1945	HSR (1925–1951)	Other Popular	CD	2007	OEA-10598-1
O Light of Life	I live not where I love	1945	HSR (1925–1951)	Other Popular	CD	2007	OEA-10602-1
O Light of Life	The old woman	1945	HSR (1925–1951)	Scottish Popular	CD	2007	2EA-10601-1/2
20 Classic Recordings	The lord's my shepherd	1947	HSR (1925–1951)	Church Music	CD	1992	2EA-12247-1
20 Classic Recordings	Ellan Vannin	1947	HSR (1925–1951)	Other Popular	CD	1992	OEA-12250-2
Glasgow Orpheus Choir	The dashing white sergeant	1947	HSR (1925–1951)	Scottish Popular	EP	1957	OEA-12258-2
O Light of Life	O light of life	1947	HSR (1925–1951)	Church Music	CD	2007	OEA-12251-2
O Light of Life	All creatures now	1947	HSR (1925–1951)	Other Popular	CD	2007	OEA-12249-2
Crimond	O for a closer walk with god	1948	HSR (1925–1951)	Church Music	CD	2002	2EA-13411-1
O Light of Life	To take the air a bonny lass...	1949	HSR (1925–1951)	Other Popular	CD	2007	OEA-14161-1A
O Light of Life	The shower	1949	HSR (1925–1951)	Other Popular	CD	2007	OEA-14164-1A
O Light of Life	Come, kindly death	1949	HSR (1925–1951)	Church Music	CD	2007	OEA-14163-1A
20 Classic Recordings	The cloud capp'd towers	1951	HSR (1925–1951)	Other Popular	CD	1992	OEA-16031-2
20 Classic Recordings	O god of Bethel (Orlington)	1951	HSR (1925–1951)	Church Music	CD	1992	OEA-16032-3A
Glasgow Orpheus Choir	Ae fond kiss	1951	HSR (1925–1951)	Scottish Popular	EP	1957	OEA-16004-1A

Table B.2: Glasgow Orpheus Choir Exclusions

Album	Song	Recorded	Master	Commercial serial number
20 Classic Recordings	An Eriskay love lilt	1925	Bb-7057-1	HMV E-409
The Isle of Mull	Dim-lit woods	1927	BR-1302-1	HMV E-482; HMVAu EA-482; Starline MRS-5175(LP)
O Light of Life	Dumbarton's drums	1927	BR-1311-1	HMV E-456
O Light of Life	Deep river	1927	CR-1303-1	HMV C-1512; HMVSA C-1512(12")
20 Classic Recordings	The Campbells are comin'	1929	Bb-16335-1	HMV B-3109; HMVSA B-3109; Starline MRS-5175(LP)
20 Classic Recordings	Cradle song	1929	Bb-16344-2	HMV B-3109; HMVSA B-3109; Starline MRS-5175(LP)
O Light of Life	O can ye sew cushions?	1945	OEA-10763-1	HMV B-9464; DLP-1028(LP); GCS-1017(LP)
20 Classic Recordings	The blue bird	1945	OEA-10603-2	HMV B-9464; HMV DLP-1028(LP); GCS-1017(LP)
20 Classic Recordings	Jesu, joy of man's desiring	1947	OEA-12248-2	HMV B-9697; 7P-257(7".45); DLP-1020(LP); 7EG-8476(EP)
20 Classic Recordings	The faery song	1947	OEA-12252-2	HMV B-9608; 7EG-8476(EP); 7EG-8517(EP); HMVIr IP-449; HMV DLP-1020(LP)
20 Classic Recordings	Sea sorrow	1947	2EA-12254-2	HMV C-3639; 7P-247(7".45); HMVIr IPX-86; HMVAu C-3639; EB-580(12"); Starline MRS-5175(LP)
20 Classic Recordings	Peat-fire smooring prayer	1948	2EA-13459-1	HMV C-3903(12"); HMV DLP-1019(LP)
O Light of Life	Gretna Green	1949	OEA-13458-3	HMV B-9897; Starline MRS-5175(LP)
20 Classic Recordings	Ca' the yowes	1951	OEA-16001-2A	HMV B-10163; DLP-1019(LP); 7EG-8248(EP)
O Light of Life	White waves on the water	1951	OEA-16029-2A	HMV B-10196; HMV DLP-1020(LP)
20 Classic Recordings	Hark, hark the echo falling	1951	OEA-16030-3A	HMV B-10196; HMV DLP-1020(LP)
20 Classic Recordings	An Eriskay love lilt	1951	OEA-16033-2A	HMV B-10463; DLP-1019(LP); 7EG-8248(EP)

Table B.3: Glasgow Orpheus Choir unavailable

Song	YearRecorded	Master	Commercial.serial.number
A man's a man for a' that	1923	C-5813	Aco G-15365; Bel 247
The song of the blacksmith	1923	C-5814	Aco G-15364; Bel 245
Loch Lomond	1923	C-5815	Aco G-15364; Bel 246
Wi' a hundred pipers	1923	C-5817	Aco G-15344; Bel 245
French	1923	C-5818	Aco G-15344; Bel 246
The barrin' o' the door	1923	C-5819	Aco G-15365; Bel 247
Scots wha hae	1924	MC-6329	Bel 5008(12")
Highland love song	1924	MC-6331	Bel 5008(12")
Stracathro – psalm tune	1924	MC-6330	Bel 5009(12")
O come all ye faithful	1924	MC-6332	Bel 5009(12")
All in the April evening	1925	Bb-7052-1	HMV E-441
Great god of love	1927	BR-1308-1/2	HMV E-482; HMVAu EA-482
In going to my lonely bed	1929	Bb-16342-1	HMV B-3577; HMVSA B-3577
The turtle dove	1945	2EA-10764-1	HMV C-3463(12")
The herdmaiden's song	1945	OEA-10604-3	HMV B-9501; JO-163; HMVAu EA-3623; Starline MRS-5175(LP)
Haste thee nymph	1947	OEA-12257-2	HMV B-9697, 7P-257\(7".45)

Table B.4: Glasgow Phoenix Choir Corpus.
Format ‘EP’ = Extended play record; ‘LP’ = Long play record; ‘CD’ = Compact Disc.

Album	Song	Time/Director	Genre	Format	YearReleased
The Road to the Isles	All in the April evening	Peter Mooney (1959–1975)	Church Music	LP	1959
The Road to the Isles	A rosebud by my early walk	Peter Mooney (1959–1975)	Scottish Popular	LP	1959
The Road to the Isles	Come let us to the lord our god	Peter Mooney (1959–1975)	Church Music	LP	1959
The Road to the Isles	Dashing white sergeant	Peter Mooney (1959–1975)	Scottish Popular	LP	1959
The Road to the Isles	Go lovely rose	Peter Mooney (1959–1975)	Other Popular	LP	1959
The Road to the Isles	Scots wha hae	Peter Mooney (1959–1975)	Scottish Popular	LP	1959
The Road to the Isles	The cloud capp’d towers	Peter Mooney (1959–1975)	Other Popular	LP	1959
The Road to the Isles	The lord’s my shepherd (Crimond)	Peter Mooney (1959–1975)	Church Music	LP	1959
Songs We Love	An Eriskay lovelilt	Peter Mooney (1959–1975)	Scottish Popular	LP	1962
Songs We Love	By cool Siloam’s shady rill (Belmont)	Peter Mooney (1959–1975)	Church Music	LP	1962
Songs We Love	Dream Angus	Peter Mooney (1959–1975)	Scottish Popular	LP	1962
Songs We Love	Far away	Peter Mooney (1959–1975)	Other Popular	LP	1962
Songs We Love	In silent night	Peter Mooney (1959–1975)	Other Popular	LP	1962
Songs We Love	Psalm 124	Peter Mooney (1959–1975)	Church Music	LP	1962
Songs We Love	The hundred pipers	Peter Mooney (1959–1975)	Scottish Popular	LP	1962
Will ye no come back again?	Auld lang syne	Peter Mooney (1959–1975)	Scottish Popular	LP	1963
Will ye no come back again?	Deep river	Peter Mooney (1959–1975)	Church Music	LP	1963
Will ye no come back again?	King Arthur	Peter Mooney (1959–1975)	Other Popular	LP	1963
Will ye no come back again?	The winter it is past	Peter Mooney (1959–1975)	Other Popular	LP	1963
Will ye no come back again?	Will ye no come back again?	Peter Mooney (1959–1975)	Scottish Popular	LP	1963
Onward Christian Soldiers	Creation’s hymn	Peter Mooney (1959–1975)	Church Music	LP	1964
Onward Christian Soldiers	Hear, lord our god have mercy	Peter Mooney (1959–1975)	Church Music	LP	1964
Onward Christian Soldiers	O light of life	Peter Mooney (1959–1975)	Church Music	LP	1964
Onward Christian Soldiers	O love that wilt not let me go	Peter Mooney (1959–1975)	Church Music	LP	1964
Onward Christian Soldiers	The church’s one foundation	Peter Mooney (1959–1975)	Church Music	LP	1964

Album	Song	Time/Director	Genre	Format	Released
Worship the Lord	Abide with me	Peter Mooney (1959–1975)	Church Music	LP	1964
Worship the Lord	O send thy light forth	Peter Mooney (1959–1975)	Church Music	LP	1964
Worship the Lord	When I survey the wondrous cross	Peter Mooney (1959–1975)	Church Music	LP	1964
Worship the Lord	Worship the lord	Peter Mooney (1959–1975)	Church Music	LP	1964
Everyone Sang	Aye she kaimed her yellow hair	Peter Mooney (1959–1975)	Scottish Popular	LP	1966
Everyone Sang	Birthday song for a royal child	Peter Mooney (1959–1975)	Other Popular	LP	1966
Everyone Sang	Everyone sang	Peter Mooney (1959–1975)	Other Popular	LP	1966
Everyone Sang	Give praise and thanks	Peter Mooney (1959–1975)	Church Music	LP	1966
Everyone Sang	Swing low, sweet chariot	Peter Mooney (1959–1975)	Other Popular	LP	1966
Everyone Sang	The ould Lammas fair	Peter Mooney (1959–1975)	Other Popular	LP	1966
Everyone Sang	Wilt thou be my dearie	Peter Mooney (1959–1975)	Scottish Popular	LP	1966
Songs From Scotland	All in the April evening	Peter Mooney (1959–1975)	Church Music	LP	1968
Songs From Scotland	By cool Siloam's shady rill (Belmont)	Peter Mooney (1959–1975)	Church Music	LP	1968
Songs From Scotland	Come let us to the lord our god	Peter Mooney (1959–1975)	Church Music	LP	1968
Songs From Scotland	Johnnie Cope	Peter Mooney (1959–1975)	Scottish Popular	LP	1968
Songs From Scotland	Loch Lomond	Peter Mooney (1959–1975)	Scottish Popular	LP	1968
Songs From Scotland	My love is like a red, red rose	Peter Mooney (1959–1975)	Scottish Popular	LP	1968
Songs From Scotland	O perfect love	Peter Mooney (1959–1975)	Church Music	LP	1968
Songs From Scotland	The lord's my shepherd (Crimond)	Peter Mooney (1959–1975)	Church Music	LP	1968
Songs From Scotland	The road to the Isles	Peter Mooney (1959–1975)	Scottish Popular	LP	1968
Songs From Scotland	Were you there	Peter Mooney (1959–1975)	Church Music	LP	1968
The Phoenix Sings	Auld lang syne	Peter Mooney (1959–1975)	Scottish Popular	LP	1969
The Phoenix Sings	Loch Lomond	Peter Mooney (1959–1975)	Scottish Popular	LP	1969
The Phoenix Sings	My love is like a red, red rose	Peter Mooney (1959–1975)	Scottish Popular	LP	1969
The Phoenix Sings	Scots wha hae	Peter Mooney (1959–1975)	Scottish Popular	LP	1969
The Phoenix Sings	Will ye no come back again	Peter Mooney (1959–1975)	Scottish Popular	LP	1969
Jesu Joy of Man's Desiring	All in the April evening	Peter Mooney (1959–1975)	Church Music	LP	1970
Jesu Joy of Man's Desiring	By cool Siloam's shady rill (Belmont)	Peter Mooney (1959–1975)	Church Music	LP	1970

Album	Song	Time/Director	Genre	Format	Released
Jesu Joy of Man's Desiring	Come let us to the lord our god	Peter Mooney (1959–1975)	Church Music	LP	1970
Jesu Joy of Man's Desiring	O for a closer walk with god	Peter Mooney (1959–1975)	Church Music	LP	1970
Jesu Joy of Man's Desiring	O light of life	Peter Mooney (1959–1975)	Church Music	LP	1970
Jesu Joy of Man's Desiring	Psalm 124	Peter Mooney (1959–1975)	Church Music	LP	1970
Jesu Joy of Man's Desiring	The lord's my shepherd (Crimond)	Peter Mooney (1959–1975)	Church Music	LP	1970
Jesu Joy of Man's Desiring	Were you there	Peter Mooney (1959–1975)	Church Music	LP	1970
Glasgow Phoenix Choir	Hear, lord our god have mercy	Peter Mooney (1959-1975)	Church Music	LP	1973
Glasgow Phoenix Choir	I to the hills will lift mine eyes	Peter Mooney (1959–1975)	Church Music	LP	1973
Glasgow Phoenix Choir	O perfect love	Peter Mooney (1959–1975)	Church Music	LP	1973
Glasgow Phoenix Choir	The day thou gavest lord is ended	Peter Mooney (1959–1975)	Church Music	LP	1973
Glasgow Phoenix Choir	Ye gates lift up your heads	Peter Mooney (1959–1975)	Church Music	LP	1973
World of Song	Far away	Peter Mooney (1959–1975)	Other Popular	LP	1974
World of Song	Loch Lomond	Peter Mooney (1959–1975)	Scottish Popular	LP	1974
World of Song	The hundred pipers	Peter Mooney (1959–1975)	Scottish Popular	LP	1974
Scotland's Favourite Songs of Praise	Abide with me	Peter Mooney (1959–1975)	Church Music	LP	1975
Scotland's Favourite Songs of Praise	All people that on earth do dwell	Peter Mooney (1959–1975)	Church Music	LP	1975
Scotland's Favourite Songs of Praise	Be still my soul	Peter Mooney (1959–1975)	Church Music	LP	1975
Scotland's Favourite Songs of Praise	By cool Siloam's shady rill (Belmont)	Peter Mooney (1959–1975)	Church Music	LP	1975
Scotland's Favourite Songs of Praise	Love divine all loves excelling	Peter Mooney (1959–1975)	Church Music	LP	1975
Scotland's Favourite Songs of Praise	O god of Bethel (Orlington)	Peter Mooney (1959–1975)	Church Music	LP	1975
Scotland's Favourite Songs of Praise	O love that wilt not let me go	Peter Mooney (1959–1975)	Church Music	LP	1975
Scotland's Favourite Songs of Praise	The day thou gavest lord is ended	Peter Mooney (1959–1975)	Church Music	LP	1975
Scotland's Favourite Songs of Praise	The lord's my shepherd (Crimond)	Peter Mooney (1959–1975)	Church Music	LP	1975
Scotland's Favourite Songs of Praise	What a friend we have in Jesus	Peter Mooney (1959–1975)	Church Music	LP	1975
Scotland's Favourite Songs of Praise	When I survey the wondrous cross	Peter Mooney (1959–1975)	Church Music	LP	1975
The Glasgow Phoenix Choir	Caller herring	Peter S. Shand (1983–1990)	Scottish Popular	LP	1987
The Glasgow Phoenix Choir	Deep river	Peter S. Shand (1983–1990)	Other Popular	LP	1987
The Glasgow Phoenix Choir	Far away	Peter S. Shand (1983–1990)	Other Popular	LP	1987

Album	Song	Time/Director	Genre	Format	Released
The Glasgow Phoenix Choir	I know where I’m going	Peter S. Shand (1983–1990)	Other Popular	LP	1987
With Voices Rising	Scots wha hae	Marilyn J. Smith (1990–2016)	Scottish Popular	CD	1990
With Voices Rising	When the saints go marching in	Marilyn J. Smith (1990–2016)	Church Music	CD	1990
With Voices Rising	Time for man go home	Marilyn J. Smith (1990–2016)	Other Popular	CD	1990
With Voices Rising	Psalm 23 (Brother James’ Air)	Marilyn J. Smith (1990–2016)	Church Music	CD	1990
With Voices Rising	Shenandoah	Marilyn J. Smith (1990–2016)	Other Popular	CD	1990
With Voices Rising	John Anderson my jo	Marilyn J. Smith (1990–2016)	Scottish Popular	CD	1990
With Voices Rising	Dream Angus	Marilyn J. Smith (1990–2016)	Scottish Popular	CD	1990
With Voices Rising	Loch Lomond	Marilyn J. Smith (1990–2016)	Scottish Popular	CD	1990
With Voices Rising	All my trials lord	Marilyn J. Smith (1990–2016)	Church Music	CD	1990
Highlands of Praise	What a friend we have in Jesus	Marilyn J. Smith (1990–2016)	Church Music	CD	1996
Highlands of Praise	O love that wilt not let me go	Marilyn J. Smith (1990–2016)	Church Music	CD	1996
Highlands of Praise	O god of Bethel (Orlington)	Marilyn J. Smith (1990–2016)	Church Music	CD	1996
Highlands of Praise	When I survey the wondrous cross	Marilyn J. Smith (1990–2016)	Church Music	CD	1996
Highlands of Praise	O perfect love	Marilyn J. Smith (1990–2016)	Church Music	CD	1996
Highlands of Praise	Were you there	Marilyn J. Smith (1990–2016)	Church Music	CD	1996
Highlands of Praise	Abide with me	Marilyn J. Smith (1990–2016)	Church Music	CD	1996
Highlands of Praise	The day thou gavest lord is ended	Marilyn J. Smith (1990–2016)	Church Music	CD	1996
Scotland Land of Praise	All in the April evening	Marilyn J. Smith (1990–2016)	Church Music	CD	1999
Titanic	Lord I don’t feel noways tired	Marilyn J. Smith (1990–2016)	Church Music	CD	1999
Celebrating 100 years…	Annie Laurie	Marilyn J. Smith (1990–2016)	Scottish Popular	CD	2000
Celebrating 100 years…	Far away	Marilyn J. Smith (1990–2016)	Other Popular	CD	2000
Celebrating 100 years…	All in the April evening	Marilyn J. Smith (1990–2016)	Church Music	CD	2000
Celebrating 100 years…	All through the night	Marilyn J. Smith (1990–2016)	Other Popular	CD	2000
Celebrating 100 years…	Hush somebody’s callin’ my name	Marilyn J. Smith (1990–2016)	Other Popular	CD	2000
Celebrating 100 years…	The isle of Mull	Marilyn J. Smith (1990–2016)	Scottish Popular	CD	2000
Celebrating 100 years…	Ellan Vannin	Marilyn J. Smith (1990–2016)	Other Popular	CD	2000
Celebrating 100 years…	Go lovely rose	Marilyn J. Smith (1990–2016)	Other Popular	CD	2000

Album	Song	Time/Director	Genre	Format	Released
Celebrating 100 years…	The cloud capp'd towers	Marilyn J. Smith (1990–2016)	Other Popular	CD	2000
Auld Lang Syne	Ca the yowes	Marilyn J. Smith (1990–2016)	Scottish Popular	CD	2001
Auld Lang Syne	Lament of Mary Queen of Scots	Marilyn J. Smith (1990–2016)	Scottish Popular	CD	2001
Auld Lang Syne	Ye banks and braes	Marilyn J. Smith (1990–2016)	Scottish Popular	CD	2001
Auld Lang Syne	Flow gently sweet Afton	Marilyn J. Smith (1990–2016)	Scottish Popular	CD	2001
Auld Lang Syne	A rosebud by my early walk	Marilyn J. Smith (1990–2016)	Scottish Popular	CD	2001
We Rise Again	God so loved the world	Marilyn J. Smith (1990–2016)	Church Music	CD	2003
We Rise Again	Lord I don't feel noways tired	Marilyn J. Smith (1990–2016)	Church Music	CD	2003
Iona Abbey	The lamb	Marilyn J. Smith (1990–2016)	Church Music	CD	2004
Iona Abbey	All in the April evening	Marilyn J. Smith (1990–2016)	Church Music	CD	2004
Iona Abbey	God so loved the world	Marilyn J. Smith (1990–2016)	Church Music	CD	2004
Feel Good	Balm in Gilead	Marilyn J. Smith (1990–2016)	Church Music	CD	2006
Feel Good	Hear, lord our god have mercy	Marilyn J. Smith (1990–2016)	Church Music	CD	2006
Feel Good	My spirit sang all day	Marilyn J. Smith (1990–2016)	Church Music	CD	2006
Feel Good	Ye banks and braes	Marilyn J. Smith (1990–2016)	Scottish Popular	CD	2006
Feel Good	All in the April evening	Marilyn J. Smith (1990–2016)	Church Music	CD	2006
Feel Good	Aye waukin' o	Marilyn J. Smith (1990–2016)	Scottish Popular	CD	2006
Rosslyn Chapel	The lamb	Marilyn J. Smith (1990–2016)	Church Music	CD	2006
Orkney St Magnus Cathedral	All in the April evening	Marilyn J. Smith (1990–2016)	Church Music	CD	2016
Orkney St Magnus Cathedral	The road home	Marilyn J. Smith (1990–2016)	Church Music	CD	2016

Table B.5: Glasgow Phoenix Choir unavailable

Album	YearRecorded	Commercial serial number	Format
Amazing Grace	1976	Word (UK) Ltd, WST9560	LP
For Auld Lang Syne	1980	GPC Records GPC104	CD

B.2 King's Corpus

Table B.6: Corpus of the Choir of King's College, Cambridge. Format 'EP' = Extended play record; 'LP' = Long play record; 'CD' = Compact Disc; 'DD' = Digital Download; 'RB;YT' = Radio Broadcast, YouTube; 'TV;YT' = Television Broadcast, YouTube.

Album	Released	Song	Time/Director	Genre	Format
Carols	1949	Three kings	Boris Ord (1945–1958)	Carols	EP
Carols	1949	In dulci jubilo	Boris Ord (1945–1958)	Carols	EP
Carols	1949	Ding dong merrily on high	Boris Ord (1945–1958)	Carols	EP
A Festival of Lessons and Carols	1954	Up good Christen folk	Boris Ord (1945–1958)	Carols	DD
A Festival of Lessons and Carols	1954	The noble stem of Jesse	Boris Ord (1945–1958)	Carols	DD
A Festival of Lessons and Carols	1954	God rest ye merry gentlemen	Boris Ord (1945–1958)	Carols	DD
A Festival of Lessons and Carols	1954	In dulci jubilo	Boris Ord (1945–1958)	Carols	DD
A Festival of Lessons and Carols	1954	Hail blessed virgin Mary	Boris Ord (1945–1958)	Carols	DD
A Festival of Lessons and Carols	1954	A virgin most pure	Boris Ord (1945–1958)	Carols	DD
A Festival of Lessons and Carols	1954	The infant king	Boris Ord (1945–1958)	Carols	DD
Evensong (1956a)	1956	O praise the lord	Boris Ord (1945–1958)	Evensong	CD
Evensong (1956a)	1956	Responses	Boris Ord (1945–1958)	Evensong	CD
Evensong (1956a)	1956	Creed	Boris Ord (1945–1958)	Evensong	CD
Evensong (1956a)	1956	Collects	Boris Ord (1945–1958)	Evensong	CD
Evensong (1956a)	1956	Final responses	Boris Ord (1945–1958)	Evensong	CD
Evensong (1956b)	1956	Collects	Boris Ord (1945–1958)	Evensong	LP
Evensong (1956b)	1956	Creed	Boris Ord (1945–1958)	Evensong	LP
Evensong (1956b)	1956	Preces	Boris Ord (1945–1958)	Evensong	LP
Evensong (1956b)	1956	Responses	Boris Ord (1945–1958)	Evensong	LP
Orlando Gibbons	1956	Almighty and everlasting God	Boris Ord (1945–1958)	Evensong	LP
Orlando Gibbons	1956	Preces	Boris Ord (1945–1958)	Evensong	LP
An Easter Matins	1957	This joyful Eastertide	Boris Ord (1945–1958)	Evensong	CD
An Easter Matins	1957	Preces	Boris Ord (1945–1958)	Evensong	CD
An Easter Matins	1957	The Creed	Boris Ord (1945–1958)	Evensong	CD
An Easter Matins	1957	Responses	Boris Ord (1945–1958)	Evensong	CD

Album	Released	Song	Time/Director	Genre	Format
An Easter Matins	1957	Lord’s prayer	Boris Ord (1945–1958)	Evensong	CD
An Easter Matins	1957	Collects	Boris Ord (1945–1958)	Evensong	CD
A Festival of Lessons and Carols	1958	Once in royal David’s city	Boris Ord (1945–1958)	Carols	DD
A Festival of Lessons and Carols	1958	Adam lay ybounden	Boris Ord (1945–1958)	Carols	DD
A Festival of Lessons and Carols	1958	I saw three ships	Boris Ord (1945–1958)	Carols	DD
A Festival of Lessons and Carols	1958	Gabriel’s message	Boris Ord (1945–1958)	Carols	DD
A Festival of Lessons and Carols	1958	God rest ye merry gentlemen	Boris Ord (1945–1958)	Carols	DD
A Festival of Lessons and Carols	1958	Sussex carol	Boris Ord (1945–1958)	Carols	DD
A Festival of Lessons and Carols	1958	In dulci jubilo	Boris Ord (1945–1958)	Carols	DD
A Festival of Lessons and Carols	1958	Away in a manger	Boris Ord (1945–1958)	Carols	DD
A Festival of Lessons and Carols	1958	While shepherds watched	Boris Ord (1945–1958)	Carols	DD
Evensong for Ash Wednesday	1959	Magnificat	David Willcocks (1959–1974)	Evensong	RB;YT
Evensong for Ash Wednesday	1959	Nunc dimittis	David Willcocks (1959–1974)	Evensong	RB;YT
Evensong for Ash Wednesday	1959	Drop drop slow tears	David Willcocks (1959–1974)	Evensong	RB;YT
Evensong for Ash Wednesday	1959	Office hymn	David Willcocks (1959–1974)	Evensong	RB;YT
Evensong for Ash Wednesday	1959	Psalm 102	David Willcocks (1959–1974)	Evensong	RB;YT
Evensong for Ash Wednesday	1959	Responses	David Willcocks (1959–1974)	Evensong	RB;YT
Bach Motets	1960	O Jesu so meek	David Willcocks (1959–1974)	Evensong	LP
Bach Motets	1960	Jesus is this dark world’s light	David Willcocks (1959–1974)	Evensong	LP
Bach Motets	1960	Lord pour not thy vengeance	David Willcocks (1959–1974)	Evensong	LP
Bach Motets	1960	It is finished	David Willcocks (1959–1974)	Evensong	LP
Bach Motets	1960	Breath of god	David Willcocks (1959–1974)	Evensong	LP
Bach Motets	1960	God liveth still	David Willcocks (1959–1974)	Evensong	LP
Carols from King’s	1960	Rejoice and be merry	David Willcocks (1959–1974)	Carols	DD
Carols from King’s	1960	Away in a manger	David Willcocks (1959–1974)	Carols	DD
Carols from King’s	1960	While shepherds watched	David Willcocks (1959–1974)	Carols	DD
Carols from King’s	1960	Sussex carol	David Willcocks (1959–1974)	Carols	DD
Carols from King’s	1960	God rest ye merry gentlemen	David Willcocks (1959–1974)	Carols	DD

Album	Released	Song	Time/Director	Genre	Format
Carols from King's live	1962	Once in royal David's city	David Willcocks (1959–1974)	Carols	DD
Carols from King's live	1962	Herefordshire carol	David Willcocks (1959–1974)	Carols	DD
Carols from King's live	1962	Adam lay ybounden	David Willcocks (1959–1974)	Carols	DD
Carols from King's live	1962	Ding dong merrily on high	David Willcocks (1959–1974)	Carols	DD
Carols from King's live	1962	Sussex carol	David Willcocks (1959–1974)	Carols	DD
Carols from King's live	1962	God rest ye merry gentlemen	David Willcocks (1959–1974)	Carols	DD
Carols from King's live	1962	In dulci jubilo	David Willcocks (1959–1974)	Carols	DD
Carols from King's live	1962	Gabriel's message	David Willcocks (1959–1974)	Carols	DD
Carols from King's live	1962	The holly and the ivy	David Willcocks (1959–1974)	Carols	DD
Carols from King's live	1962	In the bleak midwinter	David Willcocks (1959–1974)	Carols	DD
On Christmas Night	1962	O come all ye faithful	David Willcocks (1959–1974)	Carols	LP
On Christmas Night	1962	O little town of Bethlehem	David Willcocks (1959–1974)	Carols	LP
On Christmas Night	1962	Blessed be that maid Mary	David Willcocks (1959–1974)	Carols	LP
On Christmas Night	1962	Ding dong merrily on high	David Willcocks (1959–1974)	Carols	LP
On Christmas Night	1962	See amid the winter snow	David Willcocks (1959–1974)	Carols	LP
On Christmas Night	1962	In the bleak midwinter	David Willcocks (1959–1974)	Carols	LP
On Christmas Night	1962	Coventry carol	David Willcocks (1959–1974)	Carols	LP
On Christmas Night	1962	Shepherds in the field abiding	David Willcocks (1959–1974)	Carols	LP
A Festival of Lessons and Carols	1964	Once in royal David's city	David Willcocks (1959–1974)	Carols	DD
A Festival of Lessons and Carols	1964	Alleluya	David Willcocks (1959–1974)	Carols	DD
A Festival of Lessons and Carols	1964	There is no rose	David Willcocks (1959–1974)	Carols	DD
A Festival of Lessons and Carols	1964	O little town of Bethlehem	David Willcocks (1959–1974)	Carols	DD
A Festival of Lessons and Carols	1964	Infant holy	David Willcocks (1959–1974)	Carols	DD
A Festival of Lessons and Carols	1964	Lullay (Holst)	David Willcocks (1959–1974)	Carols	DD
A Festival of Lessons and Carols	1964	O babe divine	David Willcocks (1959–1974)	Carols	DD
A Festival of Lessons and Carols	1964	As with gladness	David Willcocks (1959–1974)	Carols	DD
A Festival of Lessons and Carols	1964	In dulci jubilo	David Willcocks (1959–1974)	Carols	DD
A Festival of Lessons and Carols	1964	A great and mighty wonder	David Willcocks (1959–1974)	Carols	DD

Album	Released	Song	Time/Director	Genre	Format
Evensong for Ash Wednesday	1964	Hide not thou thy face	David Willcocks (1959–1974)	Evensong	LP
Evensong for Ash Wednesday	1964	Preces	David Willcocks (1959–1974)	Evensong	LP
Evensong for Ash Wednesday	1964	Psalm 143, 130	David Willcocks (1959–1974)	Evensong	LP
Evensong for Ash Wednesday	1964	Lent prose	David Willcocks (1959–1974)	Evensong	LP
Evensong for Ash Wednesday	1964	Magnificat	David Willcocks (1959–1974)	Evensong	LP
Evensong for Ash Wednesday	1964	Nunc dimittis	David Willcocks (1959–1974)	Evensong	LP
Evensong for Ash Wednesday	1964	Responses	David Willcocks (1959–1974)	Evensong	LP
Sing Praises	1966	I sing of a maiden	David Willcocks (1959–1974)	Carols	LP
Sing Praises	1966	Jesus Christ the apple tree	David Willcocks (1959–1974)	Carols	LP
Sing Praises	1966	Morning hymn	David Willcocks (1959–1974)	Carols	LP
Sing Praises	1966	The holly and the ivy	David Willcocks (1959–1974)	Carols	LP
Sing Praises	1966	The lord that lay	David Willcocks (1959–1974)	Carols	LP
The Psalms of David	1969	Psalm 121	David Willcocks (1959–1974)	Evensong	LP
The Psalms of David	1969	Psalm 137	David Willcocks (1959–1974)	Evensong	LP
The Psalms of David	1969	Psalm 15	David Willcocks (1959–1974)	Evensong	LP
The Psalms of David	1969	Psalm 42–43	David Willcocks (1959–1974)	Evensong	LP
The Psalms of David	1969	Psalm 61	David Willcocks (1959–1974)	Evensong	LP
Once in royal David’s city	1971	Adam lay ybounden	David Willcocks (1959–1974)	Carols	LP
Once in royal David’s city	1971	Herefordshire carol	David Willcocks (1959–1974)	Carols	LP
Once in royal David’s city	1971	How far is it	David Willcocks (1959–1974)	Carols	LP
Anthems from King’s	1974	Let all mortal flesh	David Willcocks (1959–1974)	Evensong	CD
Anthems from King’s	1974	Hail gladdening light	David Willcocks (1959–1974)	Evensong	CD
Anthems from King’s	1974	O gladsome light	David Willcocks (1959–1974)	Evensong	CD
Anthems from King’s	1974	Faire is the heaven	David Willcocks (1959–1974)	Evensong	CD
Carols for Christmas Eve	1976	Up good Christen folk	Philip Ledger (1976–1982)	Carols	LP
Carols for Christmas Eve	1976	I saw three ships	Philip Ledger (1976–1982)	Carols	LP
Carols for Christmas Eve	1976	A spotless rose	Philip Ledger (1976–1982)	Carols	LP
Carols for Christmas Eve	1976	O little town of Bethlehem	Philip Ledger (1976–1982)	Carols	LP

Album	Released	Song	Time/Director	Genre	Format
Carols for Christmas Eve	1976	Alleluya	Philip Ledger (1976–1982)	Carols	LP
Carols for Christmas Eve	1976	Away in a manger	Philip Ledger (1976–1982)	Carols	LP
Carols for Christmas Eve	1976	Coventry carol	Philip Ledger (1976–1982)	Carols	LP
Carols for Christmas Eve	1976	The first nowell	Philip Ledger (1976–1982)	Carols	LP
Carols for Christmas Eve	1976	In dulci jubilo	Philip Ledger (1976–1982)	Carols	LP
Carols for Christmas Eve	1976	Remember O thou man	Philip Ledger (1976–1982)	Carols	LP
Carols for Christmas Eve	1976	Sans day carol	Philip Ledger (1976–1982)	Carols	LP
Christmas Carols from Cambridge	1978	Adam lay ybounden	Philip Ledger (1976–1982)	Carols	TV;YT
Christmas Carols from Cambridge	1978	Away in a manger	Philip Ledger (1976–1982)	Carols	TV;YT
Christmas Carols from Cambridge	1978	Ding dong merrily on high	Philip Ledger (1976–1982)	Carols	TV;YT
Christmas Carols from Cambridge	1978	Gabriel’s message	Philip Ledger (1976–1982)	Carols	TV;YT
Christmas Carols from Cambridge	1978	In dulci jubilo	Philip Ledger (1976–1982)	Carols	TV;YT
Christmas Carols from Cambridge	1978	I saw three ships	Philip Ledger (1976–1982)	Carols	TV;YT
Christmas Carols from Cambridge	1978	Once in royal David’s city	Philip Ledger (1976–1982)	Carols	TV;YT
Christmas Carols from Cambridge	1978	O come all ye faithful	Philip Ledger (1976–1982)	Carols	TV;YT
Christmas Carols from Cambridge	1978	O little town of Bethlehem	Philip Ledger (1976–1982)	Carols	TV;YT
Christmas Carols from Cambridge	1978	Past three o’clock	Philip Ledger (1976–1982)	Carols	TV;YT
Christmas Carols from Cambridge	1978	Sussex carol	Philip Ledger (1976–1982)	Carols	TV;YT
Christmas Carols from Cambridge	1978	The first nowell	Philip Ledger (1976–1982)	Carols	TV;YT
A Festival of Lessons and Carols	1979	Once in royal David’s city	Philip Ledger (1976–1982)	Carols	CD
A Festival of Lessons and Carols	1979	Adam lay ybounden	Philip Ledger (1976–1982)	Carols	CD
A Festival of Lessons and Carols	1979	Sussex carol	Philip Ledger (1976–1982)	Carols	CD
A Festival of Lessons and Carols	1979	Joseph and Mary	Philip Ledger (1976–1982)	Carols	CD
A Festival of Lessons and Carols	1979	A maiden most gentle	Philip Ledger (1976–1982)	Carols	CD
A Festival of Lessons and Carols	1979	Chester carol	Philip Ledger (1976–1982)	Carols	CD
A Festival of Lessons and Carols	1979	Angels from the realms of glory	Philip Ledger (1976–1982)	Carols	CD
A Festival of Lessons and Carols	1979	A babe is born	Philip Ledger (1976–1982)	Carols	CD
Evensong	1981	Preces	Philip Ledger (1976–1982)	Evensong	RB;YT

Album	**Released**	**Song**	**Time/Director**	**Genre**	**Format**
Evensong	1981	Responses	Philip Ledger (1976–1982)	Evensong	RB;YT
Evensong	1981	Final responses	Philip Ledger (1976–1982)	Evensong	RB;YT
Procession with Carols on Advent Sunday	1981	I look afar	Philip Ledger (1976–1982)	Carols	CD
Procession with Carols on Advent Sunday	1981	Come thou redeemer of the earth	Philip Ledger (1976–1982)	Carols	CD
Procession with Carols on Advent Sunday	1981	Drop down ye heavens	Philip Ledger (1976–1982)	Carols	CD
Procession with Carols on Advent Sunday	1981	Up awake and away	Philip Ledger (1976–1982)	Carols	CD
Procession with Carols on Advent Sunday	1981	Twas in the year	Philip Ledger (1976–1982)	Carols	CD
Procession with Carols on Advent Sunday	1981	Cherry tree carol	Philip Ledger (1976–1982)	Carols	CD
Procession with Carols on Advent Sunday	1981	King Jesus hath a garden	Philip Ledger (1976–1982)	Carols	CD
Procession with Carols on Advent Sunday	1981	Gabriel’s message	Philip Ledger (1976–1982)	Carols	CD
Procession with Carols on Advent Sunday	1981	I wonder as I wander	Philip Ledger (1976–1982)	Carols	CD
Procession with Carols on Advent Sunday	1981	Tomorrow shall be my dancing day	Philip Ledger (1976–1982)	Carols	CD
Procession with Carols on Advent Sunday	1981	Judah and Jerusalem fear not	Philip Ledger (1976–1982)	Carols	CD
Orlando Gibbons	1982	Almighty and everlasting God	Philip Ledger (1976–1982)	Evensong	CD
Orlando Gibbons	1982	Magnificat	Philip Ledger (1976–1982)	Evensong	CD
Orlando Gibbons	1982	Nunc dimittis	Philip Ledger (1976–1982)	Evensong	CD
Orlando Gibbons	1982	Now shall the praises	Philip Ledger (1976–1982)	Evensong	CD
Orlando Gibbons	1982	O Lord of hosts	Philip Ledger (1976–1982)	Evensong	CD
Orlando Gibbons	1982	A song of joy	Philip Ledger (1976–1982)	Evensong	CD
Orlando Gibbons	1982	Come kiss me	Philip Ledger (1976–1982)	Evensong	CD
O come all ye faithful	1984	Once in royal David’s city	Stephen Cleobury (1984–2019)	Carols	CD
O come all ye faithful	1984	Up good Christen folk	Stephen Cleobury (1984–2019)	Carols	CD
O come all ye faithful	1984	Sussex carol	Stephen Cleobury (1984–2019)	Carols	CD
O come all ye faithful	1984	Ding dong merrily on high	Stephen Cleobury (1984–2019)	Carols	CD
O come all ye faithful	1984	O little town of Bethlehem	Stephen Cleobury (1984–2019)	Carols	CD
O come all ye faithful	1984	Silent night	Stephen Cleobury (1984–2019)	Carols	CD
O come all ye faithful	1984	In the bleak midwinter	Stephen Cleobury (1984–2019)	Carols	CD
O come all ye faithful	1984	The first nowell	Stephen Cleobury (1984–2019)	Carols	CD

Album	Released	Song	Time/Director	Genre	Format
O come all ye faithful	1984	God rest ye merry gentlemen	Stephen Cleobury (1984–2019)	Carols	CD
O come all ye faithful	1984	The holly and the ivy	Stephen Cleobury (1984–2019)	Carols	CD
The world of favourite hymns	1986	Christ is made the sure foundation	Stephen Cleobury (1984–2019)	Evensong	CD
The world of favourite hymns	1986	When I survey the wondrous cross	Stephen Cleobury (1984–2019)	Evensong	CD
The world of favourite hymns	1986	Praise to the holiest	Stephen Cleobury (1984–2019)	Evensong	CD
The world of favourite hymns	1986	The church’s one foundation	Stephen Cleobury (1984–2019)	Evensong	CD
The world of favourite hymns	1986	Crown him with many crowns	Stephen Cleobury (1984–2019)	Evensong	CD
The world of favourite hymns	1986	Love divine all loves excelling	Stephen Cleobury (1984–2019)	Evensong	CD
The world of favourite hymns	1986	Holy holy holy	Stephen Cleobury (1984–2019)	Evensong	CD
Byrd – The great service	1987	Byrd First Preces	Stephen Cleobury (1984–2019)	Evensong	CD
Byrd – The great service	1987	Byrd Preces	Stephen Cleobury (1984–2019)	Evensong	CD
Byrd – The great service	1987	Byrd Responses	Stephen Cleobury (1984–2019)	Evensong	CD
Byrd – The great service	1987	Collects	Stephen Cleobury (1984–2019)	Evensong	CD
Byrd – The great service	1987	O Lord make thy servant Elizabeth	Stephen Cleobury (1984–2019)	Evensong	CD
Britten A ceremony of carols	1990	Rejoice in the lamb	Stephen Cleobury (1984–2019)	Carols	CD
Britten A ceremony of carols	1990	A boy was born (track 20)	Stephen Cleobury (1984–2019)	Carols	CD
Britten A ceremony of carols	1990	A boy was born (track 23)	Stephen Cleobury (1984–2019)	Carols	CD
Bernstein and Copland	1991	The last invocation	Stephen Cleobury (1984–2019)	Misc	CD
Bernstein and Copland	1991	The unknown region	Stephen Cleobury (1984–2019)	Misc	CD
Bernstein and Copland	1991	To all to each	Stephen Cleobury (1984–2019)	Misc	CD
Bernstein and Copland	1991	In the beginning	Stephen Cleobury (1984–2019)	Misc	CD
Carols from King’s	1991	Once in royal David’s city	Stephen Cleobury (1984–2019)	Carols	CD
Carols from King’s	1991	Sussex carol	Stephen Cleobury (1984–2019)	Carols	CD
Carols from King’s	1991	Jesus Christ the apple tree	Stephen Cleobury (1984–2019)	Carols	CD
Carols from King’s	1991	O little town of Bethlehem	Stephen Cleobury (1984–2019)	Carols	CD
Carols from King’s	1991	It came upon a midnight clear	Stephen Cleobury (1984–2019)	Carols	CD
Carols from King’s	1991	The lamb	Stephen Cleobury (1984–2019)	Carols	CD
Carols from King’s	1991	Gabriel’s message	Stephen Cleobury (1984–2019)	Carols	CD

Album	Released	Song	Time/Director	Genre	Format
Carols from King’s	1991	God rest ye merry gentlemen	Stephen Cleobury (1984–2019)	Carols	CD
Carols from King’s	1991	Infant holy	Stephen Cleobury (1984–2019)	Carols	CD
Carols from King’s	1991	While shepherds watched	Stephen Cleobury (1984–2019)	Carols	CD
Carols from King’s	1991	In the bleak midwinter	Stephen Cleobury (1984–2019)	Carols	CD
Carols from King’s	1991	Tomorrow shall be my dancing day	Stephen Cleobury (1984–2019)	Carols	CD
A celebration of Herbert Howells	1992	Preces	Stephen Cleobury (1984–2019)	Evensong	CD
A celebration of Herbert Howells	1992	Responses	Stephen Cleobury (1984–2019)	Evensong	CD
A celebration of Herbert Howells	1992	Take him earth for cherishing	Stephen Cleobury (1984–2019)	Evensong	CD
Choral Evensong Live	1992	Preces	Stephen Cleobury (1984–2019)	Evensong	CD
Choral Evensong Live	1992	Responses	Stephen Cleobury (1984–2019)	Evensong	CD
Choral Evensong Live	1992	Collects	Stephen Cleobury (1984–2019)	Evensong	CD
Choral Evensong Live	1992	Lord let me know mine end	Stephen Cleobury (1984–2019)	Evensong	CD
Choral Evensong Live	1992	Final responses	Stephen Cleobury (1984–2019)	Evensong	CD
Solstice of light	1992	Hawkship	Stephen Cleobury (1984–2019)	Misc	CD
Solstice of light	1992	What tidings bringest thou	Stephen Cleobury (1984–2019)	Misc	CD
English Anthems	1993	Hail gladdening light	Stephen Cleobury (1984–2019)	Evensong	CD
English Anthems	1993	Faire is the heaven	Stephen Cleobury (1984–2019)	Evensong	CD
English Anthems	1993	Set me as a seal	Stephen Cleobury (1984–2019)	Evensong	CD
Evensong and Vespers	1996	Preces	Stephen Cleobury (1984–2019)	Evensong	CD
Evensong and Vespers	1996	Responses	Stephen Cleobury (1984–2019)	Evensong	CD
Carols from King’s	1997	Alleluya	Stephen Cleobury (1984–2019)	Carols	TV;YT
Carols from King’s	1997	God so loved the world	Stephen Cleobury (1984–2019)	Evensong	TV;YT
Carols from King’s	1997	In the bleak midwinter	Stephen Cleobury (1984–2019)	Carols	TV;YT
Carols from King’s	1997	Once in royal David’s city	Stephen Cleobury (1984–2019)	Carols	TV;YT
Carols from King’s	1997	O little town of Bethlehem	Stephen Cleobury (1984–2019)	Carols	TV;YT
Carols from King’s	1997	The first nowell	Stephen Cleobury (1984–2019)	Carols	TV;YT
Carols from King’s	1997	Up good Christen folk	Stephen Cleobury (1984–2019)	Carols	TV;YT
Carols from King’s	1999	Away in a manger	Stephen Cleobury (1984–2019)	Carols	TV;YT

Album	Released	Song	Time/Director	Genre	Format
Carols from King’s	1999	A spotless rose	Stephen Cleobury (1984–2019)	Carols	TV;YT
Carols from King’s	1999	Gabriel’s message	Stephen Cleobury (1984–2019)	Carols	TV;YT
Carols from King’s	1999	In the bleak midwinter	Stephen Cleobury (1984–2019)	Carols	TV;YT
Carols from King’s	1999	Jesus Christ the apple tree	Stephen Cleobury (1984–2019)	Carols	TV;YT
Carols from King’s	1999	Of one that is	Stephen Cleobury (1984–2019)	Carols	TV;YT
Carols from King’s	1999	Once in royal David’s city	Stephen Cleobury (1984–2019)	Carols	TV;YT
Carols from King’s	1999	Sussex carol	Stephen Cleobury (1984–2019)	Carols	TV;YT
Nine Lessons and Carols	1999	Once in royal David’s city	Stephen Cleobury (1984–2019)	Carols	CD
Nine Lessons and Carols	1999	Up good Christen folk	Stephen Cleobury (1984–2019)	Carols	CD
Nine Lessons and Carols	1999	Herefordshire carol	Stephen Cleobury (1984–2019)	Carols	CD
Nine Lessons and Carols	1999	Adam lay ybounden	Stephen Cleobury (1984–2019)	Carols	CD
Nine Lessons and Carols	1999	Sussex carol	Stephen Cleobury (1984–2019)	Carols	CD
Nine Lessons and Carols	1999	In the bleak midwinter	Stephen Cleobury (1984–2019)	Carols	CD
Nine Lessons and Carols	1999	In dulci jubilo	Stephen Cleobury (1984–2019)	Carols	CD
Nine Lessons and Carols	1999	God rest ye merry gentlemen	Stephen Cleobury (1984–2019)	Carols	CD
Nine Lessons and Carols	1999	A tender shoot	Stephen Cleobury (1984–2019)	Carols	CD
Nine Lessons and Carols	1999	Gabriel’s message	Stephen Cleobury (1984–2019)	Carols	CD
Nine Lessons and Carols	1999	I saw three ships	Stephen Cleobury (1984–2019)	Carols	CD
Best Loved Hymns	2001	Come down O love divine	Stephen Cleobury (1984–2019)	Evensong	CD
Best Loved Hymns	2001	O what their joy	Stephen Cleobury (1984–2019)	Evensong	CD
Best Loved Hymns	2001	When I survey the wondrous cross	Stephen Cleobury (1984–2019)	Evensong	CD
Best Loved Hymns	2001	Be thou my vision	Stephen Cleobury (1984–2019)	Evensong	CD
Best Loved Hymns	2001	My song is love unknown	Stephen Cleobury (1984–2019)	Evensong	CD
Best Loved Hymns	2001	The lord’s my shepherd	Stephen Cleobury (1984–2019)	Evensong	CD
Best Loved Hymns	2001	Thine be the glory	Stephen Cleobury (1984–2019)	Evensong	CD
Best Loved Hymns	2001	Drop drop slow tears	Stephen Cleobury (1984–2019)	Evensong	CD
Carols from King’s	2003	Away in a manger	Stephen Cleobury (1984–2019)	Carols	TV;YT
Carols from King’s	2003	Coventry carol	Stephen Cleobury (1984–2019)	Carols	TV;YT

Album	Released	Song	Time/Director	Genre	Format
Carols from King’s	2003	Ding dong merrily on high	Stephen Cleobury (1984–2019)	Carols	TV;YT
Carols from King’s	2003	Drop drop slow tears	Stephen Cleobury (1984–2019)	Evensong	TV;YT
Carols from King’s	2003	Gabriel’s message	Stephen Cleobury (1984–2019)	Carols	TV;YT
Carols from King’s	2003	God is with us	Stephen Cleobury (1984–2019)	Carols	TV;YT
Carols from King’s	2003	Once in royal David’s city	Stephen Cleobury (1984–2019)	Carols	TV;YT
Carols from King’s	2003	O little town of Bethlehem	Stephen Cleobury (1984–2019)	Carols	TV;YT
Carols from King’s	2003	Shepherd’s carol	Stephen Cleobury (1984–2019)	Carols	TV;YT
Carols from King’s	2003	What sweeter music	Stephen Cleobury (1984–2019)	Carols	TV;YT
On Christmas Day	2005	Shepherd’s carol	Stephen Cleobury (1984–2019)	Carols	CD
On Christmas Day	2005	Christo paremus cantica	Stephen Cleobury (1984–2019)	Carols	CD
On Christmas Day	2005	In wintertime	Stephen Cleobury (1984–2019)	Carols	CD
On Christmas Day	2005	What sweeter music	Stephen Cleobury (1984–2019)	Carols	CD
On Christmas Day	2005	One star at last	Stephen Cleobury (1984–2019)	Carols	CD
On Christmas Day	2005	The birthday of thy king	Stephen Cleobury (1984–2019)	Carols	CD
I heard a voice	2007	When David heard	Stephen Cleobury (1984–2019)	Evensong	CD
A Festival of Lessons and Carols	2008	Once in royal David’s city	Stephen Cleobury (1984–2019)	Carols	CD
A Festival of Lessons and Carols	2008	What sweeter music	Stephen Cleobury (1984–2019)	Carols	CD
A Festival of Lessons and Carols	2008	Infant holy	Stephen Cleobury (1984–2019)	Carols	CD
A Festival of Lessons and Carols	2008	God rest ye merry gentlemen	Stephen Cleobury (1984–2019)	Carols	CD
A Festival of Lessons and Carols	2008	Remember O thou man	Stephen Cleobury (1984–2019)	Carols	CD
A Festival of Lessons and Carols	2008	Adam lay ybounden	Stephen Cleobury (1984–2019)	Carols	CD
A Festival of Lessons and Carols	2008	Angels from the realms of glory	Stephen Cleobury (1984–2019)	Carols	CD
A Festival of Lessons and Carols	2008	Nowell sing ye now	Stephen Cleobury (1984–2019)	Carols	CD
A Festival of Lessons and Carols	2008	The lamb	Stephen Cleobury (1984–2019)	Carols	CD
A Festival of Lessons and Carols	2008	A spotless rose	Stephen Cleobury (1984–2019)	Carols	CD
A Festival of Lessons and Carols	2008	I sing of a maiden	Stephen Cleobury (1984–2019)	Carols	CD
A year at King’s	2010	Away in a manger	Stephen Cleobury (1984–2019)	Carols	CD
A year at King’s	2010	When to the temple	Stephen Cleobury (1984–2019)	Evensong	CD

Album	Released	Song	Time/Director	Genre	Format
A year at King’s	2010	Tis the day of resurrection	Stephen Cleobury (1984–2019)	Evensong	CD
Nine Lessons and Carols	2010–2012	Adam lay ybounden	Stephen Cleobury (1984–2019)	Carols	CD
Nine Lessons and Carols	2010–2012	A tender shoot	Stephen Cleobury (1984–2019)	Carols	CD
Nine Lessons and Carols	2010–2012	A virgin most pure	Stephen Cleobury (1984–2019)	Carols	CD
Nine Lessons and Carols	2010–2012	God rest ye merry gentlemen	Stephen Cleobury (1984–2019)	Carols	CD
Nine Lessons and Carols	2010–2012	Herefordshire carol	Stephen Cleobury (1984–2019)	Carols	CD
Nine Lessons and Carols	2010–2012	Once in royal David’s city	Stephen Cleobury (1984–2019)	Carols	CD
Easter from King’s	2012	Bring us o lord god	Stephen Cleobury (1984–2019)	Evensong	TV;YT
Easter from King’s	2012	Crown of roses	Stephen Cleobury (1984–2019)	Evensong	TV;YT
Easter from King’s	2012	God so loved the world	Stephen Cleobury (1984–2019)	Evensong	TV;YT
Easter from King’s	2012	I sat down under his shadow	Stephen Cleobury (1984–2019)	Evensong	TV;YT
Easter from King’s	2012	This joyful Eastertide	Stephen Cleobury (1984–2019)	Evensong	TV;YT
Easter from King’s	2012	When I survey the wondrous cross	Stephen Cleobury (1984–2019)	Evensong	TV;YT
Favourite Carols from King’s	2014	Once in royal David’s city	Stephen Cleobury (1984–2019)	Carols	CD
Favourite Carols from King’s	2014	Herefordshire carol	Stephen Cleobury (1984–2019)	Carols	CD
Favourite Carols from King’s	2014	Adam lay ybounden	Stephen Cleobury (1984–2019)	Carols	CD
Favourite Carols from King’s	2014	Sussex carol	Stephen Cleobury (1984–2019)	Carols	CD
Favourite Carols from King’s	2014	In dulci jubilo	Stephen Cleobury (1984–2019)	Carols	CD
Favourite Carols from King’s	2014	Joy to the world	Stephen Cleobury (1984–2019)	Carols	CD
Favourite Carols from King’s	2014	Gabriel’s message	Stephen Cleobury (1984–2019)	Carols	CD
Favourite Carols from King’s	2014	The holly and the ivy	Stephen Cleobury (1984–2019)	Carols	CD
Favourite Carols from King’s	2014	O little town of Bethlehem	Stephen Cleobury (1984–2019)	Carols	CD
Favourite Carols from King’s	2014	A spotless rose	Stephen Cleobury (1984–2019)	Carols	CD
Favourite Carols from King’s	2014	Shepherd’s carol	Stephen Cleobury (1984–2019)	Carols	CD
Favourite Carols from King’s	2014	Angels from the realms of glory	Stephen Cleobury (1984–2019)	Carols	CD
Favourite Carols from King’s	2014	In the bleak midwinter	Stephen Cleobury (1984–2019)	Carols	CD
Favourite Carols from King’s	2014	Coventry carol	Stephen Cleobury (1984–2019)	Carols	CD
Favourite Carols from King’s	2014	God rest ye merry gentlemen	Stephen Cleobury (1984–2019)	Carols	CD

Album	Released	Song	Time/Director	Genre	Format
Favourite Carols from King’s	2014	Away in a manger	Stephen Cleobury (1984–2019)	Carols	CD
Hymns from King’s	2016	Thine be the glory	Stephen Cleobury (1984–2019)	Evensong	CD
Hymns from King’s	2016	Alleluya sing to Jesus	Stephen Cleobury (1984–2019)	Evensong	CD
Hymns from King’s	2016	Love divine all loves excelling	Stephen Cleobury (1984–2019)	Evensong	CD
Hymns from King’s	2016	Christians awake	Stephen Cleobury (1984–2019)	Evensong	CD
Hymns from King’s	2016	Abide with me	Stephen Cleobury (1984–2019)	Evensong	CD
Hymns from King’s	2016	As with gladness	Stephen Cleobury (1984–2019)	Evensong	CD
Hymns from King’s	2016	My song is love unknown	Stephen Cleobury (1984–2019)	Evensong	CD
Hymns from King’s	2016	O God our help in ages past	Stephen Cleobury (1984–2019)	Evensong	CD
Hymns from King’s	2016	Just as I am	Stephen Cleobury (1984–2019)	Evensong	CD
Nine Lessons and Carols Centenary	2019	Once in royal David’s city	Stephen Cleobury (1984–2019)	Carols	CD
Nine Lessons and Carols Centenary	2019	Up good Christen folk	Stephen Cleobury (1984–2019)	Carols	CD
Nine Lessons and Carols Centenary	2019	Adam lay ybounden	Stephen Cleobury (1984–2019)	Carols	CD
Nine Lessons and Carols Centenary	2019	Jesus Christ the apple tree	Stephen Cleobury (1984–2019)	Carols	CD
Nine Lessons and Carols Centenary	2019	In dulci jubilo	Stephen Cleobury (1984–2019)	Carols	CD
Nine Lessons and Carols Centenary	2019	Nowell sing we now all and some	Stephen Cleobury (1984–2019)	Carols	CD
Nine Lessons and Carols Centenary	2019	A spotless rose	Stephen Cleobury (1984–2019)	Carols	CD
Nine Lessons and Carols Centenary	2019	The lamb	Stephen Cleobury (1984–2019)	Carols	CD
Nine Lessons and Carols Centenary	2019	In the bleak midwinter	Stephen Cleobury (1984–2019)	Carols	CD
Carols from King’s	2020	Once in royal David’s city	Daniel Hyde (2020–present)	Carols	DD
Carols from King’s	2020	A maiden most gentle	Daniel Hyde (2020–present)	Carols	DD
Carols from King’s	2020	Herefordshire carol	Daniel Hyde (2020–present)	Carols	DD
Carols from King’s	2020	The angel Gabriel	Daniel Hyde (2020–present)	Carols	DD
Carols from King’s	2020	Coventry carol	Daniel Hyde (2020–present)	Carols	DD
Carols from King’s	2020	O little town of Bethlehem	Daniel Hyde (2020–present)	Carols	DD
Carols from King’s	2020	Candlelight carol	Daniel Hyde (2020–present)	Carols	DD

Appendix C

Glasgow post hoc comparison tables

Table C.1: Glasgow: Front vowel F1 model post hoc comparisons

Contrast	Estimate	95% CI	
vowel = FLEECE			
directorPM (1959–1975) – directorHSR (1925–1951)	0.1897	−0.0172	0.4038
directorMJS (1987–2016) – directorHSR (1925–1951)	0.1080	−0.1250	0.3252
directorMJS (1987–2016) – directorPM (1959–1975)	−0.0810	−0.2453	0.1074
vowel = KIT			
directorPM (1959–1975) – directorHSR (1925–1951)	0.1522	−0.0313	0.3518
directorMJS (1987–2016) – directorHSR (1925–1951)	**0.3447**	**0.1477**	**0.5592**
directorMJS (1987–2016) – directorPM (1959–1975)	**0.1925**	**0.0355**	**0.3584**
vowel = DRESS			
directorPM (1959–1975) – directorHSR (1925–1951)	0.1097	−0.1136	0.3298
directorMJS (1987–2016) – directorHSR (1925–1951)	**0.3998**	**0.1635**	**0.6459**
directorMJS (1987–2016) – directorPM (1959–1975)	**0.2925**	**0.0949**	**0.4711**
vowel = TRAP			
directorPM (1959–1975) – directorHSR (1925–1951)	0.0567	−0.1638	0.2636
directorMJS (1987–2016) – directorHSR (1925–1951)	**0.4564**	**0.2154**	**0.6797**
directorMJS (1987–2016) – directorPM (1959–1975)	**0.4023**	**0.2164**	**0.5728**

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

Table C.2: Glasgow: Front vowel F2 model post hoc comparisons

Contrast	Estimate	95% CI	
vowel = FLEECE			
directorPM (1959–1975) – directorHSR (1925–1951)	**−0.1664**	**−0.3047**	**−0.0289**
directorMJS (1987–2016) – directorHSR (1925–1951)	0.1041	−0.0405	0.2496
directorMJS (1987–2016) – directorPM (1959–1975)	**0.2698**	**0.1668**	**0.3881**
vowel = KIT			
directorPM (1959–1975) – directorHSR (1925–1951)	**−0.2079**	**−0.3420**	**−0.0811**
directorMJS (1987–2016) – directorHSR (1925–1951)	**−0.2499**	**−0.3839**	**−0.1161**
directorMJS (1987–2016) – directorPM (1959–1975)	−0.0408	−0.1429	0.0712
vowel = DRESS			
directorPM (1959–1975) – directorHSR (1925–1951)	**−0.2854**	**−0.4294**	**−0.1464**
directorMJS (1987–2016) – directorHSR (1925–1951)	**−0.3266**	**−0.4833**	**−0.1734**
directorMJS (1987–2016) – directorPM (1959–1975)	−0.0399	−0.1620	0.0846
vowel = TRAP			
directorPM (1959–1975) – directorHSR (1925–1951)	**−0.1688**	**−0.3128**	**−0.0345**
directorMJS (1987–2016) – directorHSR (1925–1951)	**−0.3107**	**−0.4643**	**−0.1680**
directorMJS (1987–2016) – directorPM (1959–1975)	**−0.1428**	**−0.2510**	**−0.0207**

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

Table C.3: Glasgow: Back vowel F1 model post hoc comparisons (Vowel:Time/Director by Vowel)

Contrast	Estimate	95% CI	
vowel = BATH			
directorPM (1959–1975) – directorHSR (1925–1951)	−0.1842	−0.4842	0.1167
directorMJS (1987–2016) – directorHSR (1925–1951)	0.0857	−0.2327	0.4181
directorMJS (1987–2016) – directorPM (1959–1975)	**0.2688**	**0.0245**	**0.5224**
vowel = STRUT			
directorPM (1959–1975) – directorHSR (1925–1951)	−0.1477	−0.4477	0.1255
directorMJS (1987–2016) – directorHSR (1925–1951)	0.1747	−0.1439	0.4769
directorMJS (1987–2016) – directorPM (1959–1975)	**0.3221**	**0.0684**	**0.5369**
vowel = LOT			
directorPM (1959–1975) – directorHSR (1925–1951)	0.0770	−0.1915	0.3538
directorMJS (1987–2016) – directorHSR (1925–1951)	0.2727	−0.0223	0.5582
directorMJS (1987–2016) – directorPM (1959–1975)	0.1972	−0.0220	0.4149
vowel = THOUGHT			
directorPM (1959–1975) – directorHSR (1925–1951)	0.0223	−0.2377	0.3042
directorMJS (1987–2016) – directorHSR (1925–1951)	**0.3234**	**0.0559**	**0.6260**
directorMJS (1987–2016) – directorPM (1959–1975)	**0.3024**	**0.0841**	**0.5164**
vowel = FOOT			
directorPM (1959–1975) – directorHSR (1925–1951)	−0.1449	−0.5682	0.2600
directorMJS (1987–2016) – directorHSR (1925–1951)	−0.1168	−0.6021	0.3941
directorMJS (1987–2016) – directorPM (1959–1975)	0.0321	−0.3510	0.4267
vowel = GOOSE			
directorPM (1959–1975) – directorHSR (1925–1951)	−0.0195	−0.3031	0.2636
directorMJS (1987–2016) – directorHSR (1925–1951)	0.0364	−0.2617	0.3445
directorMJS (1987–2016) – directorPM (1959–1975)	0.0573	−0.1712	0.2774

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

Table C.4: Glasgow: Back vowel F1 model post hoc comparisons (Vowel:Time/Director by Time/Director)

Contrast	Estimate	95% CI	
directorHSR (1925–1957)			
BATH – STRUT	0.1936	−0.0342	0.3956
BATH – LOT	**0.5411**	**0.3309**	**0.7426**
LOT – THOUGHT	−0.0650	−0.2422	0.1124
FOOT – GOOSE	0.3007	−0.0688	0.6464
directorPM (1959–1975)			
BATH – STRUT	**0.1550**	**0.0237**	**0.2952**
BATH – LOT	**0.2801**	**0.1461**	**0.4132**
LOT – THOUGHT	−0.0088	−0.1204	0.0952
FOOT – GOOSE	0.1768	−0.0277	0.3942
directorMJS (1987–2016)			
BATH – STRUT	0.1027	−0.0877	0.2934
BATH – LOT	**0.3527**	**0.1775**	**0.5330**
LOT – THOUGHT	−0.1149	−0.2533	0.0235
FOOT – GOOSE	0.1536	−0.1876	0.4765

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

Table C.5: Glasgow: Back vowel F2 model post hoc comparisons (Vowel:Time/Director by Vowel)

Contrast	Estimate	95% CI	
vowel = BATH			
directorPM (1959–1975) – directorHSR (1925–1951)	−0.1246	−0.2777	0.0153
directorMJS (1987–2016) – directorHSR (1925–1951)	**−0.2027**	**−0.3691**	**−0.0460**
directorMJS (1987–2016) – directorPM (1959–1975)	−0.0779	−0.2038	0.0491
vowel = STRUT			
directorPM (1959–1975) – directorHSR (1925–1951)	**−0.1437**	**−0.2825**	**−0.0109**
directorMJS (1987–2016) – directorHSR (1925–1951)	−0.0417	−0.1946	0.1056
directorMJS (1987–2016) – directorPM (1959–1975)	0.1034	−0.0094	0.2144
vowel = LOT			
directorPM (1959–1975) – directorHSR (1925–1951)	−0.0284	−0.1548	0.0965
directorMJS (1987–2016) – directorHSR (1925–1951)	−0.0427	−0.1819	0.0900
directorMJS (1987–2016) – directorPM (1959–1975)	−0.0146	−0.1087	0.0905
vowel = THOUGHT			
directorPM (1959–1975) – directorHSR (1925–1951)	0.0186	−0.1026	0.1408
directorMJS (1987–2016) – directorHSR (1925–1951)	−0.0386	−0.1696	0.0926
directorMJS (1987–2016) – directorPM (1959–1975)	−0.0575	−0.1511	0.0455
vowel = FOOT			
directorPM (1959–1975) – directorHSR (1925–1951)	−0.0741	−0.3109	0.1490
directorMJS (1987–2016) – directorHSR (1925–1951)	−0.1352	−0.4259	0.1458
directorMJS (1987–2016) – directorPM (1959–1975)	−0.0588	−0.2847	0.1679
vowel = GOOSE			
directorPM (1959–1975) – directorHSR (1925–1951)	−0.0323	−0.1656	0.1017
directorMJS (1987–2016) – directorHSR (1925–1951)	0.0691	−0.0708	0.2222
directorMJS (1987–2016) – directorPM (1959–1975)	0.1007	−0.0080	0.2066

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

Table C.6: Glasgow: Back vowel F2 post hoc comparisons (Vowel:Time/Director by Time/Director)

Contrast	Estimate	95% CI	
directorHSR (1925–1951)			
BATH – STRUT	**0.1759**	**0.0398**	**0.3164**
BATH – LOT	**0.4110**	**0.2770**	**0.5441**
LOT – THOUGHT	0.0212	−0.0932	0.1361
FOOT – GOOSE	0.2194	−0.0141	0.4415
directorPM (1959–1975)			
BATH – STRUT	**0.1951**	**0.1053**	**0.2818**
BATH – LOT	**0.3154**	**0.2347**	**0.4023**
LOT – THOUGHT	−0.0258	−0.0957	0.0426
FOOT – GOOSE	**0.1764**	**0.0377**	**0.3118**
directorMJS (1987–2016)			
BATH – STRUT	0.0135	−0.1031	0.1378
BATH – LOT	**0.2524**	**0.1354**	**0.3613**
LOT – THOUGHT	0.0182	−0.0712	0.1102
FOOT – GOOSE	0.0157	−0.1984	0.2272

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

Table C.7: Glasgow: TRAP–BATH F1 model post hoc comparisons (Vowel:Time/Director by Vowel)

Contrast	Estimate	95% CI	
directorHSR (1925–1951)			
BATH – TRAP	0.1324	−0.1108	0.3665
directorPM (1959–1975)			
BATH – TRAP	−0.1130	−0.2856	0.0725
directorMJS (1987–2016)			
BATH – TRAP	−0.1793	−0.4063	0.0363

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

Table C.8: Glasgow: TRAP–BATH F1 model post hoc comparisons (Vowel:Time/Director by Time/Director)

Contrast	Estimate	95% CI	
vowel = BATH			
directorPM (1959–1975) – directorHSR (1925–1951)	−0.1650	−0.5283	0.1813
directorMJS (1987–2016) – directorHSR (1925–1951)	0.1390	−0.2344	0.5431
directorMJS (1987–2016) – directorPM (1959–1975)	**0.3086**	**0.0061**	**0.6017**
vowel = TRAP			
directorPM (1959–1975) – directorHSR (1925–1951)	0.0783	-0.2215	0.4144
directorMJS (1987–2016) – directorHSR (1925–1951)	**0.4517**	**0.0989**	**0.7798**
directorMJS (1987–2016) – directorPM (1959–1975)	**0.3745**	**0.1117**	**0.6480**

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

Table C.9: Glasgow: TRAP–BATH F2 model post hoc comparisons (Vowel:Time/Director by Time/Director)

Contrast	Estimate	95% CI	
directorHSR (1925–1951)			
BATH – TRAP	**−0.3918**	**−0.5137**	**−0.2586**
directorPM (1959–1975)			
BATH – TRAP	**−0.3833**	**−0.4854**	**−0.2851**
directorMJS (1987–2016)			
BATH – TRAP	**−0.2580**	**−0.3869**	**−0.1406**

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

Table C.10: Glasgow: TRAP–BATH F2 model post hoc comparisons (Vowel:Time/Director by Vowel)

Contrast	Estimate	95% CI	
vowel = BATH			
directorPM (1959–1975) – directorHSR (1925–1951)	−0.1249	−0.2937	0.0431
directorMJS (1987–2016) – directorHSR (1925–1951)	−0.1647	−0.3445	0.0108
directorMJS (1987–2016) – directorPM (1959–1975)	−0.0387	−0.1745	0.0998
vowel = TRAP			
directorPM (1959–1975) – directorHSR (1925–1951)	−0.1333	−0.2808	0.0069
directorMJS (1987–2016) – directorHSR (1925–1951)	**−0.2967**	**−0.4492**	**−0.1497**
directorMJS (1987–2016) – directorPM (1959–1975)	**−0.1649**	**−0.2753**	**−0.0392**

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

Table C.11: Glasgow: Vowel duration model post hoc comparisons by Time/Director

Contrast	Estimate	95% CI	
directorPM (1959–1975) – directorHSR (1925–1951)	−0.0797	−0.1984	0.0428
directorMJS (1987–2016) – directorHSR (1925–1951)	**−0.1950**	**−0.3288**	**−0.0552**
directorMJS (1987–2016) – directorPM (1959–1975)	**−0.1155**	**−0.2199**	**−0.0121**

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

Table C.12: Glasgow: Duration model post hoc comparisons by Vowel

Contrast	Estimate	95% CI	
FLEECE – KIT	**0.6518**	**0.5566**	**0.7479**
TRAP – BATH	**−0.2248**	**−0.3864**	**−0.0593**
BATH – STRUT	**0.2238**	**0.0568**	**0.3965**
BATH – LOT	0.1172	−0.0485	0.2751
LOT – THOUGHT	−0.0326	−0.1767	0.1174
FOOT – GOOSE	**−0.2926**	**−0.5009**	**−0.0864**

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

Table C.13: Glasgow: Duration model post hoc comparisons by Genre

Contrast	Estimate	95% CI	
Other Popular – Church Music	**−0.3428**	**−0.5471**	**−0.1494**
Scottish Vernacular – Church Music	**−0.2682**	**−0.4652**	**−0.0518**
Scottish Vernacular – Other Popular	0.0755	−0.1519	0.2901

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

Appendix D

Following Segment

Initially, Following Segment was included as a factor with up to 26 levels for each model. However, I decided to collapse some factor levels, leading to 15 levels in most models. The reason that I decided to model the front vowel and back vowel sets separately stems from a contrary effect of Following Segment. That is, Following Segment seemed to have opposing effects on front and back vowels. In addition, certain consonants are restricted in following certain vowels. For example, it is comparatively very rare for back vowels to be followed by /g, b, z/ in English. Tables D.1 and D.2, summarise the effects of Following Segment for the Glasgow front vowel formant models. Tables D.3 and D.4 summarise the effects of Following Segment for the Glasgow back vowel formant models. The impact of Following Segment will vary by vowel height. However, not all vowels are followed by all consonants, so I thought including the interaction Vowel:FollowingSegment would overfit the model.

The following Tables are to give an idea of the effects that Following Segment can have on vowels in choral singing. If you wish to inspect the effect reported in each model, you can download the models and the code from the OSF.

Table D.1: Glasgow front vowel F1 model: Following Segment

	Estimate	95% CI	
Intercept	−0.05	−0.14	0.04
followingSeg_/p, b/	−0.08	−0.22	0.07
followingSeg_/f, v/	−0.07	−0.23	0.10
followingSeg_/m/	−0.03	−0.11	0.05
followingSeg_/θ/	**0.11**	**0.01**	**0.21**
followingSeg_/ð/	−0.03	−0.21	0.15
followingSeg_/t/	−0.10	−0.29	0.09
followingSeg_/d/	0.11	−0.01	0.23
followingSeg_/s, ʃ, z/	−0.01	−0.10	0.09
followingSeg_/l/	−0.11	−0.23	0.02
followingSeg_/k, g/	0.02	−0.07	0.11
followingSeg_/n/	0.05	−0.04	0.15
followingSeg_/ŋ/	**−0.08**	**−0.15**	**−0.00**
followingSeg_/d͡ʒ, t͡ʃ, j/	0.08	−0.06	0.22
followingSeg_/w/	−0.05	−0.16	0.06
followingSeg_/r/	**0.14**	**0.03**	**0.25**

Bold type indicates 0 outside 95% credible interval.

Table D.2: Glasgow front vowel F2 model: Following Segment

	Estimate	95% CI	
Intercept	**0.64**	**0.59**	**0.70**
followingSeg_/p, b/	**0.09**	**0.00**	**0.17**
followingSeg_/f, v/	0.03	−0.07	0.13
followingSeg_/m/	0.00	−0.05	0.05
followingSeg_/θ/	**−0.09**	**−0.16**	**−0.02**
followingSeg_/ð/	−0.07	−0.21	0.08
followingSeg_/t/	−0.11	−0.24	0.01
followingSeg_/d/	−0.06	−0.13	0.02
followingSeg_/s, ʃ, z/	0.06	−0.01	0.13
followingSeg_/l/	0.03	−0.05	0.11
followingSeg_/k, g/	−0.00	−0.06	0.06
followingSeg_/n/	**0.15**	**0.09**	**0.21**
followingSeg_/ŋ/	0.05	−0.00	0.10
followingSeg_/d͡ʒ, t͡ʃ, j/	0.08	−0.00	0.17
followingSeg_/w/	0.00	−0.08	0.09
followingSeg_/r/	**−0.26**	**−0.32**	**−0.19**

Bold type indicates 0 outside 95% credible interval.

Table D.3: Glasgow back vowel F1 model: Following Segment

	Estimate	95% CI	
Intercept	0.11	−0.00	0.23
followingSeg_/p/	**0.21**	**0.00**	**0.42**
followingSeg_/v, f/	−0.00	−0.17	0.18
followingSeg_/m/	0.01	−0.07	0.09
followingSeg_/θ/	−0.02	−0.14	0.11
followingSeg_/ð/	0.00	−0.26	0.27
followingSeg_/t/	−0.02	−0.22	0.19
followingSeg_/d/	−0.03	−0.14	0.08
followingSeg_/s, ʃ/	−0.05	−0.15	0.04
followingSeg_/l/	0.08	−0.04	0.20
followingSeg_/k/	−0.06	−0.17	0.05
followingSeg_/n/	**0.24**	**0.02**	**0.45**
followingSeg_/ŋ/	**−0.12**	**−0.21**	**−0.04**
followingSeg_/t͡ʃ, j/	−0.05	−0.19	0.08
followingSeg_/w/	−0.14	−0.32	0.04
followingSeg_/r/	0.05	−0.06	0.17

Bold type indicates 0 outside 95% credible interval.

Table D.4: Glasgow back vowel F2 model: Following Segment

	Estimate	95% CI	
Intercept	**−0.99**	**−1.04**	**−0.93**
followingSeg_/p/	−0.05	−0.18	0.09
followingSeg_/v, f/	−0.01	−0.13	0.10
followingSeg_/m/	**0.06**	**0.00**	**0.11**
followingSeg_/θ/	0.03	−0.06	0.11
followingSeg_/ð/	0.02	−0.16	0.20
followingSeg_/t/	−0.07	−0.20	0.06
followingSeg_/d/	−0.06	−0.13	0.02
followingSeg_/s, ʃ/	−0.01	−0.07	0.06
followingSeg_/l/	0.03	−0.05	0.10
followingSeg_/k/	−0.03	−0.11	0.04
followingSeg_/n/	0.02	−0.12	0.17
followingSeg_/ŋ/	−0.01	−0.06	0.05
followingSeg_/t͡ʃ, j/	0.02	−0.07	0.11
followingSeg_/w/	−0.01	−0.12	0.10
followingSeg_/r/	0.07	−0.01	0.14

Bold type indicates 0 outside 95% credible interval.

Appendix E

King's post hoc comparison tables

Post hoc comparisons were calculated using the package `emmeans` (Lenth, 2021) in R. Tables were exported in Latex using the package `xtable` (Dahl et al., 2019).

Table E.1: King's: Front vowel F1 model post hoc comparisons

Contrast	Estimate	95% CI	
vowel = FLEECE			
directorDW (1959–1974) – directorBO (1945–1958)	**−0.3458**	**−0.6005**	**−0.1014**
directorPL (1976–1982) – directorBO (1945–1958)	−0.1768	−0.4526	0.0980
directorPL (1976–1982) – directorDW (1959–1974)	0.1685	−0.0833	0.4096
directorSC (1984–2019) – directorBO (1945–1958)	−0.0717	−0.2939	0.1672
directorSC (1984–2019) – directorDW (1959–1974)	**0.2747**	**0.0880**	**0.4612**
directorSC (1984–2019) – directorPL (1976–1982)	0.1047	−0.1163	0.3329
vowel = KIT			
directorDW (1959–1974) – directorBO (1945–1958)	**−0.4617**	**−0.7136**	**−0.2355**
directorPL (1976–1982) – directorBO (1945–1958)	−0.2522	−0.5146	0.0125
directorPL (1976–1982) – directorDW (1959–1974)	0.2103	−0.0224	0.4514
directorSC (1984–2019) – directorBO (1945–1958)	−0.1103	−0.3294	0.1138
directorSC (1984–2019) – directorDW (1959–1974)	**0.3534**	**0.1698**	**0.5240**
directorSC (1984–2019) – directorPL (1976–1982)	0.1414	−0.0719	0.3631
vowel = DRESS			
directorDW (1959–1974) – directorBO (1945–1958)	**−0.5914**	**−0.8507**	**−0.3396**
directorPL (1976–1982) – directorBO (1945–1958)	−0.2703	−0.5501	0.0102
directorPL (1976–1982) – directorDW (1959–1974)	**0.3235**	**0.0783**	**0.5842**
directorSC (1984–2019) – directorBO (1945–1958)	0.1597	−0.0673	0.3985
directorSC (1984–2019) – directorDW (1959–1974)	**0.7534**	**0.5641**	**0.9414**
directorSC (1984–2019) – directorPL (1976–1982)	**0.4284**	**0.1888**	**0.6535**
vowel = TRAP			
directorDW (1959–1974) – directorBO (1945–1958)	**−0.4613**	**−0.7212**	**−0.2178**
directorPL (1976–1982) – directorBO (1945–1958)	−0.2688	−0.5408	0.0130
directorPL (1976–1982) – directorDW (1959–1974)	0.1918	−0.0537	0.4447
directorSC (1984–2019) – directorBO (1945–1958)	0.1143	−0.1104	0.3487
directorSC (1984–2019) – directorDW (1959–1974)	**0.5759**	**0.3908**	**0.7636**
directorSC (1984–2019) – directorPL (1976–1982)	**0.3830**	**0.1653**	**0.6222**

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

Table E.2: King's: Front vowel F2 model post hoc comparisons

Contrast	Estimate	95% CI	
vowel = FLEECE			
directorDW (1959–1974) – directorBO (1945–1958)	−0.1036	−0.3485	0.1583
directorPL (1976–1982) – directorBO (1945–1958)	−0.1065	−0.3876	0.1724
directorPL (1976–1982) – directorDW (1959–1974)	−0.0026	−0.2622	0.2519
directorSC (1984–2019) – directorBO (1945–1958)	0.1231	−0.1130	0.3548
directorSC (1984–2019) – directorDW (1959–1974)	**0.2294**	**0.0318**	**0.4118**
directorSC (1984–2019) – directorPL (1976–1982)	**0.2332**	**0.0027**	**0.4608**
vowel = KIT			
directorDW (1959–1974) – directorBO (1945–1958)	0.1804	−0.0588	0.4261
directorPL (1976–1982) – directorBO (1945–1958)	0.1562	−0.0959	0.4393
directorPL (1976–1982) – directorDW (1959–1974)	−0.0229	−0.2659	0.2265
directorSC (1984–2019) – directorBO (1945–1958)	**0.2889**	**0.0668**	**0.5174**
directorSC (1984–2019) – directorDW (1959–1974)	0.1117	−0.0774	0.2872
directorSC (1984–2019) – directorPL (1976–1982)	0.1336	−0.0882	0.3557
vowel = DRESS			
directorDW (1959–1974) – directorBO (1945–1958)	0.0712	−0.1820	0.3274
directorPL (1976–1982) – directorBO (1945–1958)	0.0341	−0.2487	0.3192
directorPL (1976–1982) – directorDW (1959–1974)	−0.0354	−0.2991	0.2198
directorSC (1984–2019) – directorBO (1945–1958)	0.0358	−0.1958	0.2816
directorSC (1984–2019) – directorDW (1959–1974)	−0.0345	−0.2263	0.1594
directorSC (1984–2019) – directorPL (1976–1982)	0.0021	−0.2398	0.2317
vowel = TRAP			
directorDW (1959–1974) – directorBO (1945–1958)	−0.0247	−0.2672	0.2373
directorPL (1976–1982) – directorBO (1945–1958)	−0.2134	−0.4919	0.0702
directorPL (1976–1982) – directorDW (1959–1974)	−0.1881	−0.4461	0.0705
directorSC (1984–2019) – directorBO (1945–1958)	**−0.2620**	**−0.4901**	**−0.0233**
directorSC (1984–2019) – directorDW (1959–1974)	**−0.2348**	**−0.4263**	**−0.0468**
directorSC (1984–2019) – directorPL (1976–1982)	−0.0473	−0.2843	0.1751

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

Table E.3: King's: Back vowel F1 model post hoc comparisons

Contrast	Estimate	95% CI	
vowel = BATH			
directorDW (1959–1974) – directorBO (1945–1958)	**−0.4672**	**−0.7176**	**−0.2086**
directorPL (1976–1982) – directorBO (1945–1958)	**−0.3739**	**−0.6582**	**−0.0857**
directorPL (1976–1982) – directorDW (1959–1974)	0.0937	−0.1599	0.3553
directorSC (1984–2019) – directorBO (1945–1958)	−0.0465	−0.2765	0.1883
directorSC (1984–2019) – directorDW (1959–1974)	**0.4212**	**0.2263**	**0.6105**
directorSC (1984–2019) – directorPL (1976–1982)	**0.3254**	**0.0937**	**0.5554**
vowel = STRUT			
directorDW (1959–1974) – directorBO (1945–1958)	**−0.3469**	**−0.5781**	**−0.0964**
directorPL (1976–1982) – directorBO (1945–1958)	**−0.2776**	**−0.5362**	**−0.0039**
directorPL (1976–1982) – directorDW (1959–1974)	0.0691	−0.1707	0.3077
directorSC (1984–2019) – directorBO (1945–1958)	0.0419	−0.1766	0.2553
directorSC (1984–2019) – directorDW (1959–1974)	**0.3882**	**0.2130**	**0.5655**
directorSC (1984–2019) – directorPL (1976–1982)	**0.3175**	**0.1029**	**0.5362**
vowel = LOT			
directorDW (1959–1974) – directorBO (1945–1958)	**−0.4657**	**−0.7041**	**−0.2332**
directorPL (1976–1982) – directorBO (1945–1958)	**−0.3313**	**−0.6105**	**−0.0850**
directorPL (1976–1982) – directorBO (1959–1974)	0.1334	−0.0925	0.3659
directorSC (1984–2019) – directorBO (1945–1958)	0.0292	−0.1902	0.2360
directorSC (1984–2019) – directorDW (1959–1974)	**0.4942**	**0.3213**	**0.6605**
directorSC (1984–2019) – directorPL (1976–1982)	**0.3598**	**0.1525**	**0.5716**
vowel = THOUGHT			
directorDW (1959–1974) – directorBO (1945–1958)	**−0.4227**	**−0.6578**	**−0.1824**
directorPL (1976–1982) – directorBO (1945–1958)	**−0.2651**	**−0.5209**	**−0.0028**
directorPL (1976–1982) – directorDW (1959–1974)	0.1588	−0.0833	0.3809
directorSC (1984–2019) – directorBO (1945–1958)	0.1998	−0.0259	0.4103
directorSC (1984–2019) – directorDW (1959–1974)	**0.6216**	**0.4446**	**0.7913**
directorSC (1984–2019) – directorPL (1976–1982)	**0.4633**	**0.2469**	**0.6648**
vowel = FOOT			
directorDW (1959–1974) – directorBO (1945–1958)	**−0.4727**	**−0.7962**	**−0.1320**
director PL (1976–1982) – directorBO (1945–1958)	−0.0146	−0.3691	0.3373
directorPL (1976–1982) – directorDW (1959–1974)	**0.4571**	**0.1394**	**0.7734**
directorSC (1984–2019) – directorBO (1945–1958)	−0.1939	−0.4924	0.1016
directorSC (1984–2019) – directorPL (1959–1974)	**0.2790**	**0.0222**	**0.5139**
directorSC (1984–2019) – directorPL (1976–1982)	−0.1799	−0.4539	0.1101

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

Table E.4: King's: Back vowel F1 model post hoc comparisons

Contrast	Estimate	95% CI	
director = Boris Ord (1945–1958)			
STRUT – BATH	−0.1423	−0.3129	0.0141
THOUGHT – LOT	**−0.4991**	**−0.6537**	**−0.3550**
FOOT – GOOSE	0.2102	−0.0434	0.4669
director = David Willcocks (1959–1974)			
STRUT – BATH	−0.0219	−0.1630	0.1215
THOUGHT – LOT	**−0.4573**	**−0.5806**	**−0.3267**
FOOT – GOOSE	−0.0015	−0.2077	0.2143
director = Philip Ledger (1976–1982)			
STRUT – BATH	−0.0467	−0.2142	0.1220
THOUGHT – LOT	**−0.4325**	**−0.5750**	**−0.2970**
FOOT – GOOSE	**0.2929**	**0.0575**	**0.5210**
director = Stephen Cleobury (1984–2019)			
STRUT – BATH	−0.0551	−0.1821	0.0684
THOUGHT – LOT	**−0.3287**	**−0.4476**	**−0.2186**
FOOT – GOOSE	**0.2178**	**0.0362**	**0.389**

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

Table E.5: King's: Back vowel F2 model post hoc comparisons

Contrast	Estimate	95% CI	
vowel = BATH			
directorDW (1959–1974) – directorBO (1945–1958)	**−0.1657**	**−0.3038**	**−0.0386**
directorPL (1976–1982) – directorBO (1945–1958)	−0.0483	−0.1928	0.0933
directorPL (1976–1982) – directorDW (1959–1974)	0.1179	−0.0186	0.2512
directorSC (1984–2019) – directorBO (1945–1958)	−0.0262	−0.1460	0.0908
directorSC (1984–2019) – directorDW (1959–1974)	**0.1408**	**0.0390**	**0.2447**
directorSC (1984–2019) – directorPL (1976–1982)	0.0228	−0.0968	0.1415
vowel = STRUT			
directorDW (1959–1974) – directorBO (1945–1958)	−0.0823	−0.2030	0.0326
directorPL (1976–1982) – directorBO (1945–1958)	0.0047	−0.1265	0.1327
directorPL (1976–1982) – directorDW (1959–1974)	0.0871	−0.0295	0.2021
directorSC (1984–2019) – directorBO (1945–1958)	0.0567	−0.0500	0.1609
directorSC (1984–2019) – directorDW (1959–1974)	**0.1395**	**0.0535**	**0.2279**
directorSC (1984–2019) – directorPL (1976–1982)	0.0516	−0.0537	0.1583
vowel = LOT			
directorDW (1959–1974) – directorBO (1945–1958)	**−0.1532**	**−0.2683**	**−0.0390**
directorPL (1976–1982) – directorBO (1945–1958)	**−0.1337**	**−0.2592**	**−0.0128**
directorPL (1976–1982) – directorDW (1959–1974)	0.0192	−0.0921	0.1248
directorSC (1984–2019) – directorBO (1945–1958)	−0.0020	−0.1047	0.0991
directorSC (1984–2019) – directorDW (1959–1974)	**0.1512**	**0.0679**	**0.2327**
directorSC (1984–2019) – directorPL (1976–1982)	**0.1317**	**0.0366**	**0.2307**
vowel = THOUGHT			
directorDW (1959–1974) – directorBO (1945–1958)	−0.0078	−0.1284	0.1025
directorPL (1976–1982) – directorBO (1945–1958)	0.0289	−0.1006	0.1496
directorPL (1976–1982) – directorDW (1959–1974)	0.0365	−0.0676	0.1524
directorSC (1984–2019) – directorBO (1945–1958)	**0.1606**	**0.0557**	**0.2638**
directorSC (1984–2019) – directorDW (1959–1974)	**0.1679**	**0.0839**	**0.2521**
directorSC (1984–2019) – directorPL (1976–1982)	**0.1318**	**0.0370**	**0.2323**
vowel = FOOT			
directorDW (1959–1974) – directorBO (1945–1958)	**−0.2867**	**−0.4751**	**−0.0908**
directorPL (1976–1982) – directorBO (1945–1958)	**−0.0719**	**−0.2751**	**0.1303**
directorPL (1976–1982) – directorDW (1959–1974)	**0.2135**	**0.0369**	**0.3959**
directorSC (1984–2019) – directorBO (1945–1958)	0.0287	−0.1441	0.2002
directorSC (1984–2019) – directorDW (1959–1974)	**0.3149**	**0.1711**	**0.4547**
directorSC (1984–2019) – directorPL (1976–1982)	0.1008	−0.0516	0.2601
vowel = GOOSE			
directorDW (1959–1974) – directorBO (1945–1958)	**−0.1437**	**−0.2690**	**−0.0168**
directorPL (1976–1982) – directorBO (1945–1958)	−0.0350	−0.1759	0.1020
directorPL (1976–1982) – directorDW (1959–1974)	0.1083	−0.0102	0.2298
directorSC (1984–2019) – directorBO (1945–1958)	0.0720	−0.0418	0.1843
directorSC (1984–2019) – directorDW (1959–1974)	**0.2154**	**0.1282**	**0.3050**
directorSC (1984–2019) – directorPL (1976–1982)	**0.1071**	**0.0016**	**0.2161**

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

Table E.6: King's: Back vowel F2 model post hoc comparisons

Contrast	Estimate	95% CI	
director = Boris Ord 1945–1958			
STRUT – BATH	0.0332	−0.0737	0.1406
THOUGHT – LOT	**−0.2722**	**−0.3733**	**−0.1758**
FOOT – GOOSE	0.0782	−0.0879	0.2479
director = David Willcocks 1959–1974			
STRUT – BATH	**0.1169**	**0.0269**	**0.2121**
THOUGHT – LOT	**−0.1261**	**−0.2090**	**−0.0430**
FOOT – GOOSE	−0.0638	−0.2039	0.0698
director = Philip Ledger 1976–1982			
STRUT – BATH	0.0867	−0.0237	0.1972
THOUGHT – LOT	−0.1095	−0.2021	−0.0193
FOOT – GOOSE	0.0413	−0.1093	0.1880
director = Stephen Cleobury 1984–2019			
STRUT – BATH	**0.1160**	**0.0354**	**0.1956**
THOUGHT – LOT	**−0.1096**	**−0.1842**	**−0.0336**
FOOT – GOOSE	0.0357	−0.0784	0.1552

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

Table E.7: King's: TRAP–BATH F1 model post hoc comparisons

Contrast	Estimate	95% CI	
vowel = BATH			
directorDW (1959–1974) – directorBO (1945–1958)	**−0.5181**	**−0.8574**	**−0.1636**
directorPL (1976–1982) – directorBO (1945–1958)	**−0.4392**	**−0.8281**	**−0.0586**
directorPL (1976–1982) – directorDW (1959–1974)	0.0799	−0.2628	0.4313
directorSC (1984–2019) – directorBO (1945–1958)	−0.1083	−0.4137	0.2235
directorSC (1984–2019) – directorDW (1959–1974)	**0.4109**	**0.1519**	**0.6643**
directorSC (1984–2019) – directorPL (1976–1982)	**0.3296**	**0.0271**	**0.6522**
vowel = TRAP			
directorDW (1959–1974) – directorBO (1945–1958)	**−0.5080**	**−0.8229**	**−0.1840**
directorPL (1976–1982) – directorBO (1945–1958)	−0.3505	−0.7078	0.0085
directorPL (1976–1982) – directorDW (1959–1974)	0.1564	−0.1666	0.4667
directorSC (1984–2019) – directorBO (1945–1958)	0.0539	−0.2426	0.3455
directorSC (1984–2019) – directorDW (1959–1974)	**0.5604**	**0.3290**	**0.7961**
directorSC (1984–2019) – directorPL (1976–1982)	**0.4034**	**0.1255**	**0.6894**

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

Table E.8: King's: TRAP–BATH F2 model post hoc pairwise comparisons

Contrast	Estimate	95% CI	
vowel = BATH			
directorDW (1959–1974) – directorBO (1945–1958)	−0.1531	−0.3478	0.0260
directorPL (1976–1982) – directorBO (1945–1958)	0.0086	−0.1937	0.2225
directorPL (1976–1982) – directorDW (1959–1974)	0.1606	−0.0264	0.3522
directorSC (1984–2019) – directorBO (1945–1958)	−0.0142	−0.1797	0.1644
directorSC (1984–2019) – directorDW (1959–1974)	0.1383	−0.0036	0.2804
directorSC (1984–2019) – directorPL (1976–1982)	−0.0220	−0.1933	0.1525
vowel = TRAP			
directorDW (1959–1974) – directorBO (1945–1958)	−0.0245	−0.2020	0.1444
directorPL (1976–1982) – directorBO (1945–1958)	**−0.2436**	**−0.4355**	**−0.0517**
directorPL (1976–1982) – directorDW (1959–1974)	**−0.2181**	**−0.3840**	**−0.0442**
directorSC (1984–2019) – directorBO (1945–1958)	**−0.2361**	**−0.3952**	**−0.0819**
directorSC (1984–2019) – directorDW (1959–1974)	**−0.2126**	**−0.3388**	**−0.0867**
directorSC (1984–2019) – directorPL (1976–1982)	0.0055	−0.1517	0.1572

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

Table E.9: King's: Duration model post hoc comparisons by Vowel

Contrast	Estimate	95% CI	
FLEECE – KIT	**0.3755**	**0.3021**	**0.4458**
KIT – STRUT	**−0.2869**	**−0.3720**	**−0.1984**
KIT – FOOT	**0.0207**	**−0.1356**	**0.1683**
KIT – SCHWA	**0.3135**	**0.2615**	**0.3684**
DRESS – TRAP	0.0379	−0.0561	0.1406
TRAP – BATH	**−0.3506**	**−0.4706**	**−0.2287**
TRAP – STRUT	0.0100	−0.1027	0.1305
TRAP – FOOT	**0.3139**	**0.1431**	**0.4865**
TRAP – SCHWA	**0.6093**	**0.5091**	**0.7051**
BATH – STRUT	**0.3588**	**0.2459**	**0.4742**
BATH – LOT	**0.2033**	**0.0827**	**0.3305**
STRUT – FOOT	**0.3064**	**0.1444**	**0.4733**
STRUT – SCHWA	**0.5993**	**0.5063**	**0.6899**
LOT – THOUGHT	−0.0574	−0.1892	0.0670
THOUGHT – GOOSE	**0.2763**	**0.1475**	**0.4128**
FOOT – GOOSE	**−0.2444**	**−0.4235**	**−0.0645**
FOOT – SCHWA	**0.2929**	**0.1451**	**0.4552**

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

Table E.10: King's: Duration model post hoc comparisons by Time/Director

Contrast	Estimate	95% CI	
directorDW (1959–1974) – directorBO (1945–1958)	0.0063	−0.2141	0.2185
directorPL (1976–1982) – directorBO (1945–1958)	−0.0420	−0.2887	0.1920
directorPL (1976–1982) – directorDW (1959–1974)	−0.0459	−0.2667	0.1638
directorSC (1984–2019) – directorBO (1945–1958)	0.0228	−0.1691	0.2075
directorSC (1984–2019) – directorDW (1959–1974)	0.0205	−0.1355	0.1849
directorSC (1984–2019) – directorPL (1976–1982)	0.0673	−0.1275	0.2511

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

Appendix F

Combined post hoc comparison tables

Table F.1: Combined: Front vowel F1 model post hoc comparisons, Vowel by Time/Director

Contrast	Estimate	95% CI	
vowel = FLEECE			
directorBO (1945–1958) – directorHSR (1925–1951)	**0.3189**	**0.0101**	**0.6140**
directorBO (1945–1958) – directorPM (1959–1975)	0.0293	−0.2156	0.2663
directorBO (1945–1958) – directorMJS (1987–2016)	0.0636	−0.1989	0.3332
directorDW (1959–1974) – directorHSR (1925–1951)	0.0047	−0.2725	0.2709
directorDW (1959–1974) – directorPM (1959–1975)	**−0.2836**	**−0.4958**	**−0.0849**
directorDW (1959–1974)) – directorMJS (1987–2016)	**−0.2494**	**−0.4853**	**−0.0174**
directorPL (1976–1982) – directorHSR (1925–1951)	0.1499	−0.1530	0.4617
directorPL (1976–1982) – directorPM (1959–1975)	−0.1383	−0.3882	0.1113
directorPL (1976–1982) – directorMJS (1987–2016)	−0.1053	−0.3695	0.1713
directorSC (1984–2019) – directorHSR (1925–1951)	**0.2888**	**0.0315**	**0.5445**
directorSC (1984–2019) – directorPM (1959–1975)	−0.0012	−0.1869	0.1948
directorSC (1984–2019) – directorMJS (1987–2016)	0.0335	−0.1773	0.2587
vowel = KIT			
directorBO (1945–1958) – directorHSR (1925–1951)	**0.3037**	**0.0304**	**0.5918**
directorBO (1945–1958) – directorPM (1959–1975)	0.1537	−0.0810	0.3770
directorBO (1945–1958) – directorMJS (1987–2016)	−0.0424	−0.2849	0.2127
directorDW (1959–1974) – directorHSR (1925–1951)	−0.1309	−0.3695	0.1260
directorDW (1959–1974) – directorPM (1959–1975)	**−0.2815**	**−0.4692**	**−0.0814**
directorDW (1959–1974) – directorMJS (1987–2016)	**−0.4775**	**−0.6868**	**−0.2568**
directorPL (1976–1982) – directorHSR (1925–1951)	0.0540	−0.2350	0.3376
directorPL (1976–1982) – directorPM (1959–1975)	−0.0959	−0.3365	0.1395
directorPL (1976–1982) – directorMJS (1987–2016)	**−0.2923**	**−0.5454**	**−0.0341**
directorSC (1984–2019) – directorHSR (1925–1951)	0.2309	−0.0161	0.4604
directorSC (1984–2019) – directorPM (1959–1975)	0.0810	−0.0984	0.2547
directorSC (1984–2019) – directorMJS (1987–2016)	−0.1146	−0.3158	0.0830
vowel = DRESS			
directorBO (1945–1958) – directorHSR (1925–1951)	0.1645	−0.1524	0.4597
directorBO (1945–1958) – directorPM (1959–1975)	0.0150	−0.2326	0.2570
directorBO (1945–1958) – directorMJS (1987–2016)	**−0.3668**	**−0.6333**	**−0.0902**
directorDW (1959–1974) – directorHSR (1925–1951)	**−0.3987**	**−0.6821**	**−0.1337**
directorDW (1959–1974) – directorPM (1959–1975)	**−0.5464**	**−0.7513**	**−0.3401**
directorDW (1959–1974) – directorMJS (1987–2016)	**−0.9307**	**−1.1690**	**−0.6846**
directorPL (1976–1982) – directorHSR (1925–1951)	−0.1074	−0.4129	0.2104
directorPL (1976–1982) – directorPM (1959–1975)	**−0.2524**	**−0.5117**	**−0.0043**
directorPL (1976–1982) – directorMJS (1987–2016)	**−0.6387**	**−0.9171**	**−0.3564**
directorSC (1984–2019) – directorHSR (1925–1951)	**0.3574**	**0.1008**	**0.6256**
directorSC (1984–2019) – directorPM (1959–1975)	**0.2102**	**0.0215**	**0.4016**
directorSC (1984–2019) – directorMJS (1987–2016)	−0.1743	−0.3980	0.0471
vowel = TRAP			
directorBO (1945–1958) – directorHSR (1925–1951)	**0.3867**	**0.0876**	**0.6868**
directorBO (1945–1958) – directorPM (1959–1975)	**0.2415**	**0.0044**	**0.4910**
directorBO (1945–1958) – directorMJS (1987–2016)	−0.1887	−0.4616	0.0710
directorDW (1959–1974) – directorHSR (1925–1951)	−0.0480	−0.3175	0.2160

Contrast	Estimate	95% CI	
directorDW (1959–1974) – directorPM (1959–1975)	−0.1908	−0.3990	0.0118
directorDW (1959–1974) – directorMJS (1987–2016)	**−0.6224**	**−0.8517**	**−0.3900**
directorPL (1976–1982) – directorHSR (1925–1951)	0.1237	−0.1804	0.4316
directorPL (1976–1982) – directorPM (1959–1975)	−0.0186	−0.2730	0.2308
directorPL (1976–1982) – directorMJS (1987–2016)	**−0.4518**	**−0.7259**	**−0.1864**
directorSC (1984–2019) – directorHSR (1925–1951)	**0.5384**	**0.2922**	**0.8006**
directorSC (1984–2019) – directorPM (1959–1975)	**0.3955**	**0.2029**	**0.5773**
directorSC (1984–2019) – directorMJS (1987–2016)	−0.0362	−0.2467	0.1810

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

Table F.2: Combined: Front vowel F2 model post hoc comparisons, Vowel by Time/Director

Contrast	Estimate	95% CI	
vowel = FLEECE			
directorBO (1945–1958) – directorHSR (1925–1951)	**−0.2944**	**−0.5794**	**−0.0257**
directorBO (1945–1958) – directorPM (1959–1975)	**−0.0977**	**−0.3183**	**0.1273**
directorBO (1945–1958) – directorMJS (1987–2016)	**−0.3091**	**−0.5525**	**−0.0727**
directorDW (1959–1974) – directorHSR (1925–1951)	**−0.3791**	**−0.6338**	**−0.1293**
directorDW (1959–1974) – directorPM (1959–1975)	−0.1822	−0.3734	0.0062
directorDW (1959–1974) – directorMJS (1987–2016)	**−0.3935**	**−0.6042**	**−0.1836**
directorPL (1976–1982) – directorHSR (1925–1951)	**−0.4029**	**−0.6993**	**−0.1285**
directorPL (1976–1982) – directorPM (1959–1975)	−0.2047	−0.4348	0.0234
directorPL (1976–1982) – directorMJS (1987–2016)	**−0.4170**	**−0.6615**	**−0.1732**
directorSC (1984–2019) – directorHSR (1925–1951)	−0.1470	−0.3890	0.0903
directorSC (1984–2019) – directorPM (1959–1975)	0.0504	−0.1210	0.2244
directorSC (1984–2019) – directorMJS (1987–2016)	−0.1612	−0.3463	0.0340
vowel = KIT			
directorBO (1945–1958) – directorHSR (1925–1951)	**−0.6095**	**−0.8725**	**−0.3455**
directorBO (1945–1958) – directorPM (1959–1975)	**−0.3989**	**−0.6088**	**−0.1844**
directorBO (1945–1958) – directorMJS (1987–2016)	**−0.3912**	**−0.6163**	**−0.1639**
directorDW (1959–1974) – directorHSR (1925–1951)	**−0.4041**	**−0.6397**	**−0.1645**
directorDW (1959–1974) – directorPM (1959–1975)	**−0.1940**	**−0.3751**	**−0.0129**
directorDW (1959–1974) – directorMJS (1987–2016)	−0.1852	−0.3886	0.0091
directorPL (1976–1982) – directorHSR (1925–1951)	**−0.4410**	**−0.7087**	**−0.1649**
directorPL (1976–1982) – directorPM (1959–1975)	**−0.2312**	**−0.4435**	**−0.0056**
directorPL (1976–1982) – directorMJS (1987–2016)	−0.2238	−0.4548	0.0127
directorSC (1984–2019) – directorHSR (1925–1951)	**−0.2902**	**−0.5099**	**−0.0648**
directorSC (1984–2019) – directorPM (1959–1975)	−0.0808	−0.2395	0.0869
directorSC (1984–2019) – directorMJS (1987–2016)	−0.0712	−0.2518	0.1021
vowel = DRESS			
directorBO (1945–1958) – directorHSR (1925–1951)	−0.1855	−0.4643	0.0999
directorBO (1945–1958) – directorPM (1959–1975)	0.0936	−0.1332	0.3187
directorBO (1945–1958) – directorMJS (1987–2016)	0.1492	−0.0910	0.4021
directorDW (1959–1974) – directorHSR (1925–1951)	−0.0925	−0.3568	0.1562
directorDW (1959–1974) – directorPM (1959–1975)	0.1867	−0.0048	0.3798
directorDW (1959–1974) – directorMJS (1987–2016)	**0.2433**	**0.0221**	**0.4555**
directorPL (1976–1982) – directorHSR (1925–1951)	−0.1454	−0.4329	0.1504
directorPL (1976–1982) – directorPM (1959–1975)	0.1347	−0.0980	0.3682
directorPL (1976–1982) – directorMJS (1987–2016)	0.1904	−0.0608	0.4440
directorSC (1984–2019) – directorHSR (1925–1951)	−0.1262	−0.3685	0.1179
directorSC (1984–2019) – directorPM (1959–1975)	0.1547	−0.0113	0.3416
directorSC (1984–2019) – directorMJS (1987–2016)	**0.2107**	**0.0180**	**0.4114**
vowel = TRAP			
directorBO (1945–1958) – directorHSR (1925–1951)	−0.1385	−0.4252	0.1301
directorBO (1945–1958) – directorPM (1959–1975)	0.0520	−0.1670	0.2784
directorBO (1945–1958) – directorMJS (1987–2016)	0.1864	−0.0398	0.4434
directorDW (1959–1974) – directorHSR (1925–1951)	−0.1385	−0.3821	0.1220

Contrast	Estimate	95% CI	
directorDW (1959–1974) – directorPM (1959–1975)	0.0530	−0.1385	0.2440
directorDW (1959–1974) – directorMJS (1987–2016)	0.1881	−0.0118	0.4096
directorPL (1976–1982) – directorHSR (1925–1951)	**−0.3475**	**−0.6234**	**−0.0615**
directorPL (1976–1982) – directorPM (1959–1975)	−0.1569	−0.3887	0.0696
directorPL (1976–1982) – directorMJS (1987–2016)	−0.0217	−0.2662	0.2227
directorSC (1984–2019) – directorHSR (1925–1951)	**−0.3691**	**−0.5916**	**−0.1195**
directorSC (1984–2019) – directorPM (1959–1975)	**−0.1791**	**−0.3463**	**−0.0055**
directorSC (1984–2019) – directorMJS (1987–2019)	−0.0419	−0.2355	0.1393

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

Table F.3: Combined: Back vowel F1 post hoc comparisons, Vowel by Time/Director

Contrast	Estimate	95% CI	
vowel = BATH			
directorBO (1945–1958) – directorHSR (1925–1957)	0.1492	−0.1734	0.4960
directorBO (1945–1958) – directorPM (1959–1975)	0.2561	−0.0065	0.5266
directorBO (1945–1958) – directorMJS (1987–2016)	−0.0364	−0.3494	0.2564
directorDW (1959–1974) – directorHSR (1925–1951)	−0.3014	−0.6040	0.0045
directorDW (1959–1974) – directorPM (1959–1975)	−0.1935	−0.4255	0.0426
directorDW (1959–1974) – directorMJS (1987–2016)	**−0.4870**	**−0.7612**	**−0.2163**
directorPL (1976–1982) – directorHSR (1925–1951)	−0.2275	−0.5659	0.1166
directorPL (1976–1982) – directorPM (1959–1975)	−0.1206	−0.4062	0.1590
directorPL (1976–1982) – directorMJS (1987–2016)	**−0.4123**	**−0.7286**	**−0.0977**
directorSC (1984–2019) – directorHSR (1925–1951)	0.1242	−0.1644	0.4051
directorSC (1984–2019) – directorPM (1959–1975)	**0.2323**	**0.0220**	**0.4433**
directorSC (1984–2019) – directorMJS (1987–2016)	−0.0603	−0.3111	0.1951
vowel = STRUT			
directorBO (1945–1958) – directorHSR (1925–1951)	0.0459	−0.2781	0.3789
directorBO (1945–1958) – directorPM (1959–1975)	0.2165	−0.0372	0.4736
directorBO (1945–1958) – directorMJS (1987–2016)	−0.1257	−0.4006	0.1623
directorDW (1959–1974) – directorHSR (1925–1951)	−0.2646	−0.5547	0.0406
directorDW (1959–1974) – directorPM (1959–1975)	−0.0953	−0.3117	0.1234
directorDW (1959–1974) – directorMJS (1987–2016)	**−0.4376**	**−0.6827**	**−0.1929**
directorPL (1976–1982) – directorHSR (1925–1951)	−0.2192	−0.5575	0.1072
directorPL (1976–1982) – directorPM (1959–1975)	−0.0489	−0.3195	0.2046
directorPL (1976–1982) – directorMJS (1987–2016)	**−0.3924**	**−0.6829**	**−0.1116**
directorSC (1984–2019) – directorHSR (1925–1951)	0.1334	−0.1500	0.4087
directorSC (1984–2019) – directorPM (1959–1975)	**0.3045**	**0.1170**	**0.5066**
directorSC (1984–2019) – directorMJS (1987–2016)	−0.0372	−0.2641	0.1902
vowel = LOT			
directorBO (1945–1958) – directorHSR (1925–1951)	0.0553	−0.2484	0.3754
directorBO (1945–1958) – directorPM (1959–1975)	0.1019	−0.1479	0.3510
directorBO (1945–1958) – directorMJS (1987–2016)	−0.2553	−0.5119	0.0286
directorDW (1959–1974) – directorHSR (1925–1951)	**−0.3759**	**−0.6514**	**−0.1058**
directorDW (1959–1974) – directorPM (1959–1975)	**−0.3322**	**−0.5488**	**−0.1268**
directorDW (1959–1974) – directorMJS (1987–2016)	**−0.6884**	**−0.9169**	**−0.4523**
directorPL (1976–1982) – directorHSR (1925–1951)	−0.2616	−0.5655	0.0579
directorPL (1976–1982) – directorPM (1959–1975)	−0.2184	−0.4855	0.0336
directorPL (1976–1982) – directorMJS (1987–2016)	**−0.5724**	**−0.8550**	**−0.3113**
directorSC (1984–2019) – directorHSR (1925–1951)	0.1350	−0.1174	0.3976
directorSC (1984–2019) – directorPM (1959–1975)	0.1823	−0.0123	0.3708
directorSC (1984–2019) – directorMJS (1987–2016)	−0.1769	−0.3864	0.0440
vowel = THOUGHT			
directorBO (1945–1958) – directorHSR (1925–1951)	**−0.3094**	**−0.6424**	**−0.0077**
directorBO (1945–1958) – directorPM (1959–1975)	**−0.3494**	**−0.5971**	**−0.1022**
directorBO (1945–1958) – directorMJS (1987–2016)	**−0.5912**	**−0.8600**	**−0.3225**

Contrast	Estimate	95% CI	
directorDW (1959–1974) – directorHSR (1925–1951)	**−0.6909**	**−0.9746**	**−0.4003**
directorDW (1959–1974) – directorPM (1959–1975)	**−0.7312**	**−0.9496**	**−0.5253**
directorDW (1959–1974) – directorMJS (1987–2016)	**−0.9733**	**−1.2038**	**−0.7393**
directorPL (1976–1982) – directorHSR (1925–1951)	**−0.5575**	**−0.8805**	**−0.2432**
directorPL (1976–1982) – directorPM (1959–1975)	**−0.5964**	**−0.8584**	**−0.3438**
directorPL (1976–1982) – directorMJS (1987–2016)	**−0.8413**	**−1.1062**	**−0.5631**
directorSC (1984–2019) – directorHSR (1925–1951)	−0.0553	−0.3323	0.2109
directorSC (1984–2019) – directorPM (1959–1975)	−0.0954	−0.2880	0.0923
directorSC (1984–2019) – directorMJS (1987–2016)	**−0.3369**	**−0.5547**	**−0.1215**
vowel = FOOT			
directorBO (1945–1958) – directorHSR (1925–1951)	−0.0001	−0.4710	0.4504
directorBO (1945–1958) – directorPM (1959–1975)	0.1022	−0.2257	0.4661
directorBO (1945–1958) – directorMJS (1987–2016)	−0.0730	−0.5090	0.3530
directorDW (1959–1974) – directorHSR (1925–1951)	**−0.4533**	**−0.8805**	**−0.0283**
directorDW (1959–1974) – directorPM (1959–1975)	**−0.3539**	**−0.6562**	**−0.0547**
directorDW (1959–1974) – directorMJS (1987–2016)	**−0.5266**	**−0.9278**	**−0.1363**
directorPL (1976–1982) – directorHSR (1925–1951)	−0.0235	−0.4595	0.4375
directorPL (1976–1982) – directorPM (1959–1975)	0.0794	−0.2569	0.4258
directorPL (1976–1982) – directorMJS (1987–2016)	**−0.0953**	**−0.5341**	**0.3267**
directorSC (1984–2019) – directorHSR (1925–1951)	−0.1660	−0.5558	0.2355
directorSC (1984–2019) – directorPM (1959–1975)	−0.0672	−0.3320	0.2096
directorSC (1984–2019) – directorMJS (1987–2016)	−0.2399	−0.6055	0.1409
vowel = GOOSE			
directorBO (1945–1958) – directorHSR (1925–1951)	0.1265	−0.1912	0.4660
directorBO (1945–1958) – directorPM (1959–1975)	0.1658	−0.1006	0.4272
directorBO (1945–1958) – directorMJS (1987–2016)	0.0928	−0.1927	0.3804
directorDW (1959–1974) – directorHSR (1925–1951)	−0.0840	−0.3764	0.2072
directorDW (1959–1974) – directorPM (1959–1975)	−0.0452	−0.2591	0.1743
directorDW (1959–1974) – directorMJS (1987–2016)	−0.1161	−0.3703	0.1206
directorPL (1976–1982) – directorHSR (1925–1951)	0.0512	−0.2649	0.3933
directorPL (1976–1982) – directorPM (1959–1975)	0.0891	−0.1824	0.3539
directorPL (1976–1982) – directorMJS (1987–2016)	0.0177	−0.2609	0.3153
directorSC (1984–2019) – directorHSR (1925–1951)	−0.0184	−0.2928	0.2527
directorSC (1984–2019) – directorPM (1959–1975)	0.0210	−0.1696	0.2260
directorSC (1984–2019) – directorMJS (1987–2016)	−0.0512	−0.2810	0.1809

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

Table F.4: Combined: Back vowel F2 post hoc comparisons, Vowel by Time/Director

Contrast	Estimate	95% CI	
vowel = BATH			
directorBO (1945–1958) – directorHSR (1925–1951)	**−0.1899**	**−0.3621**	**−0.0148**
directorBO (1945–1958) – directorPM (1959–1975)	−0.0759	−0.2158	0.0663
directorBO (1945–1958) – directorMJS (1987–2016)	0.0238	−0.1402	0.1841
directorDW (1959–1974) – directorHSR (1925–1951)	**−0.3537**	**−0.5125**	**−0.1896**
directorDW (1959–1974) – directorPM (1959–1975)	**−0.2398**	**−0.3615**	**−0.1133**
directorDW (1959–1974) – directorMJS (1987–2016)	−0.1402	−0.2855	0.0102
directorPL (1976–1982) – directorHSR (1925–1951)	**−0.2247**	**−0.3946**	**−0.0399**
directorPL (1976–1982) – directorPM (1959–1975)	−0.1114	−0.2566	0.0336
directorPL (1976–1982) – directorMJS (1987–2016)	−0.0115	−0.1842	0.1494
directorSC (1984–2019) – directorHSR (1925–1951)	**−0.1974**	**−0.3437**	**−0.0458**
directorSC (1984–2019) – directorPM (1959–1975)	−0.0836	−0.1949	0.0319
directorSC (1984–2019) – directorMJS (1987–2016)	0.0155	−0.1152	0.1592
vowel = STRUT			
directorBO (1945–1958) – directorHSR (1925–1951)	−0.0130	−0.1898	0.1478
directorBO (1945–1958) – directorPM (1959–1975)	**0.1618**	**0.0388**	**0.2897**
directorBO (1945–1958) – directorMJS (1987–2016)	0.0709	−0.0720	0.2151
directorDW (1959–1974) – directorHSR (1925–1951)	−0.1066	−0.2584	0.0473
directorDW (1959–1974) – directorPM (1959–1975)	0.0676	−0.0364	0.1778
directorDW (1959–1974) – directorMJS (1987–2016)	−0.0223	−0.1572	0.0998
directorPL (1976–1982) – directorHSR (1925–1951)	−0.0113	−0.1808	0.1540
directorPL (1976–1982) – directorPM (1959–1975)	**0.1639**	**0.0380**	**0.2902**
directorPL (1976–1982) – directorMJS (1987–2016)	0.0735	−0.0663	0.2222
directorSC (1984–2019) – directorHSR (1925–1951)	0.0324	−0.1117	0.1806
directorSC (1984–2019) – directorPM (1959–1975)	**0.2072**	**0.1093**	**0.3074**
directorSC (1984–2019) – directorMJS (1987–2016)	0.1166	−0.0013	0.2376
vowel = LOT			
directorBO (1945–1958) – directorHSR (1925–1951)	−0.0465	−0.1984	0.1009
directorBO (1945–1958) – directorPM (1959–1975)	0.0323	−0.0957	0.1512
directorBO (1945–1958) – directorMJS (1987–2016)	0.0668	−0.0710	0.1935
directorDW (1959–1974) – directorHSR (1925–1951)	**−0.2004**	**−0.3380**	**−0.0701**
directorDW (1959–1974) – directorPM (1959–1975)	**−0.1230**	**−0.2258**	**−0.0203**
directorDW (1959–1974) – directorMJS (1987–2016)	−0.0878	−0.2044	0.0248
directorPL (1976–1982) – directorHSR (1925–1951)	**−0.1693**	**−0.3196**	**−0.0253**
directorPL (1976–1982) – directorPM (1959–1975)	−0.0921	−0.2133	0.0270
directorPL (1976–1982) – directorMJS (1987–2016)	−0.0574	−0.1907	0.0711
directorSC (1984–2019) – directorHSR (1925–1951)	−0.0387	−0.1642	0.0889
directorSC (1984–2019) – directorPM (1959–1975)	0.0389	−0.0557	0.1343
directorSC (1984–2019) – directorMJS (1987–2016)	0.0729	−0.0309	0.1827
vowel = THOUGHT			
directorBO (1945–1958) – directorHSR (1925–1951)	**−0.2380**	**−0.4012**	**−0.0847**
directorBO (1945–1958) – directorPM (1959–1975)	**−0.2174**	**−0.3415**	**−0.0930**
directorBO (1945–1958) – directorMJS (1987–2016)	**−0.1816**	**−0.3220**	**−0.0509**
directorDW (1959–1974) – directorHSR (1925–1951)	**−0.2449**	**−0.3799**	**−0.0982**

Contrast	Estimate	95% CI	
directorDW (1959–1974) – directorPM (1959–1975)	**−0.2244**	**−0.3273**	**−0.1227**
directorDW (1959–1974) – directorMJS (1987–2016)	**−0.1874**	**−0.3055**	**−0.0741**
directorPL (1976–1982) – directorHSR (1925–1951)	**−0.1994**	**−0.3565**	**−0.0430**
directorPL (1976–1982) – directorPM (1959–1975)	**−0.1790**	**−0.3019**	**−0.0585**
directorPL (1976–1982) – directorMJS (1987–2016)	**−0.1415**	**−0.2806**	**−0.0111**
directorSC (1984–2019) – directorHSR (1925–1951)	−0.0631	−0.1973	0.0753
directorSC (1984–2019) – directorPM (1959–1975)	−0.0422	−0.1405	0.0507
directorSC (1984–2019) – directorMJS (1987–2016)	−0.0051	−0.1177	0.1048
vowel = FOOT			
directorBO (1945–1958) – directorHSR (1925–1951)	0.1641	−0.1067	0.4305
directorBO (1945–1958) – directorPM (1959–1975)	**0.2247**	**0.0252**	**0.4340**
directorBO (1945–1958) – directorMJS (1987–2016)	0.2362	−0.0344	0.4954
directorDW (1959–1974) – directorHSR (1925–1951)	−0.1357	−0.3811	0.1175
directorDW (1959–1974) – directorPM (1959–1975)	−0.0759	−0.2478	0.1020
directorDW (1959–1974) – directorMJS (1987–2016)	−0.0630	−0.3132	0.1774
directorPL (1976–1982) – directorHSR (1925–1951)	0.0822	−0.1870	0.3392
directorPL (1976–1982) – directorPM (1959–1975)	0.1419	−0.0526	0.3338
directorPL (1976–1982) – directorMJS (1987–2016)	0.1526	−0.0960	0.4138
directorSC (1984–2019) – directorHSR (1925–1951)	0.1797	−0.0596	0.4165
directorSC (1984–2019) – directorPM (1959–1975)	**0.2394**	**0.0801**	**0.3990**
directorSC (1984–2019) – directorMJS (1987–2016)	**0.2515**	**0.0099**	**0.4755**
vowel = GOOSE			
directorBO (1945–1958) – directorHSR (1925–1951)	**0.2326**	**0.0609**	**0.4025**
directorBO (1945–1958) – directorPM (1959–1975)	**0.3163**	**0.1767**	**0.4502**
directorBO (1945–1958) – directorMJS (1987–2016)	**0.1777**	**0.0265**	**0.3283**
directorDW (1959–1974) – directorHSR (1925–1951)	0.0820	−0.0707	0.2288
directorDW (1959–1974) – directorPM (1959–1975)	**0.1658**	**0.0515**	**0.2705**
directorDW (1959–1974) – directorMJS (1987–2016)	0.0270	−0.1038	0.1527
directorPL (1976–1982)) – directorHSR (1925–1951)	**0.2061**	**0.0348**	**0.3651**
directorPL (1976–1982) – directorPM (1959–1975)	**0.2886**	**0.1494**	**0.4158**
directorPL (1976–1982) – directorMJS (1987–2016)	0.1495	−0.0018	0.2921
directorSC (1984–2019) – directorHSR (1925–1951)	**0.3052**	**0.1650**	**0.4482**
directorSC (1984–2019) – directorPM (1959–1975)	**0.3884**	**0.2867**	**0.4893**
directorSC (1984–2019) – directorMJS (1987–2016)	**0.2502**	**0.1330**	**0.3727**

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

Table F.5: Combined: TRAP–BATH F1 model post hoc comparisons, Vowel by Time/Director

Contrast	Estimate	95% CI	
vowel = BATH			
directorBO (1945–1958) – directorHSR (1925–1951)	0.2488	−0.1566	0.6671
directorBO (1945–1958) – directorPM (1959–1975)	0.2454	−0.1000	0.5686
directorBO (1945–1958) – directorMJS (1987–2016)	−0.0866	−0.4684	0.2755
directorDW (1959–1974) – directorHSR (1925–1951)	−0.2322	−0.5998	0.1581
directorDW (1959–1974) – directorPM (1959–1975)	−0.2367	−0.5181	0.0574
directorDW (1959–1974) – directorMJS (1987–2016)	**−0.5652**	**−0.9091**	**−0.2430**
directorPL (1976–1982) – directorHSR (1925–1951)	−0.1876	−0.6389	0.2342
directorPL (1976–1982) – directorPM (1959–1975)	−0.1934	−0.5415	0.1669
directorPL (1976–1982) – directorMJS (1987–2016)	**−0.5262**	**−0.9001**	**−0.1215**
directorSC (1984–2019) – directorHSR (1925–1951)	0.1949	−0.1470	0.5776
directorSC (1984–2019) – directorPM (1959–1975)	0.1925	−0.0762	0.4604
directorSC (1984–2019) – directorMJS (1987–2016)	−0.1399	−0.4529	0.1700
vowel = TRAP			
directorBO (1945–1958) – directorHSR (1925–1951)	0.3626	−0.0181	0.7427
directorBO (1945–1958) – directorPM (1959–1975)	0.2116	−0.0872	0.5279
directorBO (1945–1958) – directorMJS (1987–2016)	−0.2105	−0.5359	0.1315
directorDW (1959–1974) – directorHSR (1925–1951)	−0.1146	−0.4510	0.2295
directorDW (1959–1974) – directorPM (1959–1975)	**−0.2635**	**−0.5277**	**−0.0057**
directorDW (1959–1974) – directorMJS (1987–2016)	**−0.6864**	**−0.9819**	**−0.4033**
directorPL (1976–1982) – directorHSR (1925–1951)	0.0145	−0.3696	0.4182
directorPL (1976–1982) – directorPM (1959–1975)	−0.1336	−0.4696	0.1724
directorPL (1976–1982) – directorMJS (1987–2016)	**−0.5570**	**−0.9158**	**−0.2220**
directorSC (1984–2019) – directorHSR (1925–1951)	**0.4813**	**0.1512**	**0.8017**
directorSC (1984–2019) – directorPM (1959–1975)	**0.3308**	**0.0967**	**0.5669**
directorSC (1984–2019) – directorMJS (1987–2016)	−0.0912	−0.3694	0.1739

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

Table F.6: Combined: TRAP–BATH F2 model post hoc comparisons, Vowel by Time/Director

Contrast	Estimate	95% CI	
vowel = BATH			
directorBO (1945–1958) – directorHSR (1925–1951)	**−0.2521**	**−0.4701**	**−0.0194**
directorBO (1945–1958) – directorPM (1959–1975)	−0.1144	−0.2949	0.0660
directorBO (1945–1958) – directorMJS (1987–2016)	−0.0401	−0.2413	0.1614
directorDW (1959–1974) – directorHSR (1925–1951)	**−0.3895**	**−0.5900**	**−0.1815**
directorDW (1959–1974) – directorPM (1959–1975)	**−0.2517**	**−0.4077**	**−0.0945**
directorDW (1959–1974) – directorMJS (1987–2016)	**−0.1774**	**−0.3640**	**−0.0039**
directorPL (1976–1982) – directorHSR (1925–1951)	**−0.2430**	**−0.4685**	**−0.0059**
directorPL (1976–1982) – directorPM (1959–1975)	−0.1052	−0.2987	0.0822
directorPL (1976–1982) – directorMJS (1987–2016)	−0.0301	−0.2329	0.1827
directorSC (1984–2019) – directorHSR (1925–1951)	**−0.2473**	**−0.4397**	**−0.0556**
directorSC (1984–2019) – directorPM (1959–1975)	−0.1100	−0.2511	0.0333
directorSC (1984–2019) – directorMJS (1987–2016)	−0.0348	−0.1996	0.1306
vowel = TRAP			
directorBO (1945–1958) – directorHSR (1925–1951)	−0.0906	−0.2882	0.1174
directorBO (1945–1958) – directorPM (1959–1975)	0.0839	−0.0755	0.2506
directorBO (1945–1958) – directorMJS (1987–2016)	**0.2360**	**0.0532**	**0.4071**
directorDW (1959–1974) – directorHSR (1925–1951)	−0.1047	−0.2848	0.0767
directorDW (1959–1974) – directorPM (1959–1975)	0.0713	−0.0660	0.2074
directorDW (1959–1974) – directorMJS (1987–2016)	**0.2224**	**0.0700**	**0.3776**
directorPL (1976–1982) – directorHSR (1925–1951)	**−0.3360**	**−0.5408**	**−0.1289**
directorPL (1976–1982) – directorPM (1959–1975)	−0.1606	−0.3346	0.0004
directorPL (1976–1982) – directorMJS (1987–2016)	−0.0089	−0.1922	0.1707
directorSC (1984–2019) – directorHSR (1925–1951)	**−0.3177**	**−0.4901**	**−0.1552**
directorSC (1984–2019) – directorPM (1959–1975)	**−0.1424**	**−0.2649**	**−0.0194**
directorSC (1984–2019) – directorMJS (1987–2016)	0.0088	−0.1305	0.1495

Point estimate displayed: median

Bold type indicates 0 outside 95% credible interval.

Appendix G

Praat Script for extracting FOOT–GOOSE formants

```
#author: Jane Stuart-Smith
#date: 15 August 09; revised 9 September 10, revised 9 November 2011; revised 17 November 2011; revised 26 Jan 16; revised 7 June; revised 20 June 17
#Praat version: 5.0.06; edited 5.0.32; edited 5.1.01; 5.3.53; 5.3.56

#How to use this script:

#put all your sound files and textgrids into the same folder (it should be empty except for those files)
#be sure that your sound files d textgrids have exactly the same names as each other, bar the extension (.wav, .TextGrid)
#copy the script file into the same folder

#open Praat
#close the picture window
#in Praat objects, go to Praat, open script...
#using the browse window, find the script file and click Open
#the script will appear in the window
#Go to Run, and click Run
#this will bring up a window summarizing what the script needs to know to run on your data,
#you need to type in the output filename you want, being sure to end it as a .csv file (this means comma separated, and can
#be opened in Excel)

#check that the tier numbers are correct for your tiers
#click OK

#the program will automatically run through your textgrid file, pulling out all the entries, and putting them into the .csv
# file you have specified
#the script will finish by itself, and the Praat Info window will have appeared, listing all the data which has been extracted

#Tip: you must have s, or something else (a letter) in the slabel_tier intervals, otherwise the script will ignore them and move
#on to the next filled interval. Basically it searches for intervals that have a 'string' (letter(s)) in them, and then carries
#operations on the ones which are filled.
#Tip: IMPORTANT - You must have specified your spectrogram settings to ensure the appropriate spectrum will be taken (e.g. 10ms Hamming window)
#Tip: don't use IPA symbols, or spaces before text, in the intervals that you want Praat to work with; the script will crash
#Tip: avoid spaces in filenames. Use _ instead


form Edward GOOSE script
word sound_extension .wav
word textGrid_extension .TextGrid
comment output file will be created in same directory as sound files
comment type in name of output file (must end in .csv)
text filename [add here].csv
comment enter tier number which segments u (= 'U')
natural label_tier 4
comment enter tier number which contains word (= 'word')
natural word_tier 3
endform

clearinfo

# we need to set up the frame of the columns for the output csv file here

fileappend "'filename$'" soundfile, word, vowel, vowelstart, vowelend, F1, F2, F3, F4, resonance, flag 'newline$'
```

```
mySounds = Create Strings as file list... sounds *'sound_extension$'
nSounds = Get number of strings

for iSound to nSounds
select mySounds
sound$ = Get string... iSound

name$ = sound$ - sound_extension$
printline 'name$'

textGrid$ = name$ + textGrid_extension$

mySound = Read from file... 'sound$'
myTextGrid = Read from file... 'textGrid$'

select myTextGrid

ninterval = Get number of intervals: label_tier
printline 'ninterval'

for iinterval to ninterval

interval$ = Get label of interval... label_tier iinterval
if interval$ = "U"
vowel$ = Get label of interval... label_tier iinterval
vowelstart = Get start time of interval... label_tier iinterval
  vowelend = Get end time of interval... label_tier iinterval
wordInterval = Get interval at time... word_tier vowelstart
word$ = Get label of interval... word_tier wordInterval

#select myTextGrid
plus mySound
Edit
editor: myTextGrid
Select... vowelstart vowelend
View spectral slice
endeditor

Edit
endeditor
mySpectrum = LPC smoothing: 24, 50

        Edit
editor: mySpectrum
Zoom: 0, 5000

pause
f1 = Get cursor

pause
f2 = Get cursor

pause
f3 = Get cursor

pause
f4 = Get cursor

pause
resonance = Get cursor

pause
flag = Get cursor
endeditor

fileappend "'filename$'" 'sound$', 'word$', 'vowel$', 'vowelstart:3', 'vowelend:3', 'f1:0', 'f2:0', 'f3:0', 'f4:0',
        'resonance:0', 'flag:0' 'newline$'
removeObject: mySpectrum
removeObject: mySound
endif

select myTextGrid

endfor

endfor
```