Glottalisation as a cue to coda consonant voicing in Australian English: A change in progress

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Abstract

Although the presence of glottalisation has long been noted in other varieties of English, its presence has only been described recently for Australian English (AusE) and it remains an under-researched phenomenon in this variety. We report on an apparent time study designed to examine glottalisation as a cue to coda stop voicing in AusE and to determine whether there is any evidence of recent change. We analysed the temporal aspects of voiced and voiceless rhymes in the speech of younger (18-36 years, n = 36) and older (56+ years, n = 31) groups of male and female speakers. As a baseline, we analysed words in the standard hVt and hVd frame. The results show that glottalisation primarily occurs preceding voiceless codas, as is common in other varieties of English, that female speakers are more likely to employ glottalisation than male speakers, and that younger speakers are more likely to employ glottalisation than older speakers. There is also evidence that younger speakers may exhibit a reduced voicing-related vowel duration effect. These findings raise questions about the weighting of glottalisation and vowel duration as cues to coda stop voicing and suggest a change in progress regarding the management of the syllable rhyme.

Declaration

I hereby declare that this thesis has not been submitted for a higher degree to any other university or institution. I have made every effort to clearly indicate the sources of information used and acknowledge the extent to which the work of others has been used in the text. The research presented in this thesis has been approved by the Macquarie University Faculty of Human Sciences Research Ethics Sub-Committee (ref: 5201300619).

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1. Thesis overview

1.1 Motivation

Glottalisation serves as a cue to coda stop voicing in a number of varieties of English, including many dialects of British English (BrE) and American English (AmE)(Foulkes & Docherty, 2006; Pierrehumbert, 1995; Redi & Shattuck-Hufnagel, 2001; Roach, 1973). Although it has been suggested that glottalisation is spreading in Britain (Milroy, Milroy, Hartley, & Walshaw, 1994), its presence has been recorded in BrE since at least the late 19th Century (Andrésen, 1968; Tollfree, 2001), and as such it is well established as a feature of that variety. In Australian English (AusE), on the other hand, observations on the presence of glottalisation have only relatively recently emerged. Early descriptions provide no evidence that glottalisation was a historical feature of AusE (Tollfree, 2001), and even as recently as the mid-1980s descriptions have noted the apparent lack of glottalisation in the variety (Trudgill, 1986; Wells, 1982).

Glottalisation was first described in AusE in 1989 (Ingram, 1989) and is well attested as occurring in contemporary AusE today (Cox & Palethorpe, 2007; Tollfree, 2001). This may suggest that glottalisation is a recent addition to the variety. On the other hand, it is also possible that glottalisation was present in AusE prior to its emergence in the literature. Since the first mention of glottalisation at the end of the 1980s (Ingram, 1989), some researchers have noted anecdotally that glottalisation occurs on vowels before voiceless coda stops in contemporary AusE (Cox & Palethorpe, 2007; Tollfree, 2001), as it does in other varieties of English as a cue to coda voicelessness. Whether or not glottalisation has the same function in AusE is yet to be empirically examined.

1.2 Aims and objectives

The overall aim of this thesis is to provide an empirical examination of glottalisation as a cue to coda voicing in AusE. Within this broad aim, the specific objectives and research questions are as follows:

- to investigate whether glottalisation functions as a cue to coda stop voicing; is glottalisation more frequent in voiceless coda contexts than in voiced coda contexts?
- to determine whether glottalisation is a recent change; do younger speakers employ more glottalisation than older speakers?
- to explore whether gender is linked to increased use of glottalisation; do females use more glottalisation than males, or vice versa?
- to investigate whether increased glottalisation is associated with a reduction of some other cues to voicing; is there any evidence for a relationship between increased use of glottalisation and decreased use of other cues to voicing?

1.3 Organisation of thesis

This thesis is divided into six chapters. *Chapter 1* outlines the motivations for the research, lists the aims and objectives of the thesis and provides an overview of its organisation. *Chapter 2* provides a review of the literature on the production of glottalisation, and the social and phonetic/phonological factors that have been linked to the use of glottalisation, particularly with reference to coda voicelessness. Definitions of relevant terminology as used in this thesis are also presented in this chapter, as is a review of issues pertaining to coda voicing specifically related to AusE.

Chapter 3 outlines the details of the data that were analysed in this study, and lists the methods employed in the analysis. *Chapter 4* gives detail of both the raw results and those of the statistical analyses that were conducted. An interpretation of these results and a general discussion of their relevance in the context of previous research is offered in *Chapter 5,* including the limitations of the study and suggestions for the direction of future research. *Chapter 6* concludes the thesis and summarises the overall contribution of this work to the study of glottalisation and AusE.

2. Background and literature review

This chapter provides some background on glottalisation, and the physiological mechanisms behind its production, and surveys the relevant literature pertaining to glottalisation as it occurs in three different phonetic environments in English: glottal reinforcement of stops, glottalisation of word-initial vowels, and phrase final glottalisation. This survey will inform the various definitions of glottalisation used in the thesis. A review of social factors that have been found to correlate with increased glottalisation in different varieties of English is also provided. We will then discuss the use of glottalisation as a cue to coda voicelessness, which will be the main focus of this study. Finally, glottalisation in AusE is examined, including issues related to AusE vowel length and the potential phonologisation of glottalisation.

2.1 Glottal reinforcement of stops

Glottal reinforcement generally refers to the optional addition of a glottal adductive gesture to an oral stop (Esling, Fraser, & Harris, 2005; Higginbottom, 1964; Roach, 1973). In British English (BrE) this can occur for the voiceless stops /p/, /t/, and /k/, and for the voiceless affricate /ʧ/ (Roach, 1973; Wells, 1982); in American English (AmE) glottal reinforcement of /t/ is common, whereas it occurs less often for /p/ and rarely for /k/ (Huffman, 2005; Pierrehumbert, 1995; Redi & Shattuck-Hufnagel, 2001). The reinforcing glottal gesture may be realised as a complete glottal stop [ʔ], that is, as an “abrupt and sustained” adduction of the vocal folds (Garellek, 2013, p. 4). The timing of this reinforcing (secondary) glottal gesture is variable; it can occur either before, simultaneously with, or after the primary supralaryngeal gesture. Where the glottal closure occurs before the oral gesture, this is often referred to as pre-glottalisation (usually transcribed with a superscript glottal stop, e.g. [ˀt]) (Wells, 1982); where the glottal closure occurs or persists after the oral gesture, this is often referred to as post-glottalisation (e.g. [tˀ]) (Howe & Pulleyblank, 2001). In some cases, glottalisation may result in the supralaryngeal, or primary stop gesture, being obscured or even replaced by the glottal gesture, a process that is referred to as glottalling or glottal replacement (Docherty, 1992, Roach, 1973; Wells, 1982). For example, glottal replacement of the voiceless stop /t/ in the word *button* results in the phonetic output of [bɐʔn̩].

Often, however, the effect of glottalisation is not complete glottal adduction, but rather an incomplete, or weakly constricted vocal fold closure, which manifests as "longer, often stronger, irregularly spaced glottal pulses on voiced portions of neighboring sounds" (Huffman, 2005, p. 335-6). Irregular voicing of this type is commonly found in vowels preceding voiceless stop consonants (Docherty & Foulkes, 1999; Huffman, 2005). This phenomenon, which is also sometimes referred to in the literature as laryngealisation or laryngealised phonation, results in a low fundamental frequency (F0) and the auditory percept of creakiness on the vowel (Esling et al., 2005; Garellek, 2013). Such laryngealised sounds are usually phonetically transcribed with a tilde below the affected segment (e.g. [bæ̰t]).

2.2 Word-initial glottalisation

Glottalisation can also occur in English when a word begins with a vowel. This usually occurs either at the beginning of a phrase, or when the vowel initial word follows a word that ends with a vowel. Such vowel-vowel sequences are referred to as hiatus contexts, and are disallowed in about half of the world's languages (Bell & Hooper, 1978), including English. In such contexts, glottalisation acts as a form of hiatus resolution (Pierrehumbert, 1995). This is typologically very common, and can be found in many languages that do not have glottal stops as part of their phonemic inventory (Allerton, 2000; Garellek, 2013). In some of these languages, the insertion of a glottal stop is mandatory before vowels in order to satisfy a language specific phonotactic constraint that all words must begin with a consonant; this is the case for example in Arabic (Garellek, 2013; Lombardi, 2002). In English, however, glottal stop epenthesis before vowels is optional, although very common (Garellek, 2014; Pierrehumbert, 1995; Umeda, 1978), especially in clearly articulated or emphatic speech (Hayes, 2009). As with glottal reinforcement, word initial glottalisation is a gradient phenomenon that can be realised either as a complete glottal stop, or as irregular, laryngealised phonation on the vowel (Pierrehumbert, 1995). Studies have demonstrated that word-initial glottalisation in English most commonly affects words at the beginning of intonational phrases, or words that are pitch-accented (Dilley, Shattuck-Hufnagel, & Ostendorff, 1996; Pierrehumbert, 1995; Pierrehumbert & Talkin, 1992), and is more likely to occur on vowel-initial content words rather than on function words (Umeda, 1978). Rather than being due to grammatical differences between content and function words, however, this preference that Umeda (1978) found for glottal stops to occur more frequently at the beginning of content words could be due to the fact that vowels in function words are often realised as reduced (weak) vowels. Yuen, Cox and Demuth (2015) found that AusE speakers were more likely to favour r-epenthesis over glottalisation as a hiatus breaking strategy before reduced vowels, whereas glottalisation was preferred if the following vowel was realised as a full vowel. In addition, glottalisation is preferred as a hiatus breaking strategy in AusE before reduced vowels if a foot boundary coincides with the hiatus (Cox, Palethorpe, Buckley, & Bentink, 2014; Yuen et al., 2015).

2.3 Phrase final glottalisation

Glottalisation also occurs commonly at phrase boundaries in English (Garellek, 2015; Redi & Shattuck-Hufnagel, 2001). Phrase final glottalisation is often referred to as creaky voice (Garellek, 2015; Henton & Bladon, 1988; Ladefoged & Maddieson, 1996). Creaky voice can be applied across multiple words within a phrase and can appear on any voiced sound (Garellek, 2015). While creaky voice is employed phonemically in some languages, such as Jalapa Mazatec (Gordon & Ladefoged, 2001), in English it is a non-contrastive, non-obligatory phonetic feature (Redi & Shattuck-Hufnagel, 2001). Creaky voice in English is most often present at pitch accents and at prosodic boundaries (Henton & Bladon, 1988; Pierrehumbert, 1995; Redi & Shattuck-Hufnagel, 2001). Due to its frequent presence at the end of utterances, some researchers suggest that the use of creaky voice serves as a communicative marker signalling the end of a speaker's turn (e.g. Henton & Bladon, 1988; Laver, 1980; Redi & Shattuck-Hufnagel, 2001). Creaky voice is also a robust sociolinguistic marker in some varieties of English, indexing a range of macrosocial categories such as age, gender, and socio-economic status (e.g. Esling, 1978; Henton & Bladon, 1988; Trudgill, 1974; Yuhasa, 2010). The socioindexical aspect of creaky voice will be discussed in more detail in 2.6 below.

Some other terms that are often used in the literature to describe creaky voice are vocal fry and creak. Although many researchers treat all of these terms as synonymous (e.g. Gordon & Ladefoged, 2001; Henton & Bladon, 1988; Ladefoged, 1971), others make a distinction between them (e.g. Gerrat & Kreimann, 2001; Laver, 1980; Redi & Shattuck-Hufnagel, 2001). For those who make a distinction, vocal fry/creak usually refers to a specific kind of creaky voice, which exhibits a "prolonged low fundamental frequency accompanied by almost total damping of glottal pulses"

(Redi & Shattuck-Hufnagel, 2001, p. 414) resulting in auditorily identifiable individual glottal pulses (Keating & Garellek, 2015). For the purpose of this work, creak/vocal fry will be subsumed under the term creaky voice, although we acknowledge that acoustic and articulatory differences between the various different types of creaky voice can exist (see 2.5 below).

2.4 Definition of terms

As can be seen from the discussion above, the term glottalisation is used in the literature to refer to a variety of phenomena by different scholars working in different traditions. Therefore, in order to avoid potential confusion and the conflation of these phonetic phenomena, it is necessary to clarify how the various terms will be used in this work.

We consider glottalisation to be a general term that can be used to refer broadly to a range of phonetic characteristics:

- the addition of a glottal stop to a supralaryngeal gesture or the replacement of an oral stop consonant with a glottal stop
- the laryngealised phonation that affects voiced sounds adjacent to stops and word initial vowels
- creaky voice used as a phrase final or social marker.

Note that this broad definition differs from the usage of Esling et al. (2005), who suggest that the term glottalisation be restricted to secondary articulations involving a glottal stop, but not to laryngealised phonation. However, incorporating all of these types under the one descriptor demonstrates their connectedness as points of differing laryngeal constriction on a continuum that ranges from an open to a closed glottis (Ladefoged, 1971; Laver, 1980 - see 2.5 below), and is in line with researchers such as Huffman (2005) and Redi & Shattuck-Hufnagel (2001).

The three categories subsumed under the term glottalisation used here are glottal stop, laryngealisation and creaky voice defined structurally and functionally as follows:

- Glottal stop refers to total and abrupt adduction of the vocal folds functioning as a strengthening gesture which can either replace or mask a simultaneous or subsequent oral gesture or else reinforce the oral gesture. (Garellek, 2013; Higginbottom, 1964)
- Laryngealisation refers to low F0, irregular glottal pulses resulting from a weaker glottal constriction than occurs for the glottal stop giving the auditory percept of low-pitched creakiness. Laryngealisation is associated with voiced sounds such as vowels preceding stops (i.e. functioning as glottal reinforcement of stops) and also with vowel onset phenomena (although vowel onsets are not explored here)
- Creaky voice refers to phonation that occurs phrase finally as a boundary marker or as a sociolinguistic marker. It is acknowledged that both laryngealisation as stop reinforcement and creaky voice may in some instances be due to the same articulatory mechanisms, i.e. increased glottal constriction; however, as will be discussed in 2.5 below, this is not always the case. Furthermore, listeners appear to be able to distinguish perceptually between laryngealisation as stop reinforcement and phrase final creaky voice. In an identification task of near minimal pairs in which only one word could exhibit glottal reinforcement (e.g. [bʌ̰n] and [bʌ̰ʔn̰]), Garellek (2015) found

that AmE listeners made few errors even when both creaky voice and glottal reinforcement were present.

2.5 Physiological features of glottalisation

Glottalisation occurs with an increase in vocal fold adduction compared to normal, modal phonation, that is, regular, efficient vibration of the vocal folds achieved through moderate adductive tension, medial compression and longitudinal tension (Laver, 1980). One useful way of expressing the difference between glottalised and modal phonation is to use a simple model of glottal constriction along a continuum as in Figure 2.1, as proposed by Ladefoged (1971- revised in Gordon & Ladefoged, 2001). At one end of the continuum the glottis is wide open, as in the production of voicelessness, and at the other it is completely closed, as in the production of a glottal stop. Midway along the continuum is the position for modal phonation. Laryngealised phonation associated with glottalisation occurs between modal phonation and complete glottal occlusion. Conceptualised in this simple way, laryngealised phonation can be considered the result of an incomplete glottal stop.

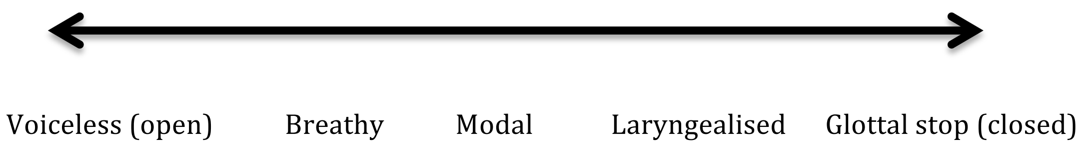

Figure 2.1. Continuum of glottal constriction (Adapted from Gordon & Ladefoged, 2001).

Of course, this model is a simplification and does not capture the intricacies of the larynx during glottalisation, a point that is recognised by its author(s) (Gordon & Ladefoged, 2001). More complex descriptions have also be made, such as the model offered by Esling and Harris (2005) and Edmondson and Esling (2006), shown in Table 2.1, which suggests that different laryngeal articulations are produced by a system of valves, rather than simple glottalic apperture.

Table 2.1. The valves of the throat. After Edmondson & Esling, 2006.

Valve 1	Glottal vocal fold adduction and abduction
Valve 2	Partial covering and damping of the adducted glottal vocal fold vibration by the ventricular folds (ventricular incursion)
Valve 3	Sphincteric compression of the arytenoids and aryepiglottic folds forwards and upwards by means of the thyroarytenoid muscle complex
Valve 4	Retraction of the tongue and epiglottis moving backwards and downwards, culminating in extreme cases in full closure onto the pharyngeal wall, by means of the hyoglossus muscles (hereafter called epiglotto-pharyngeal constriction)
Valve 5	Laryngeal raising by the suprahyoid muscle group, i.e. the anterior and posterior digastric, stylohyoid, geniohyoid and hyoglossus (and, conversely, lowering by the suprahyoid muscle group)
Valve 6	Inward constriction of the pharynx walls due to the sphincteric action of the superior/middle/inferior pharyngeal constrictors (pharyngeal narrowing)

In this model, the first valve corresponds more or less to the continuum of glottal constriction (Ladefoged, 1971) described above; however, according to Edmondson and Esling (2006), the processes that occur during laryngealised phonation are not so straightforward that they can be captured by glottal constriction alone. Rather, they suggest that glottalisation before a glottal stop involves the engagement of the second and third valves as well, i.e. adduction of the ventricular folds and the aryepiglottic folds as well as the glottis, and that for creaky voice the second valve is open but the first and third engaged. While this model has obvious benefits, in that it demonstrates in fine detail the laryngeal processes that may be involved in glottalisation and which do not solely occur at the glottis (Moisik & Esling, 2011), the simplicity of the continuum of glottal constriction is also an advantage in that it excludes details that may not be relevant or measurable in every situation. While we acknowledge that glottalisation may not simply involve just bringing the vocal folds together with varying degrees of tension, for the purposes of this work this level of detail is sufficient. As such, in what follows we will make reference to the glottal continuum, rather than to the valves of the larynx and pharynx.

Although glottalisation is generally considered to be due to an increase in vocal fold adductive tension (and perhaps other laryngeal and pharyngeal mechanisms operating simultaneously), when it comes to creaky voice (phrase final glottalisation) things are not quite so straightforward. For example, there is evidence that, at least in some instances, creaky voice is not due to vocal fold adduction at all (Hanson, Stevens, Kuo, Chen, & Slifka, 2001). Slifka (2000, 2006) found that phrase final creaky voice often occurs in conjunction with glottal *ab*duction rather than *ad*duction. In such instances, the creakiness, or irregular phonation, is caused not by increased glottal constriction, but rather by a combination of vocal-fold slackening, reduced transglottal pressure, and spreading of the vocal folds (Hanson et al., 2001). Despite this, however, a distinction will not be made herein between creaky voice due to vocal fold adduction and creaky voice due to vocal fold abduction (sometimes referred to as Slifka voice (Keating & Garellek, 2015)); rather, both will be considered as examples of creaky voice.

2.6 Glottalisation as a social marker

A number of studies have highlighted links between glottalisation and social factors in different varieties of English. These studies have shown that the social factors tied to glottalisation differ according to the different varieties. In the following section we will summarise the findings from the literature related to gender and class affiliation.

2.6.1 Gender

Some studies have suggested that glottalisation is more commonly present in the speech of males than females. Henton and Bladon (1988), for example, found creaky voice to be a marker of masculinity in two dialects of BrE: Received Pronunciation (RP) and Modified Northern (MN). Male speakers in both of these dialects demonstrated much higher rates of creaky voice than did the female speakers of the same dialects. Furthermore, the MN males employed more creaky voice than the RP males, demonstrating not only a gender effect, but also a geographic and potentially class based tendency. According to Henton and Bladon (1988), creaky voice indexes masculinity in both of these dialects, with the higher levels produced by MN males marking a hyper-masculinity that exists among that dialect's males. Milroy, Milroy, Hartley, and Walshaw (1994) report more frequent glottalisation in male speech in Tyneside. However, they also note a gender preference for the type of glottalisation employed: female speakers favoured glottal replacement, whereas males preferred glottal reinforcement (Docherty, Foulkes, Milroy, Milroy & Walshaw, 1997; Milroy, Milroy, Hartley, & Walshaw, 1994). This, they suggest, is due to female speakers' preference for using supra-local features that are, or are becoming, part of the standard dialect (RP and Estuary English). Male speakers, on the other hand, displayed a preference for localised variants (Milroy, Milroy, Hartley, & Walshaw, 1994). In New Zealand English (NZE), Docherty, Hay, and Walker (2006) found that male speakers produced more glottalised voiceless stops phrase finally than female speakers did.

On the other hand, a number of studies have also found glottalisation to be more common in the speech of women. Mees (1987, 1990) reports more prominent word final glottal reinforcement in the speech of female Cardiff English (CE) speakers. In this dialect, she suggests, glottalisation is a recent change that serves as a marker of prestige, presumably due to its associations with RP and London, and she suggests that the change is led by women (Mees, 1987, 1990). In addition, similar to the preferences reported in Milroy, Milroy, Hartley, and Walshaw (1994), Mees also found females to prefer glottal replacement, whereas males preferred glottal reinforcement, albeit in different contexts. Holmes (1995) notes that glottal reinforcement of /t/ in NZE was most common among female speakers. In American English (AmE), Dilley, et al. (1996) and Redi and Shattuck-Hufnagel (2001) found glottalisation to occur more frequently in the speech of female rather than male radio newsreaders (word-initial glottalisation was analysed in the former, whereas the latter examined glottalisation in phrase boundary contexts). Yuasa (2010) found that American females employed creaky voice more than twice as often as their masculine counterparts. Wolk, Abdelli-Beruh, and Slavin (2012) conducted a study on female American college students and found that more than two thirds of their participants employed creaky voice. By contrast, in a subsequent study Abdelli-Beruh, Wolk and Slavin (2014) found that male American students were four times less likely to employ creaky voice. Podesva (2013) found that the tendency for American women to use creaky voice more than men was consistent in both white and African American speakers. Szakay (2012) found that female Pakeha NZE speakers (i.e. speakers of European descent) used creaky voice more than male Pakeha speakers, but both male and female Maoris used more creaky voice than the Pakeha speakers. Although young Maori males employed more creaky voice than young Maori females, this pattern was reversed among older Maori speakers (Szakay, 2012).

There have been suggestions that the use of creaky voice is increasing, especially among young American speakers (Ladefoged & Johnson, 2015). However, Podevsa (2013) found no significant difference in the use of creaky voice between older and younger female speakers (aged 18-75) in his study of voice quality in Washington, DC. Yuhasa (2010) hypothesises that women the low F0 associated with creaky voice enables women to take "advantage of the positive attributes associated with low-pitch male voices" (p. 331). This analogy to masculinity has been supported by other commentators; Sicoli (2015, p. 115), for example, suggests that creaky voice can be 'turned on' in situations in which a person assumes "a position of power that goes against stereotypical norms of gender or rank, with the hyper-low pitch being a trope of masculinity and its cultural association with authority". Mendoza-Denton (2011) identifies the use of creaky voice among Hispanic American women as a sign one is tough, 'hard of heart', and does not show emotion. Although she argues this does not index masculinity, such qualities could easily be understood as traditionally masculine traits.

2.6.2 Class

Glottalisation has also been linked to class affiliation in a number of studies. Trudgill (1974) found that working class speakers in Norwich employed creaky voice whereas middle class speakers did not. Esling (1978) identified the opposite of pattern in Edinburgh, where speakers from a high prestige district of the city used creaky voice more often than speakers from less affluent parts. Milroy, Milroy and Hartley (1994) discuss how glottalisation has increasingly progressed from being a heavily stigmatised feature associated with working class – particularly Cockney – speakers in Britain to becoming a common feature of more prestige dialects such as RP. As mentioned above, word final glottalisation has been suggested to serve as a marker of prestige in CE, and is not commonly found in working class speech in this variety; it is, however, present in the speech of working class speakers with middle class aspirations (Mees, 1987; Mees & Collins, 1999). On the other hand, intervocalic glottal reinforcement is rare in middle class CE, but is common in the speech of young (especially male) working class speakers (Mees, 1990).

In AmE creaky voice use has also been linked to class mobility (Yuhasa, 2010). In Tyneside, Milroy, Milroy, Hartley, and Walshaw (1994) found no great difference in rates of glottalisation among older speakers; both older middle class and older working class speakers used similar amounts of glottal reinforcement and relatively little glottal replacement. Among younger speakers, however, there was a class-based preference for the *type* of glottalisation employed; working class speakers used more glottal reinforcement, whereas middle class speakers (especially females) tended to prefer glottal replacement. In NZE, Docherty et al. (2006) found that 'professional' speakers, which in their study is more or less analogous with middle class speakers, produced more laryngealisation than non-professional (i.e. working class) speakers.

In a study of AusE Tollfree (2001) found glottalisation to be almost categorical word finally before consonants in informal speech for both working and middle class speakers, whereas middle class speakers were half as likely to use glottalisation word finally before a pause. When formal speech was considered, the middle class speakers used less glottalisation that the working class speakers in both contexts.

2.6.3 Summary of social factors

As can be seen from this review, glottalisation can index speaker gender and class affiliation (or aspiration), and these factors can also interact with speaker age or ethnicity. Furthermore, the social factors glottalisation indexes in one variety need not be replicated in other varieties, although some commonalities may exist. Rather, the social factors tied to glottalisation appear to be variety-specific.

2.7 Coda glottalisation as a cue to voicelessness

In some varieties of English, glottalisation can serve as a cue to consonant coda voicing, particularly of /t/. In American English, for example, the voiceless stops /p, t, k/ can all exhibit glottal reinforcement (Huffman, 2005; Redi & Shattuck-Hufnagel, 2001). Glottal reinforcement of voiced coda stops, on the other hand, is not attested in AmE, although it has been observed in African American Vernacular English (AAVE) (Anderson & Nguyen, 2004; Koops & Niedielski, 2009). Similarly, Scottish English speakers from Edinburgh employ glottal reinforcement as a secondary cue for voiceless coda stops (and even as a primary cue for some speakers), whereas they do not glottalise voiced coda stops (Gordeeva & Scobbie, 2013).

Pierrehumbert (1995) has suggested that glottalisation of voiceless coda stops could be the result of a strategy to enhance voicelessness. She highlights the fact that glottalisation of stops in AmE occurs most frequently before sonorants, particularly nasals (Pierrehumbert, 1995; Seyfarth & Garellek, 2015). If the vocal folds are abducted for a voiceless stop before a nasal, this may "introduce[s] a side-branch into the vocal tract whose spectral consequences are highly confusable with spectral consequences of the side branch created by nasalization" (p. 56). Glottal fold adduction, on the other hand, ensures the perception of a stop, and as such is favoured over abduction in this context (Pierrehumbert, 1995). Similarly, Garellek (2011a) found that increased glottalisation improves listeners' perception of /t/. He offers the explanation that, particularly in instances where stops are unreleased and hence cues to a stop's place of articulation are unable to be retrieved from the burst, glottalisation can strengthen the cues that are available in order to improve perceptibility. This suggestion is supported by the finding that increased glottalisation occurs before voiceless coda stops in lower frequency, and hence, more easily confusable, lexical items (Garellek, 2011b). The use of glottalisation as a cue to voiceless stops is also attested in German. Kohler (2000) shows that underlying /ntən/ sequences in German that are reduced to [nn] remain perceptually distinct from underlying /nən/ sequences that reduce to [nn] through laryngealised phonation on the nasal. In addition, John and Harrington (2007) found that sequences that are underlyingly /ntən/ and /ndən/ but which are reduced to [nn] can nevertheless be perceived by listeners according to the timing of glottalisation: the voiceless stop is cued by laryngealisation on the preceding vowel whereas the voiced stop is cued by laryngealisation on the second nasal.

2.8 Glottalisation in Australian English

Although glottalisation in BrE has been recorded since at least the late 19th Century (Andrésen, 1968), early descriptions of AusE make no mention of either glottal replacement or glottal reinforcement (Tollfree, 2001). Neither is there evidence of glottalisation in AusE in the early literature of the colony (Tollfree, 2001). Wells

(1982) and Trudgill (1986) both note the absence of glottalisation in AusE, with Trudgill (1986, p. 131-2) stating that "Australian English does not have pre-glottalization or glottalling of word-final /p/, /t/, /k/." Linguists first noted the existence of glottalisation in AusE at the end of the 1980s (Ingram, 1989; Tollfree, 2001) and glottal reinforcement is widely attested as occurring before voiceless coda stops in AusE today (Cox & Palethorpe, 2007; Tollfree, 2001). While this could suggest that glottalisation is a recent change to AusE, this is difficult to determine clearly, as "native speaker-hearers of AusE are largely insensitive to glottalised variants" (Tollfree, 2011, p. 54). Therefore, it is possible that the feature was present prior to its being noted in the literature. As such, one of the aims of this study is to compare levels of glottalisation in the speech of both older and younger AusE speakers. This would provide some evidence as to whether glottalisation is in fact a recent change to AusE, or rather, a phenomenon that has merely recently been described.

In order to explore this question we will conduct a synchronic, apparent time analysis using two groups of AusE speakers: a group of young speakers and a group of older speakers. Apparent time analyses are based on the idea that a person's accent remains stable over their lifetime (Trudgill, 1983), which suggests that features that are present in the speech of a young cohort of speakers but are absent from the speech of an older cohort of speakers are likely to be changes that have recently entered the variety (Cox & Palethorpe, 2001). Following this line of reasoning, if glottalisation is present in the speech of the younger group, but absent from the speech of the older group, this may provide evidence that a change has taken place and that glottalisation is a recent development in AusE. Similarly, if glottalisation is found in both groups, but is more prevalent in the speech of the younger group, this would suggest that its use in AusE is increasing. However, care must nevertheless be taken in interpreting such results, as some studies have demonstrated that adult speakers' accents can indeed change over time (e.g. Bowie, 2005; Harrington, Palethorpe, & Watson, 2000). Furthermore, an apparent time analysis cannot preclude that such results are due to an age-grading effect, which is the process whereby certain features are used by young speakers, but are lost as speakers grow older, with the same process repeated over successive generations (Bailey, 2002).

Table 2.2. The vowels of Australian English.

Short monophthongs	Long monophthongs	Diphthongs
/æ/ trap	/iː/ fleece	/ɑe/ price
/e/ dress	/eː/ square	/æɪ/ face
/ɪ/ kit	/ɐː/ bath	/əʉ/ goat
/ʊ/ foot	/oː/ north	/oɪ/ choice
/ɐ/ strut	/ʉː/ goose	/æɔ/ mouth
/ɔ/ cloth	/ɜː/ nurse	/ɪə/ near
/ə/ lettER		

The AusE vowel inventory comprises both monophthongs and diphthongs. The monophthongs can be further divided according to duration (Bernard, 1967; Fletcher & McVeigh, 1993): /æ, e, ɪ, ʊ, ɐ, ɔ, ə/ are short monophthongs, whereas /iː, eː, ɐː, oː, ʉː, ɜː/ are long (Cox, 1996, 2006)[1]. These are displayed in Table 2.2. The duration of the short vowels is approximately 60% of the long vowels (Cox, 1996, 2006). This length difference is phonemic for some vowel pairs in AusE. For example, the vowels /ɐː/

[1] The phonemic symbols used in this work are based on the system outlined in Harrington, Cox, and Evans (1997) for describing AusE.

and /ɐ/ are more or less spectrally equivalent and are differentiated primarily according to durational differences (Bernard, 1967, 1970; Cox, 2006; Watson & Harrington, 1999). For some speakers this is also the case for the pairs /e/ and /eː/, and /ɪ/ and /ɪə/, in which case the latter vowel in each pair may be produced as a long monophthong rather than a diphthong (Bernard, 1967, 1970; Cox, 2006; Cox & Palethorpe, 2007). Note, however, that this is not the case for /iː/ and /ɪ/; /iː/ is higher and more fronted than /ɪ/ and displays a diphthongal quality in the form of a variable onglide (Cox, 2006; Cox & Palethorpe, 2007; Cox & Palethorpe, 2008; Cox, Palethorpe, & Bentink, 2014; Harrington, Cox, & Evans, 1997).

Vowel length is also employed as a cue to coda stop voicing in English (Klatt, 1976; Port & Dalby, 1982); vowels preceding voiced coda stops are longer compared to vowels preceding voiceless coda stops. In addition, voiced coda stops have shorter closure periods than voiceless coda stops (Cox & Palethorpe, 2011; Yuen, Cox, & Demuth, 2014). Recent work, however, suggests that long AusE vowels that are differentiated primarily by length may be resistant to shortening before voiceless stops (Cox, Palethorpe & Miles, 2015). Cox et al. (2015) found that while /iː/ was shortened before voiceless codas, /ɐː/ retained much of its length preceding voiceless codas, presumably to maintain its contrast with short /ɐ/, which is primarily achieved through vowel length duration. This resistance to shortening, however, would appear to weaken a primary cue to coda stop voicing, which raises the question of how the contrast is maintained. Kirby's (2013) probabilistic enhancement hypothesis suggests that in instances in which the precision of a contrast is reduced, other, more informative cues may be enhanced in order to preserve the contrast. There are a number of other potential cues to coda stop voicing in English, including the presence of a voice bar, differences in F0, differences in the amplitude of aspiration, and glottalisation (Cole, Kim, Choi, & Hasegawa-Johnson, 2007; Gruenenfelder & Pisoni, 1980; Lisker, 1978; Song, Demuth, & Shattuck-Hufnagel, 2012; Wright, 2004). As glottalisation is known to function as cue to voicelessness in some varieties of English (see 2.7 above), and is attested as occurring before voiceless coda stops in AusE today (Cox & Palethorpe, 2007; Tollfree 2001), it is possible that glottalisation may contribute to the perception of coda voicelessness. If this is the case, it may also exhibit enhancement in order to maintain the perceptibility of the voicing contrast for these long vowels that are resistant to shortening. Thus glottalisation may be reanalysed as a phonologically contrastive feature (Kirby, 2013). Therefore, another aim of this study is to investigate whether glottalisation is employed as a cue to stop voicing by AusE speakers, and whether there is any evidence of enhancement of glottalisation in voiceless contexts where contrast is threatened.

2.9 Summary

This chapter has briefly described and defined three different types of glottalisation and the environments in which they are known to occur. A review of the literature on glottalisation has demonstrated that different varieties of English ascribe different social meanings to glottalisation, with gender and class affiliation commonly indexed factors. Furthermore, it has suggested that glottalisation may be a recent addition to AusE as a cue to voicelessness of coda consonants. This would be consistent with a role played by glottalisation in several other varieties of English, and other languages such as German. The present study seeks to investigate these social and phonetic aspects of glottalisation in AusE. Finally, this study will investigate whether there is an association between the degree of glottalisation and a reduction of other temporal cues to voicing such as coda closure duration or vowel duration (as glottalisation is our primary interest in this study, we will not examine all of the other possible cues to coda voicing).

We hypothesise that glottalisation will be more common preceding voiceless coda consonants than voiced coda consonants, based on analogy with other varieties of English. Furthermore, we expect glottalisation to be more prevalent in the speech of younger speakers, consistent with the suggestion that it is a recent change to the variety. It is also our hypothesis that females will exhibit more glottalisation in their speech than males, based on the often observed phenomenon that females are the leaders of change in language (Labov, 1990). Finally, in the light of the results reported in Cox et al. (2015), we hypothesise that glottalisation will be associated with a reduction of other cues to coda voicing, particularly preceding vowel duration as suggested by Cox et al. (2015), indicating that glottalisation may be undergoing an enhancement process in AusE.

3. Methods

3.1 Materials

The data for analysis for this project were extracted from the AusTalk corpus (Burnham et al., 2011). This corpus is a collection of high quality recordings of speech from 1000 regionally and socially diverse AusE speakers recorded in 12 standardised, state of the art portable recording stations throughout Australia. The recordings comprise three hours of speech data from each participant, who completed four standardised read speech tasks as well as four spontaneous speech tasks (Burnham et al., 2011). In one of the standardised read speech tasks participants produced 322 words in isolation as they were randomly presented on a computer screen, thereby providing citation style pronunciations of each word. This word list task was recorded on three separate occasions for the majority of speakers using different list randomisation on each occasion. The set of citation style words included a subset of 77 monosyllabic words in the contexts hVd, hVt, hV, hVl, and hVn (where V represents a vowel). All of the words extracted from the corpus for the present study are in the form hVt and hVd. Pairs of words were extracted for each speaker, so that the vowel extracted in the hVt context was also extracted in the hVd context, thus enabling a comparison between voiceless and voiced coda stops. The vowels analysed here are /iː, ɪ, ɐː, ɐ, oː, ɔ, ʉː/. These vowels were selected to sample high front (/iː, ɪ/), back (/oː, ɔ/), and low vowels (/ɐː, ɐ/) and to allow a comparison between pairs of vowels with a long/short distinction in AusE. Initially we envisaged also including /ʊ/ (high back) to compare with /ʉː/ (high central) in the analyses but due to a high number of mispronunciations in the recordings there were not enough tokens to warrant its inclusion. The word pairs that were extracted are listed along with their vowels in Table 3.1.

Table 3.1. Word pairs in hVt and hVd contexts extracted from AusTalk corpus and their respective vowels.

Vowel	hVt	hVd
iː	heat	heed
ɪ	hit	hid
ɐː	heart	hard
ɐ	hut	hud
oː	hort	horde
ɔ	hot	hod
ʉː	hoot	who'd

3.2 Speakers

Data were extracted for 67 individual speakers. Only data for native AusE speakers who were schooled entirely in Sydney from ages 5 to 18 were considered. The finding of Cox et al. (2015) that some long vowels may be resistant to shortening before voiceless coda stops (discussed in 2.8 above) was based on AusTalk data collected from Sydney speakers under the age of 35. To our knowledge, this finding has yet to be observed for speakers in other regions of Australia or in other age groups. As such, focusing on speakers from Sydney will enable this project to further investigate and build on the findings of Cox et al. (2015) and extend the analysis to a wider population of Sydney speakers.

3.3 Age

The extracted data were sorted into two groups, younger speakers and older speakers, based on the age of the speaker at the time of recording. Speakers in the younger group were aged between 18 and 35 years (n = 36); and the older group were aged over 56 years (n = 31). As discussed in 2.8 above, the separation of young and older speakers enables a synchronic, apparent time analysis to be carried out.

3.4 Sociolinguistic factors

In addition to age, the data were also categorised according to speaker gender. As discussed in 2.6.1 above, glottalisation has been suggested to index gender in a number of varieties of English; in some varieties glottalisation is more prevalent among males, in others it is more common among females. Within the young group there were 17 female speakers and 19 male speakers; whereas the older group comprised 14 females and 17 males. Initially, it was our intention also to categorise speakers according to their socioeconomic status, as glottalisation indexes socioeconomic status in some varieties of English (see discussion of this point in 2.6.2 above). However, very few of the Sydney speakers in the AusTalk corpus could be categorised as working class according to their profession and level of education. Rather, the vast majority – particularly so among the young speakers – listed professional occupations and/or relatively high levels of tertiary or postgraduate education. As such, any such analysis would be unbalanced, and hence it was deemed that a socioeconomic analysis was not viable using the current data.

3.5 Data coding

For each speaker all three separate recordings of the 14 selected words were extracted; however, some data were missing for some of the speakers (e.g. a particular speaker might have taken part in two rather than three recording sessions). This resulted in a total of 2569 separate items. A further 142 items could not be coded satisfactorily due to unclear pronunciations, mispronunciations, noise in the recordings or some other type of anomaly. These files were excluded from the analysis resulting in a total of 2427 audio files: 1289 files for the young speakers and 1138 files for the older speakers. The data were initially processed by the MAUS automatic aligner (Schiel, Draxler, & Harrington, 2011) using an AusE model, upon presentation of the orthographic representations. MAUS returned Praat textgrids (Boersma & Weenink, 2015) containing phonemic boundaries for each of the segments within the individual words. The data were then hand corrected and coded for subsegmental components by a trained coder using Praat (Boersma & Weenink, 2015) with reference to wideband spectrograms and aligned waveforms. Each file was coded for vowel duration, voicing duration, voice bar duration, coda consonant closure duration, coda consonant release burst duration, and for the presence of glottalisation using criteria established in Shattuck-Hufnagel, Demuth, Hanson, & Stevens (2011). In addition, duration of glottalisation was also measured. Details of criteria used are given below. An example of a fully coded file is given in Figure 3.1.

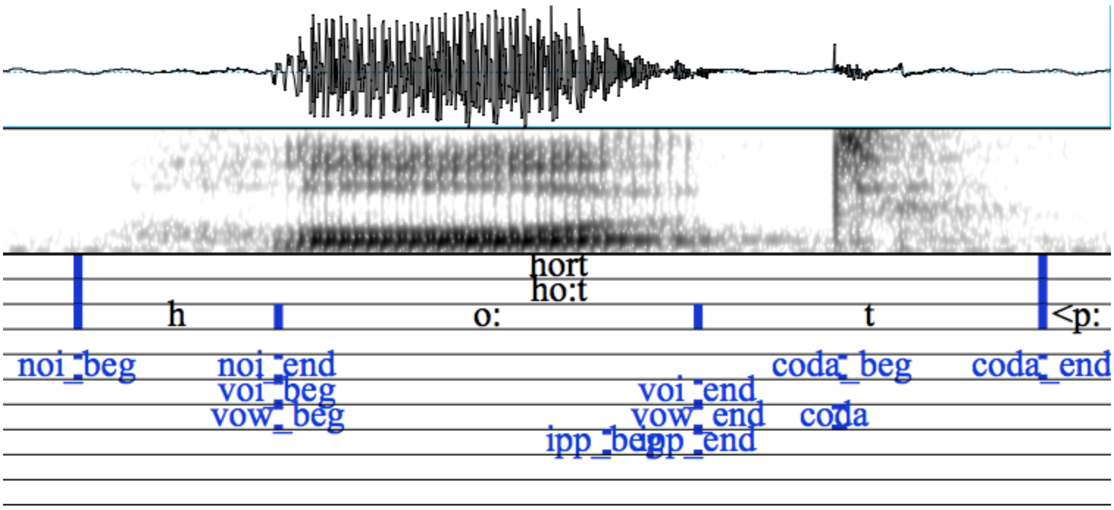

Figure 3.1. An example of a coded file showing vowel duration (vow_beg-vow_end), closure duration (vow_end-coda), and glottalisation duration (ipp_beg- ipp_end).

Vowel duration was measured from the beginning to the end of a strong F2 in the spectrogram and high amplitude regularity in the waveform (although for glottalised tokens the end of the vowel exhibited irregularity in the waveform). Coding the vowel duration was relatively straightforward for the majority of the files. However, 122 of the files displayed acoustic events in what otherwise appeared to be the coda closure period that made establishing the end of the vowel somewhat difficult. An example of this can be seen in Figure 3.2 below. The spike in the coda closure period (approximately midway through the closure in this example) did not appear to be a glottal closure event but may indicate a glottal release prior to the oral release of the stop consonant. In order to determine if spikes such as this should be included as part of the vowel or rather as part of the coda closure, we measured both the vowel and coda closure durations with and without the spike(s) for these files. We then compared the proportion of the vowel duration to the overall duration of the rhyme in those files in which the spikes were present to the overall mean vowel proportions for the same words spoken by speakers in the same age and gender group.[2] The durations in which the spike was not taken to be part of the vowel patterned with the overall durations, whereas the durations in which the spike was taken to be part of the vowel had much higher vowel to rhyme ratios than the rest of the data. As such, it was decided to code these spikes as occurring within the coda closure period, rather than as part of the vowel.

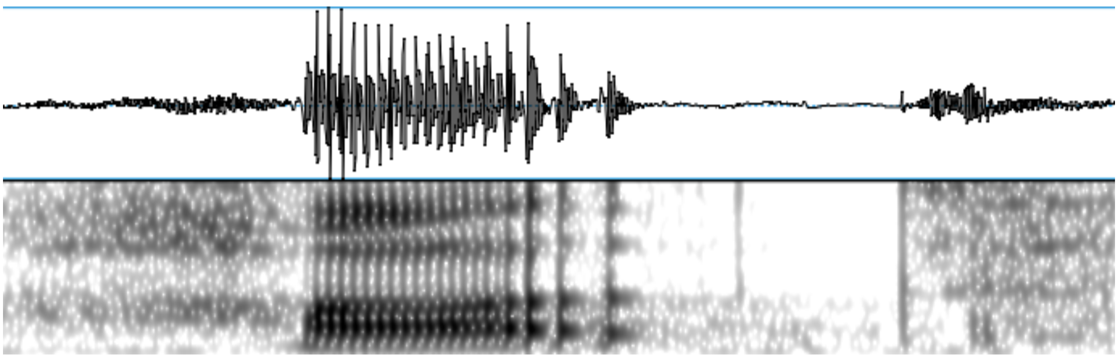

Figure 3.2. Spectrogram and waveform of the word 'hut' with a spike approximately midway through in the coda closure period.

A further 142 of the files could not be coded for coda consonant release burst for two reasons. Firstly, in some recordings the coda stop was produced as a spirantised stop and as such lacked a coda burst but showed coda frication. 72 files exhibited spirantised coda stops. An example spectrogram showing a spirantised coda stop can be seen in Figure 3.3 below. Secondly, in some of the recordings the coda stop was unreleased. 70 files exhibited unreleased coda stops. An example spectrogram showing an unreleased coda stop can be seen in Figure 3.4 below. These files with non-canonical coda stops were coded for vowel duration, voicing duration, and for the presence of glottalisation and were included in the primary analysis of factors predicting the presence of glottalisation. They were, however, excluded from the

[2] I am grateful to Paul Foulkes, who suggested this approach.

subsequent analyses that examined durational aspects of the coda closure, and the relationship between vowel duration and coda closure duration.

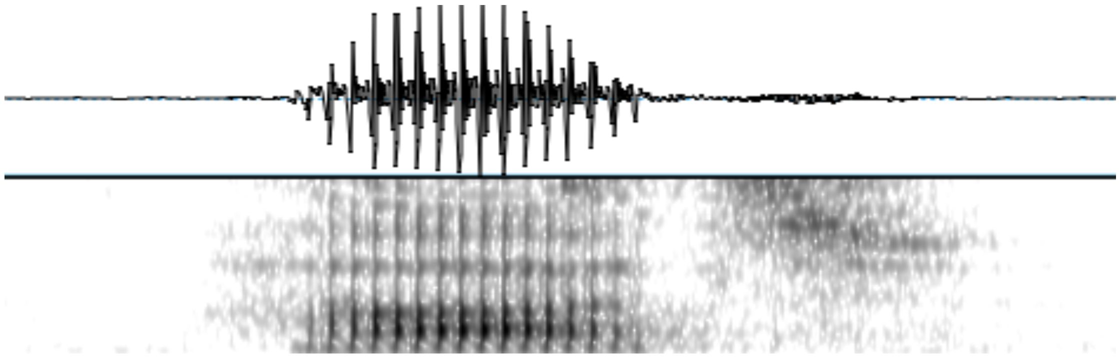

Figure 3.3. Spectrogram and waveform of the word 'heart' with spirantised coda.

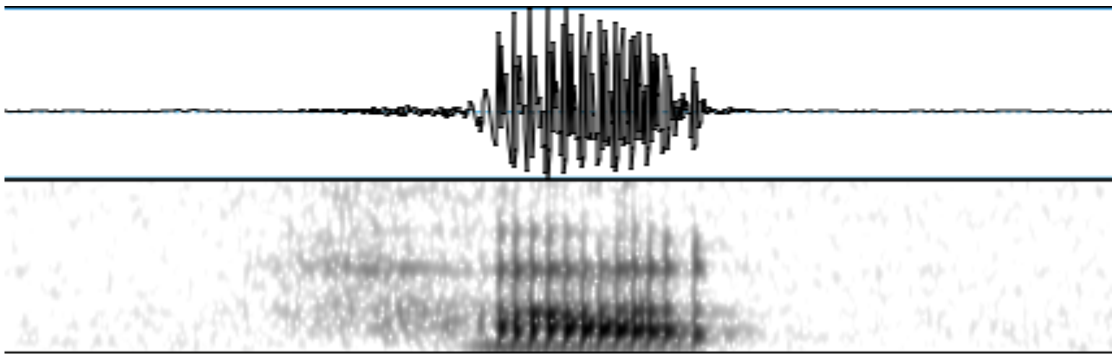

Figure 3.4. Spectrogram and waveform of the word 'hut' with unreleased coda.

The presence of glottalisation was first visually determined through inspection of the waveform and spectrogram. The presence of glottalisation is evidenced by increased space between the vertical striations towards the end of a vowel in the spectrogram and by irregularity in the waveform, as can be seen in Figure 3.5. As the data were produced in citation form, and hence as isolated utterances, it was not possible to distinguish between glottalisation due to glottal reinforcement and phrase final creaky voice, where creaky voice affected only the end of the vowel. However, cases in which glottalisation was present through more than half of the voiced section of the vowel, as in Figure 3.6, or in which a very low F0 was observed throughout the vowel, as in Figure 3.7, were taken to be examples of habitual creaky voice and were therefore not analysed as tokens of coda glottalisation, but rather were excluded from analysis. Once the presence of glottalisation was identified, the waveform was analysed to determine the starting point of the glottalised component. Objectively measuring the duration of glottalisation is difficult, as there is no single point at which phonation changes from periodic to aperiodic. Therefore, in order to ensure accuracy among the coded data a method was devised that took the start of glottalisation to be the point at which the frequency of the glottal pulses dropped substantially in relation to the preceding pulses, as measured from the points between peaks in the waveform. A sudden increase in the duration between peaks signalled the onset of glottalisation.

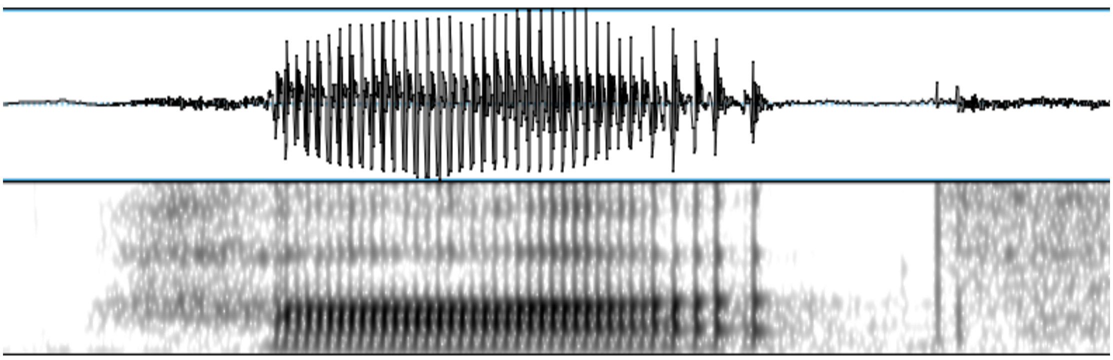

Figure 3.5. Spectrogram and waveform of the word 'heart' with irregular pulses at the end of the vowel illustrating glottalisation.

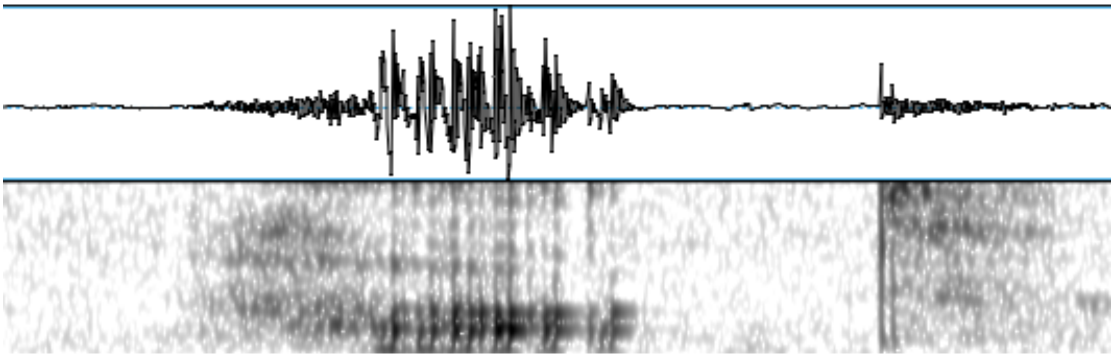

Figure 3.6. Spectrogram and waveform of the word 'heart' with irregular pulses throughout the entire voiced section of the vowel. Examples such as this were excluded from the analysis.

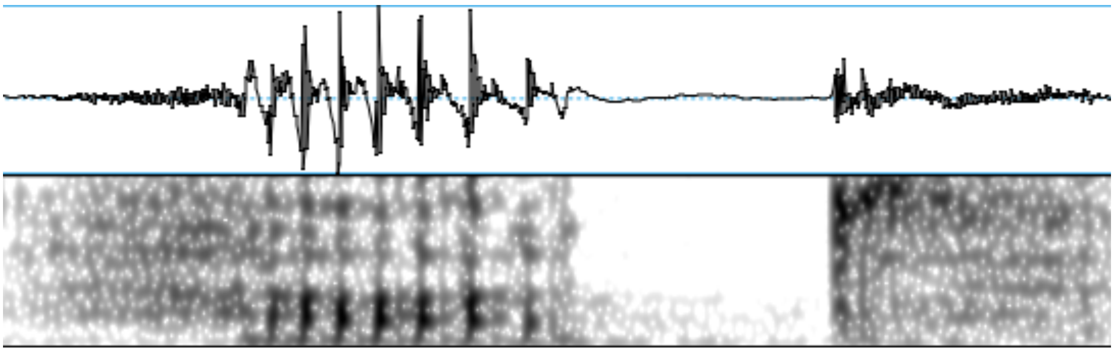

Figure 3.7. Spectrogram and waveform of the word 'hut' with very low F0 throughout the entire voiced section of the vowel. Examples such as this were excluded from the analysis.

10 per cent of the files were randomly selected and hand coded by a second trained coder to ensure intercoder reliability. Any disagreements or discrepancies that arose between the coders were discussed in consultation with an experienced phonetician and agreements reached. Both of the coders were in agreement as to the presence or absence or acoustic features, and correlations were high in terms of durational measurements (vowel duration (r = 0.936, n = 235, p = < 0.0001); coda closure duration (r = 0.936, n = 235, p = < 0.0001); glottalisation duration (r = 0.936, n = 98, p = < 0.0001). A paired sample t-test was carried out on these data and the differences between coders were found to be non-significant.

3.6 Data analysis

Once the data were coded and categorised, a number of statistical tests were applied using STATA (http://www.stata.com/) and IBM SPSS Statistics (version 22). The first analysis looked at the presence of glottalisation and the factors that contribute to its occurrence. Using STATA, we fitted a multilevel mixed effects logistic regression model (xtmelogit) in order to identify the factors that best predicted the presence of glottalisation in the data. The mixed effects logistic regression model factors speaker specific effects into the analysis, and therefore allowed us to account for multiple tokens of the same words produced by the same speakers and the consequent correlated observations in the output (Cox, Palethorpe, Buckley, & Bentink, 2014; Hu, Goldberg, Hedecker, Flay, & Pentz, 1998). The dependent variable for this analysis was the binary response of presence or absence of glottalisation, and the independent variables were age group, gender, voicing context, and vowel (/iː, ɪ, ɐː, ɐ, oː, ɔ, ʉː/). Speaker was included as a random factor. We estimated the model with main effects and interactions between all two-way combinations of variables. Post-hoc pairwise comparisons with Bonferroni correction for multiple comparisons were conducted to examine the effects of individual variables.

This analysis allowed us to examine whether glottalisation occurs more frequently in voiceless coda contexts compared to voiced coda contexts, if there is a significant difference in the amount of glottalisation present in the speech of the younger speakers versus the older speakers, whether gender has an effect on the occurrence of glottalisation, and whether particular vowels were more prone to glottalisation than others.

The subsequent analysis examined the relationship between temporal characteristics of the syllable rhyme including the proportion of the vowel that was glottalised. For this analysis multilevel modelling was carried out in SPSS linear mixed model. We measured vowel duration, coda closure duration, C/V ratio (the ratio of closure duration to vowel duration), and the ratio of glottalisation duration to vowel duration. Fixed factors included voicing, age group, gender, and vowel. Speaker was added as a random factor. For this analysis the vowel /ʉː/ was not included, to allow for a comparison between vowel pairs with a long/short opposition (/iː, ɪ/, /ɐː, ɐ/, /oː, ɔ/). We estimated the model with main effects and interactions between all two and three way combinations of variables. Post-hoc pairwise comparisons with Bonferroni correction for multiple comparisons were conducted to examine the effects of individual variables.

The two separate analyses allowed us to examine any apparent relationship between the presence of glottalisation and a reduction of durational cues to coda consonant voicing.

4. Results

This chapter provides the results of three different data analyses. First the overall descriptive figures for the presence of glottalisation in the data will be presented. Secondly, the results of the multivariate logistic regression to uncover the factors that predict glottalisation will be reported. Finally, the mixed effects multilevel modelling results of the durational analysis will be presented.

4.1 Descriptive data

4.1.1 Presence of glottalisation

From the 2427 tokens of recorded speech analysed, a total of 753 of the tokens exhibited the presence of glottalisation (31%). Of these glottalised tokens, 683 were in the voiceless coda context (55% of all voiceless coda context tokens), while only 70 tokens were glottalised preceding voiced codas (6% of all voiced coda context tokens). These results are illustrated respectively in Figures 4.1 and 4.2 below. A summary of the overall presence of glottalisation in the data can be seen in Table 4.1 below.

Table 4.1. Overall presence of glottalisation according to coda voicing context.

		Glottalisation present		
		No	Yes	Total
Voicing context	Voiced	1109 (94%)	70 (6%)	1179
	Voiceless	565 (45%)	683 (55%)	1248
Total		1674 (69%)	753 (31%)	2427

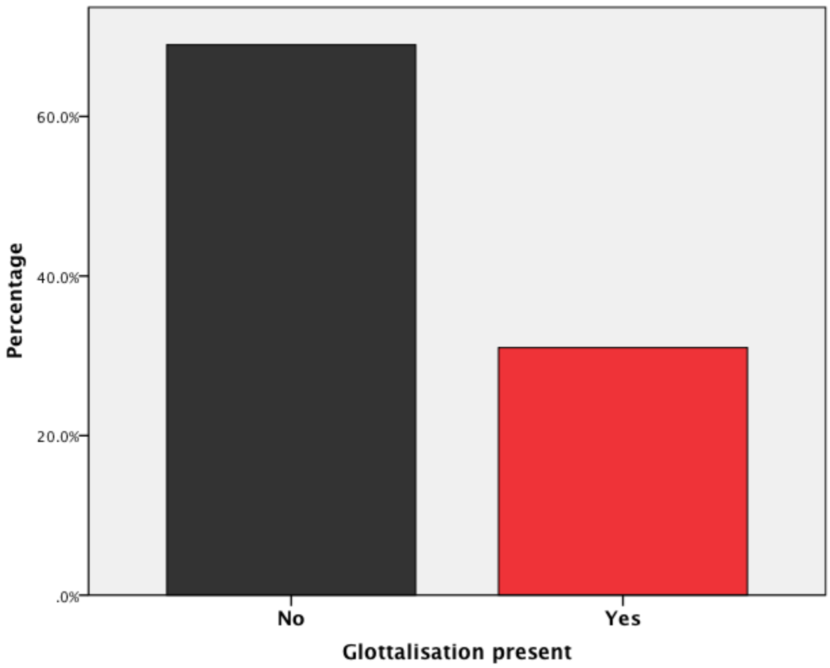

Figure 4.1. Overall percentages for the presence and absence of glottalisation.

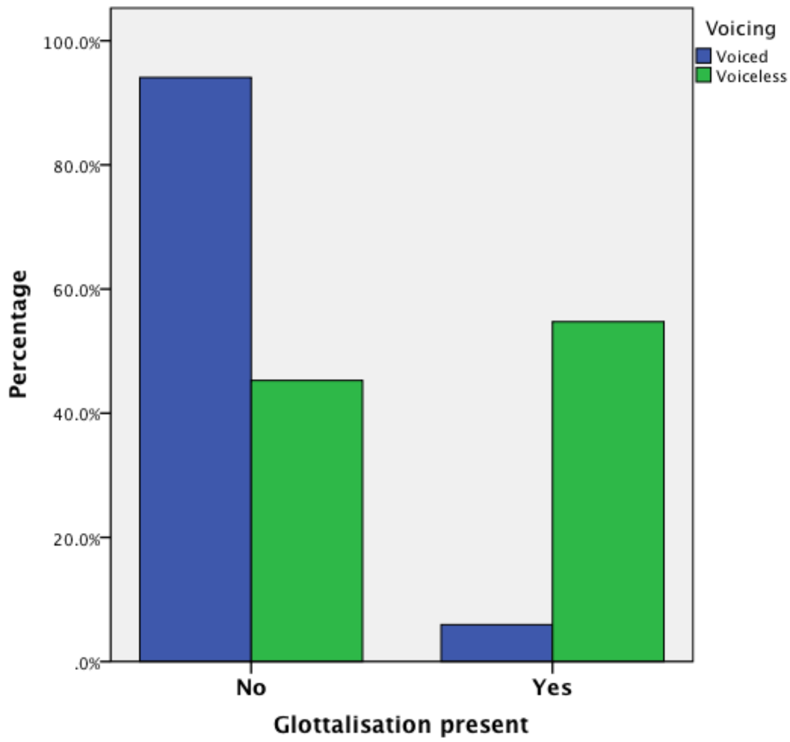

Figure 4.2. Overall percentages for the presence and absence of glottalisation according to coda voicing context.

Figure 4.3 shows the distribution of glottalisation according to coda voicing for each vowel examined. As can be seen, for each of the individual vowels glottalisation occurs more often in the voiceless context. Within the voiceless coda context the vowels /oː/ and /ɔ/ display the highest percentage of glottalised tokens, with 64% of voiceless coda tokens exhibiting glottalisation for both of these vowels. /ɐː/ shows the next highest level of glottalisation, with 61% of voiceless coda tokens exhibiting glottalisation, followed by /ɐ/ with 59%, /ɪ/ with 51%, and /ʉː/ with 47%. The vowel with the least occurrence of glottalisation recorded was /iː/, with 37.5% of tokens in the voiceless coda context displaying glottalisation. A table outlining the figures for the presence of glottalisation according to coda voicing by vowel is provided in Appendix A.

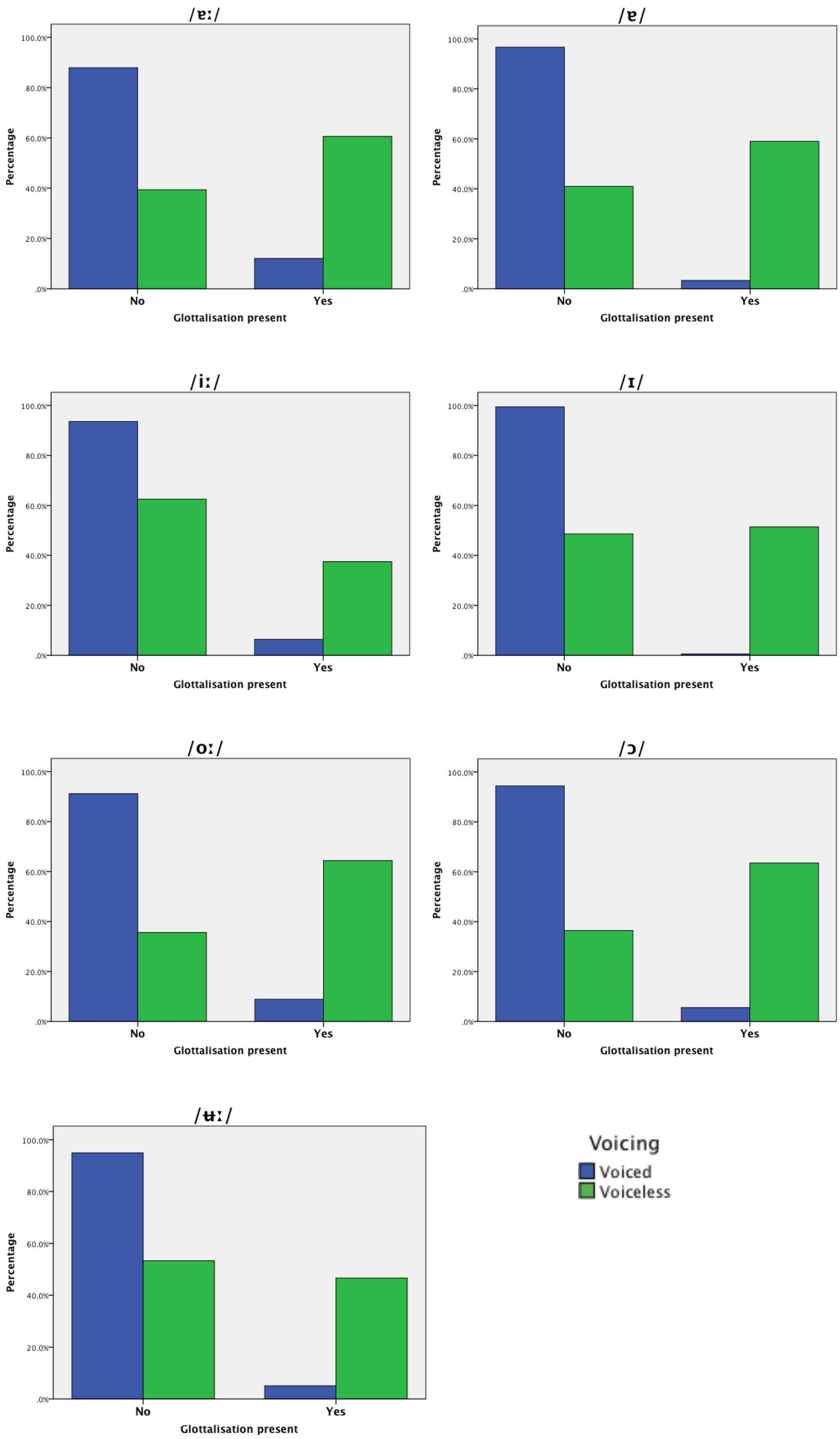

Figure 4.3. Percentages for the presence and absence of glottalisation according to coda voicing context for each vowel.

Table 4.2 displays the number of tokens that were glottalised for each vowel, for each of the voiced and voiceless coda contexts. As can be seen, of the tokens that were glottalised, 91% occurred in the voiceless coda context, whereas only 9% of the glottalised tokens occurred in the voiced coda context. Each of the individual vowels analysed displayed the same tendency with regard to coda voicing; glottalisation was far more likely to be present in the voiceless coda context than in the voiced coda context. This is illustrated in Figure 4.4 below.

Table 4.2. For glottalised tokens only, the number and percentages according to coda voicing context by vowel.

		Voicing		
		Voiced	Voiceless	Total
Vowel	ɐː	21 (17%)	106 (83%)	127
	ɐ	6 (5%)	108 (95%)	114
	iː	8 (11%)	66 (89%)	74
	ɪ	1 (1%)	92 (99%)	93
	oː	15 (12%)	112 (88%)	127
	ɔ	10 (8%)	115 (92%)	125
	ʉː	9 (10%)	84 (90%)	93
Total		70 (9%)	683 (91%)	753

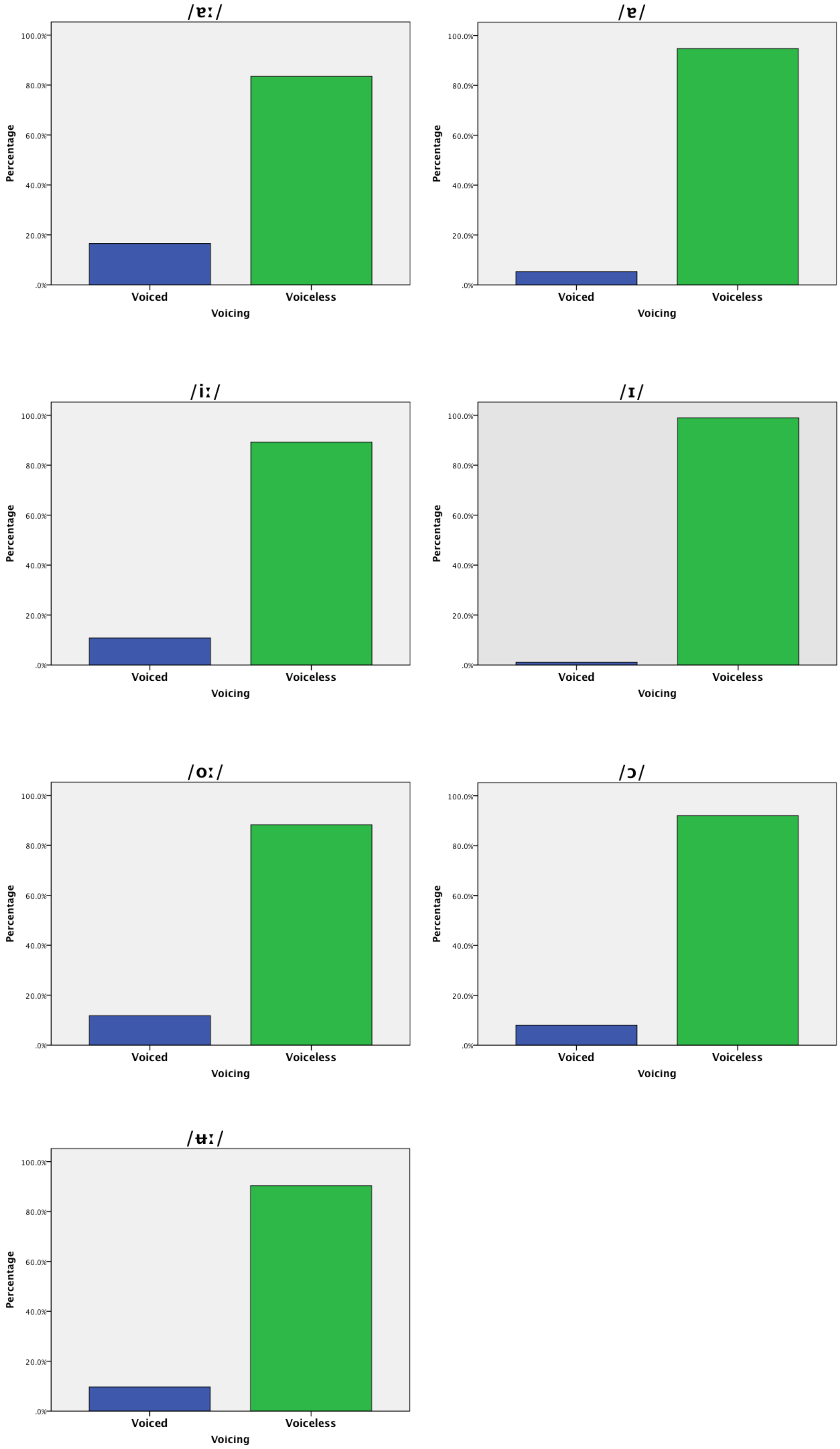

Figure 4.4. For glottalised tokens only, the percentage of occurrence according to coda voicing context for each vowel.

4.1.2 Presence of glottalisation according to age

Although 31% of all tokens were glottalised overall, when the two age groups are considered separately an interesting pattern emerges. Table 4.3 shows that the younger group produced 500 glottalised tokens from a total of 1289; that is, 39% of the tokens produced by the young group were glottalised. By contrast, the older group produced 253 glottalised tokens from a total of 1138; that is, 22% of the tokens produced by the older group exhibited glottalisation. This is illustrated in Figure 4.5 below.

Table 4.3. Presence of glottalisation according to age group.

		Glottalisation present		
		No	Yes	Total
Age group	Older	885 (78%)	253 (22%)	1138
	Younger	789 (61%)	500 (39%)	1289
Total		1674 (69%)	753 (31%)	2427

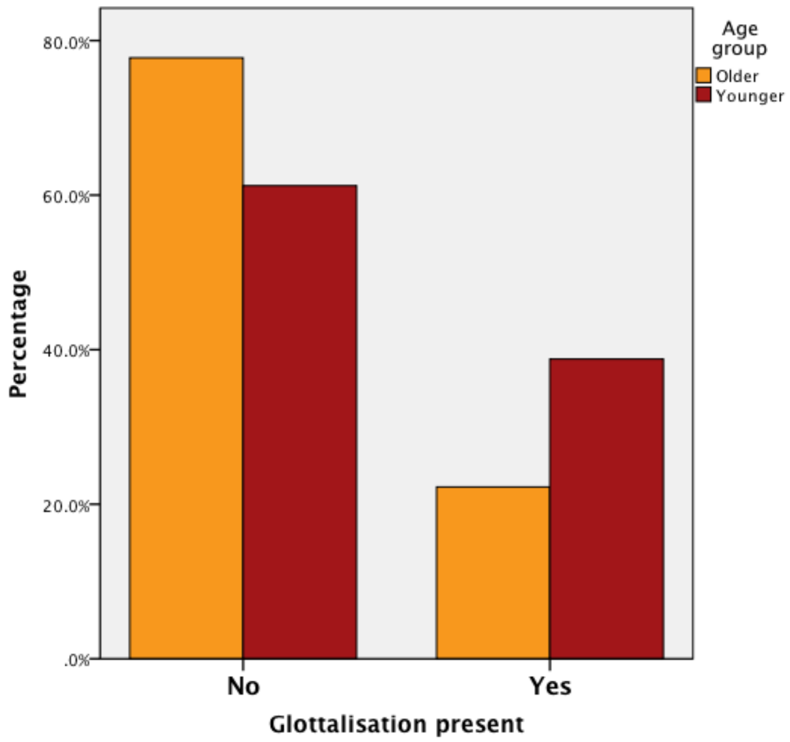

Figure 4.5. Overall percentages for the presence and absence of glottalisation according to age group.

Although the overall level of glottalisation differed between the two age groups, both of the groups produced far more glottalisation in the voiceless coda context than in the voiced coda context. Table 4.4 shows that the younger group glottalised 4% of the tokens in the voiced coda context compared to 71% of the tokens in the voiceless coda context; the older group glottalised 8% of the tokens in the voiced context compared to 36% of the tokens in the voiceless coda context. This is illustrated in Figure 4.6 below.

Table 4.4. Presence of glottalisation according to coda voicing context and age group.

Age group			Glottalisation present: No	Glottalisation present: Yes	Total
Older	Voicing	Voiced	512 (92%)	44 (8%)	556
		Voiceless	373 (64%)	209 (36%)	582
	Total		885 (78%)	253 (22%)	1138
Younger	Voicing	Voiced	597 (96%)	26 (4%)	623
		Voiceless	192 (29%)	474 (71%)	666
	Total		789 (61%)	500 (39%)	1289

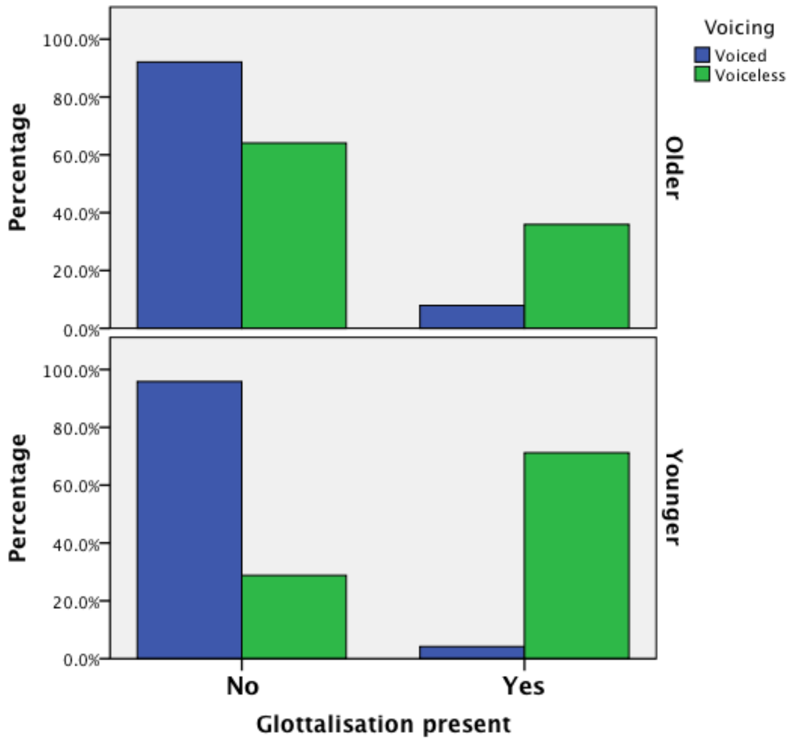

Figure 4.6. Percentages for the presence and absence of glottalisation according to coda voicing context and age group.

Figure 4.7 shows the distribution of glottalisation according to coda voicing context for each vowel examined for the older and younger age groups. Glottalisation is far more common in the voiceless coda context for each vowel in both of the age groups. For the older speakers, /oː/ exhibits the most glottalisation in the voiceless coda context, with 47.5% of tokens displaying glottalisation. This is followed by /ɐː/ with 47%, /ɔ/ with 43%, /ɐ/ with 34%, /ʉː/ with 30%, and /ɪ/ with 28%. /iː/ exhibited the least amount of glottalisation with only 22% of the tokens in the voiceless coda context being glottalised. For the younger speakers all of the vowels exhibited more glottalisation than those produced by the older speakers. /ɔ/ was most frequently glottalised by the younger speakers, with 83% of all tokens in the voiceless coda context displaying glottalisation. Following /ɔ/ was /ɐ/ with 81%, /oː/ with 79%, /ɐː/ and /ɪ/ both with 72%, and /ʉː/ with 61%. /iː/ was again the vowel that exhibited the least amount of glottalisation, with 50% of tokens in the voiceless coda context being glottalised. A table outlining the figures for the presence and absence of glottalisation according to coda voicing context by vowel and age group is provided in Appendix A.

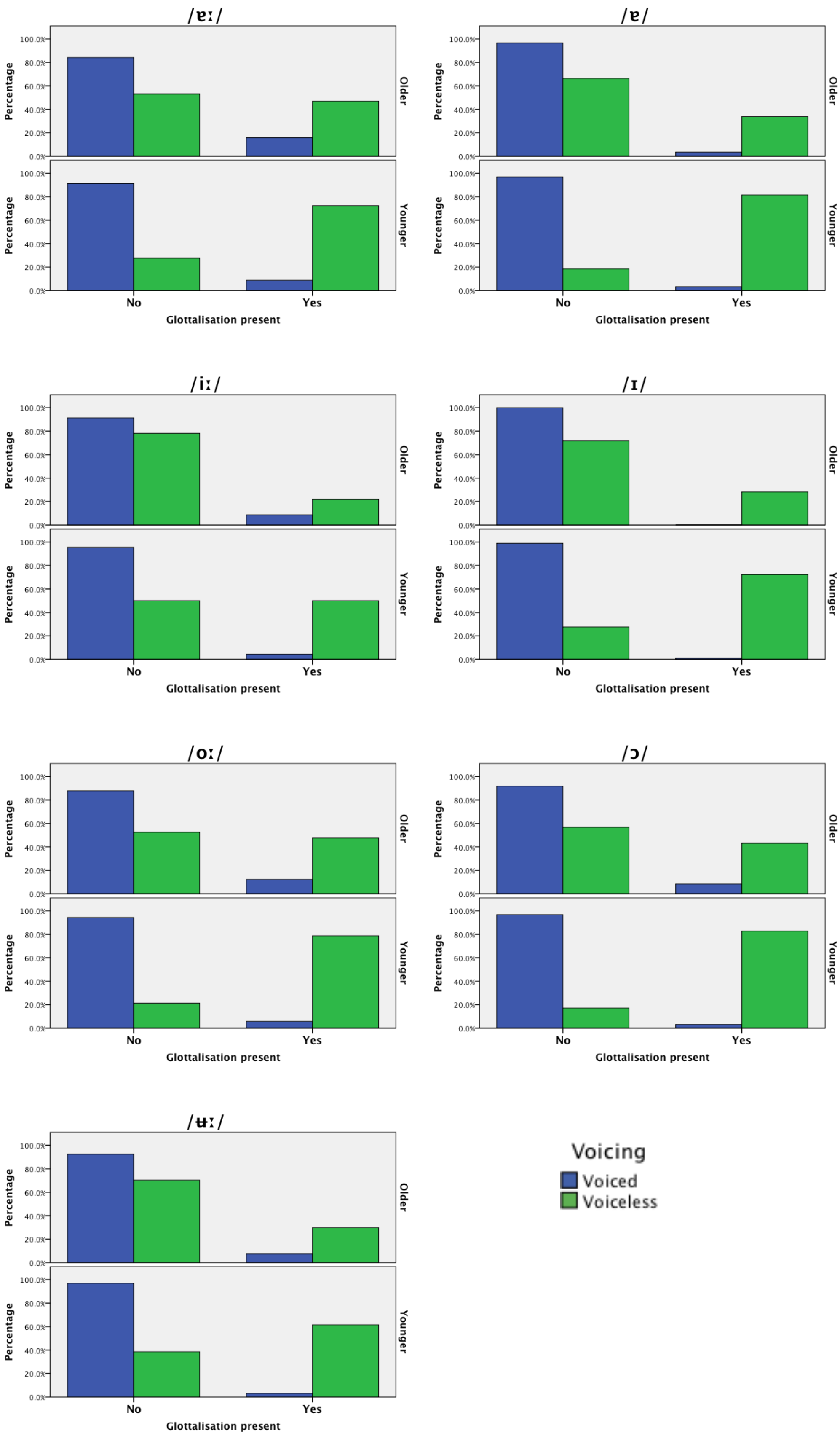

Figure 4.7. Percentages for the presence and absence of glottalisation according to coda voicing context and age group for each vowel.

Although the vast majority of glottalised tokens occurred in the voiceless coda context for both age groups, the older group produced a higher proportion of glottalised tokens in the voiced context than the younger group. When only the glottalised tokens are considered, 95% of the tokens that were glottalised by the younger group occurred in the voiceless coda context, whereas 83% of the tokens that were glottalised by the older group occurred in the voiceless context. Or put slightly differently, 5% of the younger group's glottalised tokens occurred in the voiced coda context, compared to 17% for the older group. This tendency for older speakers to produce more glottalised tokens than the younger speakers in the voiced context was visible for each of the vowels apart from /ɪ/, which exhibited no glottalisation in the voiced coda context for the older group, and only one token in the voiced coda context for the younger group. A table outlining the number and percentage of glottalised tokens according to coda voicing context for each vowel for the older and younger age groups is provided in Appendix A.

4.1.3 Presence of glottalisation according to gender

Differences in the amount of overall glottalisation were also visible when gender was examined. Table 4.5 shows that the female speakers produced 405 glottalised tokens from a total of 1099 (37%). By contrast, the male speakers produced 348 glottalised tokens from a total of 1328 (26%). This is illustrated in Figure 4.8 below.

Table 4.5. Presence of glottalisation according gender.

		Glottalisation present		Total
		No	Yes	
Gender	Female	694 (63%)	405 (37%)	1099
	Male	980 (74%)	348 (26%)	1328
Total		1674 (69%)	753 (31%)	2427

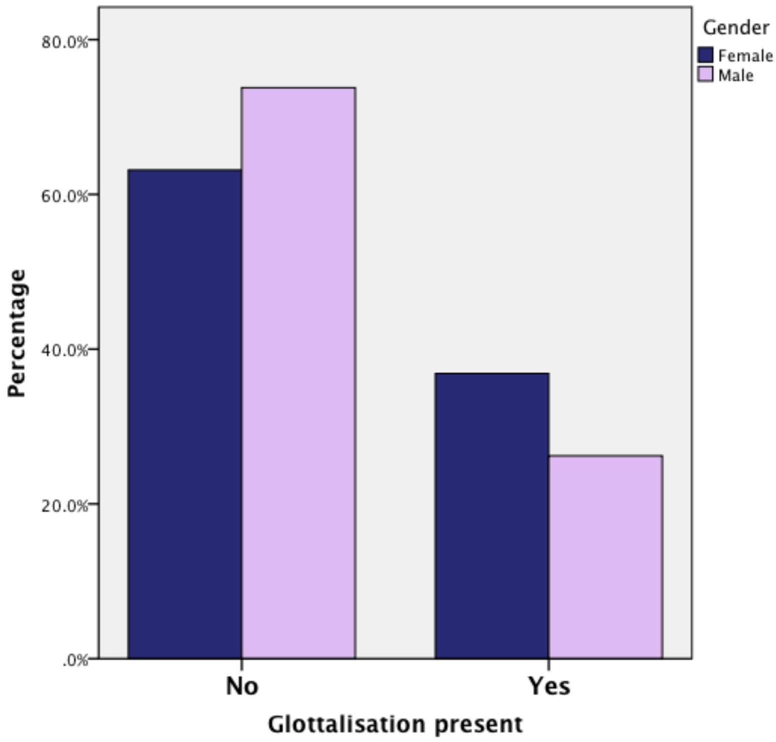

Figure 4.8. Overall percentages for the presence and absence of glottalisation according to gender.

Although the females produced more glottalised tokens overall both female and male speakers showed the same tendency to produce more glottalisation in the voiceless coda context rather than in the voiced coda context. Table 4.6 shows that the female speakers glottalised 9% of all tokens in the voiced coda context compared to 63% in the voiceless coda context. The male speakers on the other hand glottalised 4% of all tokens in the voiced context compared to 48% of all tokens in the voiceless coda context. This is illustrated in Figure 4.9 below.

Table 4.6. Presence of glottalisation according to coda voicing context and gender.

Gender			Glottalisation present: No	Glottalisation present: Yes	Total
Female	Voicing	Voiced	487 (91%)	47 (9%)	534
		Voiceless	207 (37%)	358 (63%)	565
	Total		694 (63%)	405 (37%)	1099
Male	Voicing	Voiced	622 (96%)	23 (4%)	645
		Voiceless	358 (52%)	325 (48%)	683
	Total		980 (74%)	348 (26%)	1328

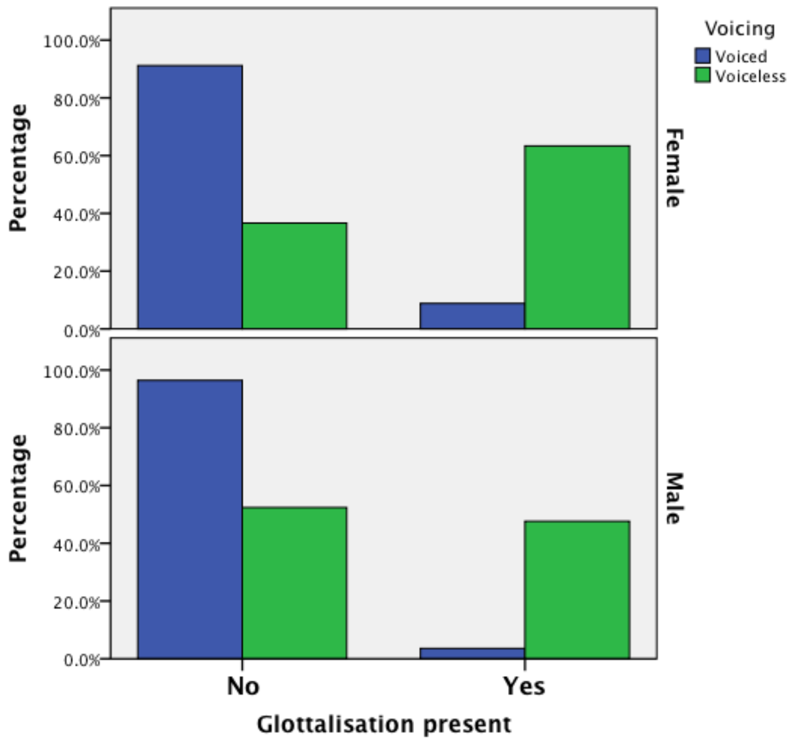

Figure 4.9. Percentages for the presence and absence of glottalisation according to coda voicing context and gender.

Table 4.7 shows the presence of glottalisation according to coda voicing context separated by both age and gender. As can be seen, the younger females produced the highest proportion of glottalised tokens in the voiceless coda context (80%), followed by the younger males (64%), the older females (44%), and then the older males (30%). These results show that in both age groups the female speakers produced more glottalisation than the males, but that the younger speakers produced more glottalisation than the older speakers regardless of gender. This is illustrated in Figure 4.10 below.

Table 4.7. Presence of glottalisation according to coda voicing context, gender, and age group.

				Glottalisation present		
Gender	Age group			No	Yes	Total
Female	Older	Voicing	Voiced	225 (90%)	24 (10%)	249
			Voiceless	144 (56%)	113 (44%)	257
		Total		369	137	506
	Younger	Voicing	Voiced	262 (92%)	23 (8%)	285
			Voiceless	63 (20%)	245 (80%)	308
		Total		325	268	593
Male	Older	Voicing	Voiced	287 (93%)	20 (7%)	307
			Voiceless	229 (70%)	96 (30%)	325
		Total		516	116	632
	Younger	Voicing	Voiced	335 (99%)	3 (1%)	338
			Voiceless	129 (36%)	229 (64%)	358
		Total		464	232	696

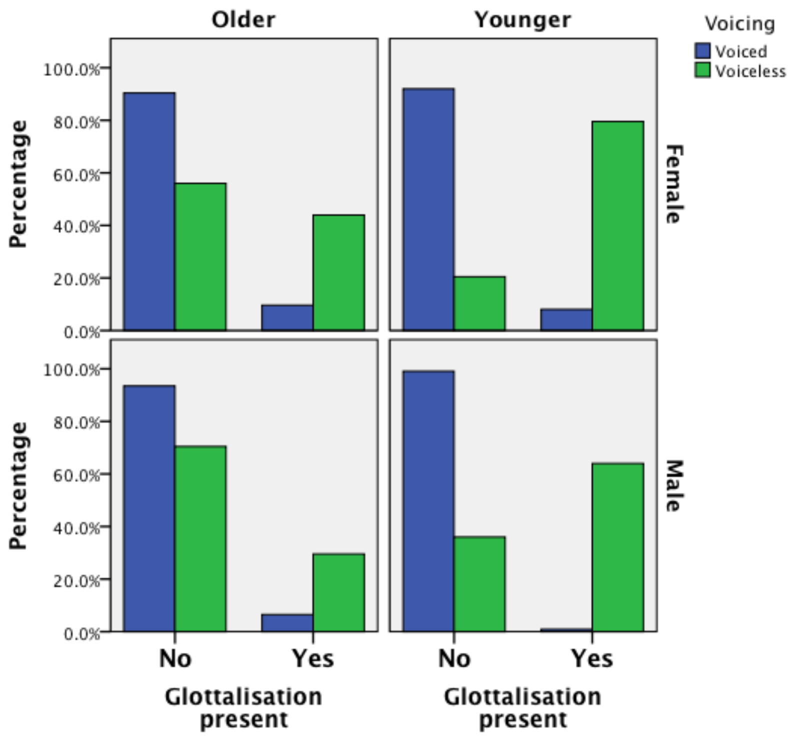

Figure 4.10. Percentages for the presence and absence of glottalisation according to coda voicing context, age group, and gender.

For each vowel speakers of both genders in both age groups produced far more glottalisation in the voiceless context. Figure 4.11 illustrates the percentage of glottalised tokens in the voiceless coda context for each vowel according to age group and gender. Within the voiceless coda context, the younger females and the older males glottalised /oː/ most often; the younger males glottalised /ɔ/ most frequently; and the older females glottalised /ɐː/ most often. The results also show that /iː/ is the vowel that is least frequently glottalised across both age groups and genders. /ʉː/ also shows a tendency to be glottalised less often than the other vowels, with all groups apart from the older males glottalising this vowel only more frequently than /iː/. A table outlining the full figures for the presence and absence of glottalisation for each vowel according to coda voicing context, age group, and gender as well as figures illustrating this distribution individually for each vowel are provided in Appendix A.

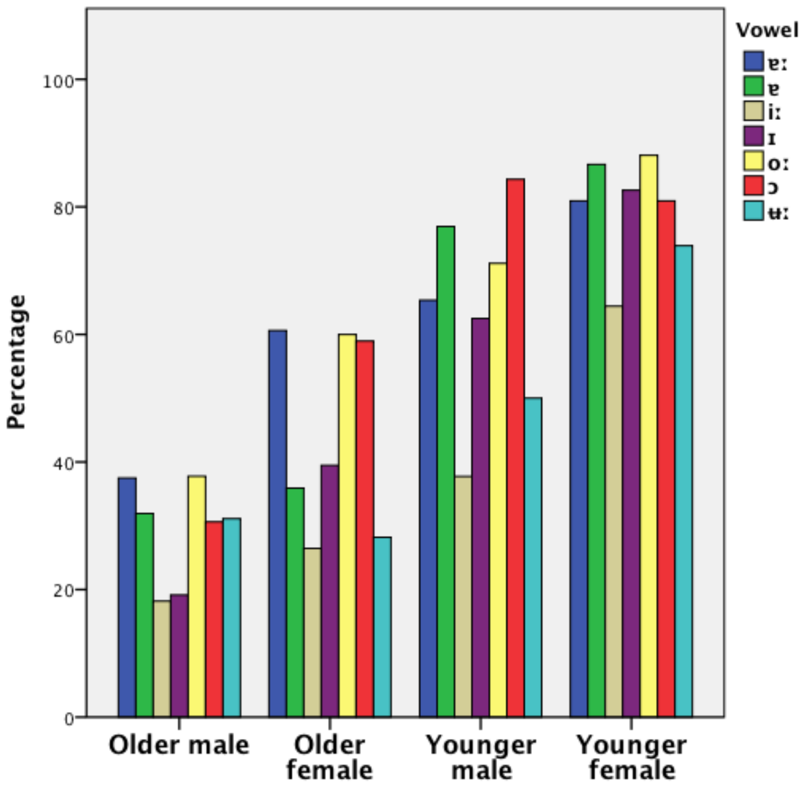

Figure 4.11. Percentage of glottalised tokens in the voiceless coda context for each vowel according to age group and gender.

Another age effect was that the younger speakers produced less glottalisation in the voiced coda context than the older speakers. 17% of the glottalised tokens produced by the older males and 18% produced by the older females were in the voiced coda context. By contrast, 9% of the overall glottalised tokens produced by the younger females and only 1% of the glottalised tokens produced by the younger males were in the voiced coda context. Therefore, the younger males produced less glottalisation in the voiced coda context than all of the other groups, with no glottalised tokens produced in this context for 5 of the 7 vowels. A table outlining the distribution of glottalised tokens only for each vowel according to coda voicing context, age group, and gender is included in Appendix A.

4.1.4 Non-canonical stops

As was discussed in 3.5 above, there were 142 tokens within the data that did not provide acoustic evidence of a coda burst. Rather, for these tokens the coda stop was realised either as an unreleased stop (n = 70) or as a spirantised stop (n = 72). The distribution of these non-canonical stops according to age, gender and coda voicing context is shown in Table 4.8 below. As can be seen, unreleased stops are produced almost exclusively by younger speakers, with the majority produced by young males. Younger female speakers only produced unreleased stops in the voiceless context, while the younger male speakers produced these in both voiced and voiceless contexts at similar levels. Both older and younger speakers use spirantisation, but is more frequent for male speakers in each age group. Among both the older and younger male speakers the spirantised stops are produced predominantly in the voiceless context.

Table 4.8. Distribution of non-canonical stops according to age group, gender, and coda voicing context.

			Stop realisation		
Age group	Gender		Unreleased	Spirantised	Total
Older	Female	Voiced	0	0	0
		Voiceless	0	8	8
	Male	Voiced	1	4	5
		Voiceless	0	15	15
Younger	Female	Voiced	0	5	5
		Voiceless	10	4	14
	Male	Voiced	27	5	32
		Voiceless	32	31	63
Total			70	72	142

In addition, the unreleased tokens within the voiceless coda context displayed a high rate of glottalisation. Table 4.9 shows the percentage of tokens that were glottalised for each vowel in the voiceless coda context preceding released, unreleased, and spirantised stops. The raw number of glottalised tokens in each category is included in brackets. As can be seen, a large proportion of the unreleased tokens were glottalised for each of the vowels apart from /ʉː/, especially compared to the released and spirantised tokens. Although we were not able to test this statistically due to the small number of unreleased stops in the data, these observations suggest that glottalisation seems more prevalent preceding unreleased coda stops than released or spirantised stops. Further work to examine these effects would allow us to explore issues related to cue weighting in production and perception.

Table 4.9. Percentage of glottalised vowels preceding released, unreleased and spirantised tokens in voiceless coda context. Number of tokens is indicated in brackets.

Vowel	Released	Unreleased	Spirantised
/ɐː/	60% (93)	100% (6)	50% (7)
/ɐ/	58% (98)	89% (8)	50% (2)
/iː/	36.5% (57)	75% (3)	37.5% (6)
/ɪ/	50% (83)	100% (8)	20% (1)
/oː/	65% (106)	100% (2)	50%(4)
/ɔ/	62% (106)	100%(7)	50%(2)
/ʉː/	47% (78)	50% (3)	43% (3)

4.2 Factors associated with the presence of glottalisation

The results showed that 31% (n = 753) of all tokens contained glottalisation on the vowel before the coda stop. A multilevel mixed effects logistic regression model was fitted to the data to identify factors associated with the use of glottalisation. The variables age group, gender, voicing context, and vowel were analysed for both main effects and interactions. The results showed that the full model containing all of these factors and their two-way interactions was significant (Wald $\chi^2 = 429.85$, $df = 30$, $p < .0001$). This indicated rejection of the null hypothesis that the model without the independent variables was no different to the model that included the independent variables.

The model was then adjusted through a process of manual stepwise backward elimination. Variables that were not statistically significant were individually removed from the model, beginning with the least significant interactions. The most parsimonious model (Wald $\chi^2 = 426.11$, $df = 16$, $p < .0001$) contained the significant variables of age group, gender, voicing context, and vowel and the significant interactions between age and voicing and between vowel and voicing. A summary of these results can be seen in Table 4.10 below.

Table 4.10. Summary of significant main effects and interactions of the multilevel logistic regression analysis

Variable	*df*	χ^2	*p =*
Age group	1	37.75	0.0000
Gender	1	9.49	0.0021
Voicing context	1	22.12	0.0000
Vowel	6	65.53	0.0000
Age group X Voicing context	1	71.23	0.0000
Vowel X Voicing context	6	23.25	0.0007

The significant effect for age group shows that glottalisation has a higher likelihood of being present for younger speakers, who are 8.4 times more likely to use glottalisation than older speakers (Wald $Z = 6.14$, $df = 1$, $p < .0001$). The significant gender effect shows that there is a reduced likelihood of glottalisation being present in the speech of males with female speakers almost three times more likely to employ glottalisation than males (Wald $Z = -3.08$, $df = 1$, $p = 0.002$). The significant effect for voicing demonstrates that the probability of glottalisation being present is more than 5 times greater preceding a voiceless coda stop than it is before a voiced coda stop (Wald $Z = -4.70$, $df = 1$, $p < .0001$). These results provide strong evidence that glottalisation serves as a cue to coda voicelessness in general but more so for younger speakers than for older speakers, and that females glottalise more than males.

The significant effect for vowel shows that the presence of glottalisation varies depending on which vowel is being produced. Pairwise comparisons between the vowels demonstrate significant differences between some of the vowels (at a Bonferroni adjusted significance level of p = < .008 to account for multiple comparisons). These differences are illustrated in Table 4.11 below. As can be seen, the presence of glottalisation on the vowel /iː/ differs significantly from all of the other vowels apart from /ʉː/. Similarly, /ʉː/demonstrates significant difference to all of the vowels apart from /iː/ and /ɪ/. These pairwise comparisons also show that there are no significant differences between the long/short vowel pairs, apart from for /iː/ versus /ɪ/. These results raise the question of whether the high vowels behave differently from the non-high vowels in the prevalence of glottalisation.

Table 4.11. Significant differences in the presence of glottalisation between vowels. Asterisks represent differences that are significant at $p < 0.008$

	/ɐː/	/iː/	/ɪ/	/oː/	/ɔ/	/ɐ/	/ʉː/
/ɐː/		*					*
/iː/	*		*	*	*	*	
/ɪ/		*		*	*		
/oː/		*	*				*
/ɔ/		*	*				*
/ɐ/		*					*
/ʉː/	*			*	*	*	

Although both age group and voicing context were significant main factors in the model, the significant interaction between age group and voicing context shows that there is a greater age effect in the voiceless context than there is in the voiced context

(Wald Z = -8.44, df = 1, p < .0001). Figure 4.12 displays the marginal probabilities for the presence of glottalisation in both the voiced and voiceless contexts according to age group. As can be seen, the difference in the probability of glottalisation according to age group is greater in the voiceless context.

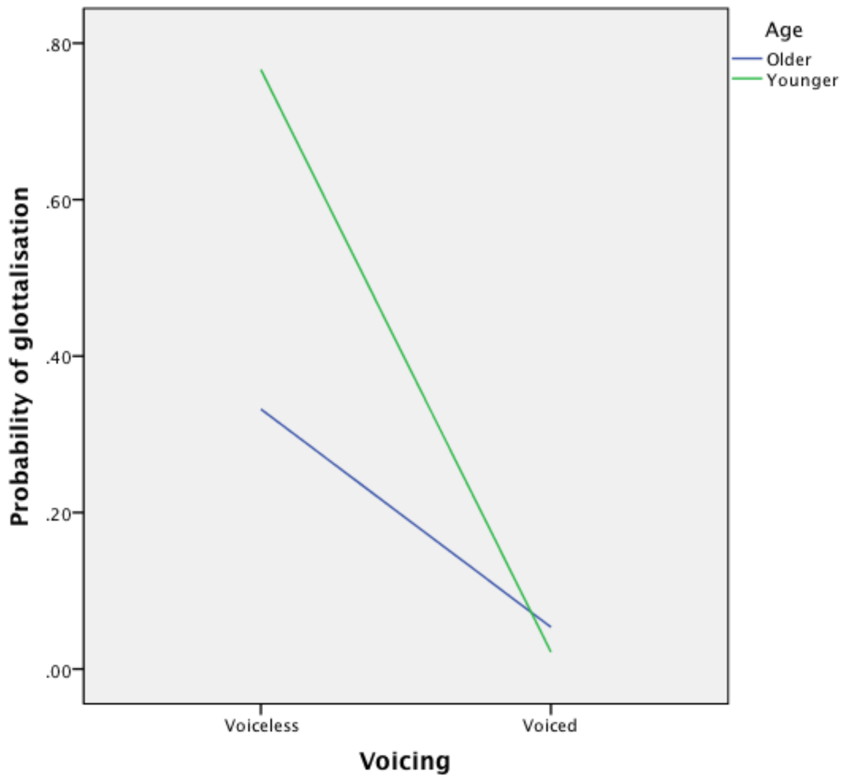

Figure 4.12. Probability of presence of glottalisation according to age and voicing context.

The results also show a significant interaction between vowel and voicing context (see Table 4.10). All of the vowels exhibited consistency in that glottalisation was far more likely to occur in the voiceless context. However, the incidence of glottalisation in the voiceless context varied according to the vowel. Figure 4.13 illustrates the marginal probabilities of the presence of glottalisation according to vowel for both voicing contexts (with other factors accounted for at their averaged values). As can be seen, the differences between vowels are rather minimal in the voiced context. In the voiceless context, on the other hand, there are quite substantial differences between the vowels. Vowel /iː/ has the least likelihood of being glottalised, followed by /ʉː/. /oː/ exhibits the greatest likelihood of being glottalised, followed by /ɔ/, /ɐː/, /ɐ/, and then /ɪ/. These results suggest that high vowels are less likely to be glottalised in the voiceless context compared to the other non-high vowels.

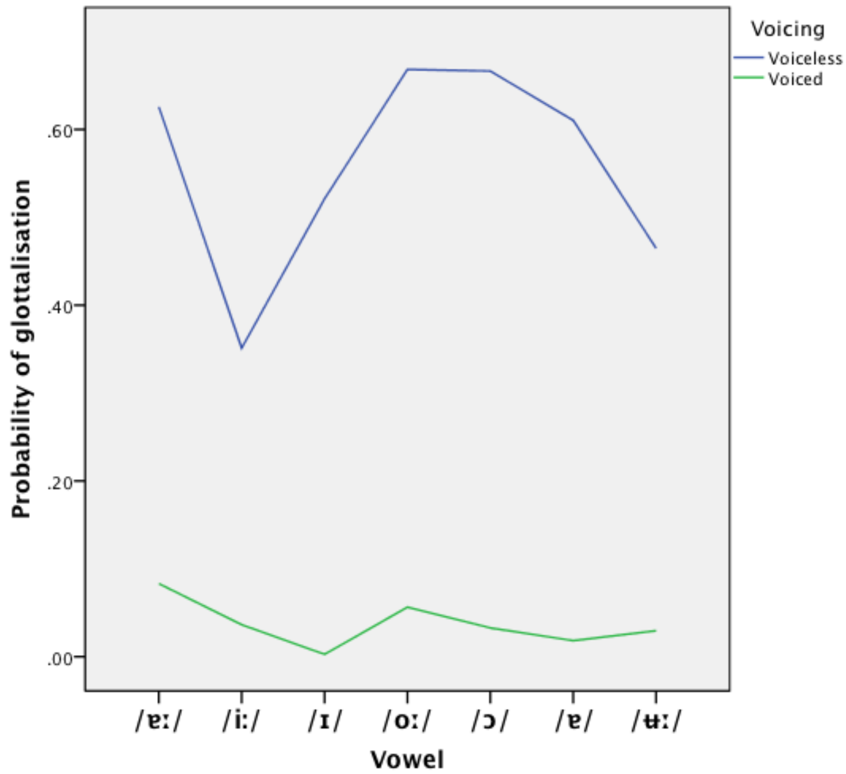

Figure 4.13. Probability of presence of glottalisation according to vowel and coda voicing context.

4.3 Durational analyses

The durational analyses were carried out to examine the temporal characteristics of the syllable rhyme. Multilevel modelling analysis included the fixed factors of age group, gender, vowel, coda voicing context and interactions between these variables. Speaker was included as a random factor. Tokens with the vowel /ʉː/ were excluded from these analyses because the short counterpart /ʊ/ was unable to be included (as discussed in 3.1 above) and we wanted to make comparisons between short and long vowel pairs, which left 2070 tokens remaining. The following parameters were examined: vowel duration, the durational difference between vowels in voiced and voiceless coda contexts, coda closure duration, the C/V ratio, and the ratio of glottalisation to vowel duration. For the coda closure duration and C/V ratio analyses, tokens in which the stop was unreleased or spirantised were excluded, leaving a total of 1953 tokens remaining for these analyses.

4.3.1 Vowel duration

Vowel duration was first examined across all of the vowels. Age group, gender, and coda voicing context were included as fixed factors. We also looked for two and three way interactions between these factors. Speaker was included as a random factor. The results showed significant main effects for gender ($F(1, 2062) = 22.188$, $p < .0001$), with females displaying longer vowels than males, and voicing ($F(1, 2062) = 278.99$, $p < .0001$) as expected, with longer vowels occurring in voiced contexts, as well as a significant interaction between age group and voicing ($F(1, 2062) = 16.528$, $p < .0001$). The interaction indicates that voicing affects the vowel duration for the older speakers more so than the younger speakers.

We then carried out an analysis of vowel duration separately for each of the vowels and gender groups, to examine whether there were differences in the behaviour of individual vowels. Fixed factors were age group and voicing. Speaker was included as a random factor. Table 4.12 displays the significant main effects and interactions of this analysis. As expected, there was a significant effect for voicing for both male and female speakers for all of the vowels. The results also showed a significant main effect for age group among the female speakers for the vowels /ɐː/, /ɐ/, and /iː/, as well as a significant interaction between age and voicing for /oː/, /iː/, and /ɪ/. Post-hoc analyses (Bonferroni corrected) revealed that voicing was significant in both the older and younger age groups, but had a larger effect on the older speakers for each of these vowels ($p < .0001$). Among the male speakers there was a significant main effect for age group for all of the vowels apart from /iː/, and a significant interaction between age group and voicing for all of the vowels apart from /ɪ/. Post-hoc analyses (Bonferroni corrected) showed that voicing was significant in both the older and younger age groups, but had a larger effect on the older speakers for all of these vowels ($p < .0001$). These results show that the differences in vowel duration according to voicing context are reduced in the younger speakers for both males and females, but for male speakers this is significant for a greater number of vowels. It is also particularly interesting that younger males have a smaller difference in vowel duration according to voicing for the vowels /ɐː/ and /ɐ/ than older males do but this effect does not occur for females. This suggests that for certain vowels the older females behave similarly to the younger females, whereas the males do not. In other words, it seems that the older males make more use of vowel duration differences than the other groups as a cue to coda voicing.

Table 4.12. Summary of significant main effects and interactions of the mixed model analysis of vowel duration for each vowel within gender group.

Variable	Vowel	*df*	*F*	*p =*
Females				
Voicing	ɐː	1, 149	79.891	.000
	ɐ	1, 161	57.294	.000
	iː	1, 131	264.256	.000
	ɪ	1, 160	56.547	.000
	oː	1, 147	123.967	.000
	ɔ	1, 160	46.702	.000
Age group	ɐː	1, 149	25.338	.000
	ɐ	1, 161	4.089	.045
	iː	1, 131	5.756	.018
Age group X Voicing	oː	1, 147	10.950	.001
	iː	1, 131	5.262	.023
	ɪ	1, 160	9.822	.002
Males				
Voicing	ɐː	1, 192	134.814	.000
	ɐ	1, 194	30.690	.000
	iː	1, 162	358.362	.000
	ɪ	1, 186	64.546	.000
	oː	1, 188	202.797	.000
	ɔ	1, 192	44.483	.000
Age group	ɐː	1, 192	13.749	.000
	ɐ	1, 194	11.021	.001
	ɪ	1, 186	9.234	.003
	oː	1, 188	5.764	.017
	ɔ	1, 192	6.216	.014
Age group X Voicing	ɐː	1, 192	11.792	.001
	ɐ	1, 194	5.352	.022
	iː	1, 162	12.311	.001
	oː	1, 188	22.304	.000
	ɔ	1, 192	7.722	.006

The results demonstrate that vowels are significantly longer preceding voiced coda consonants, and this effect is consistent regardless of gender. Figure 4.14 shows the mean vowel duration according to coda voicing for each of the vowels for the older and younger age groups separated by gender. This figure also shows that phonologically long vowels are longer than short vowels, regardless of coda voicing context. Mean vowel durations for each vowel according to age and gender are provided in Appendix B.

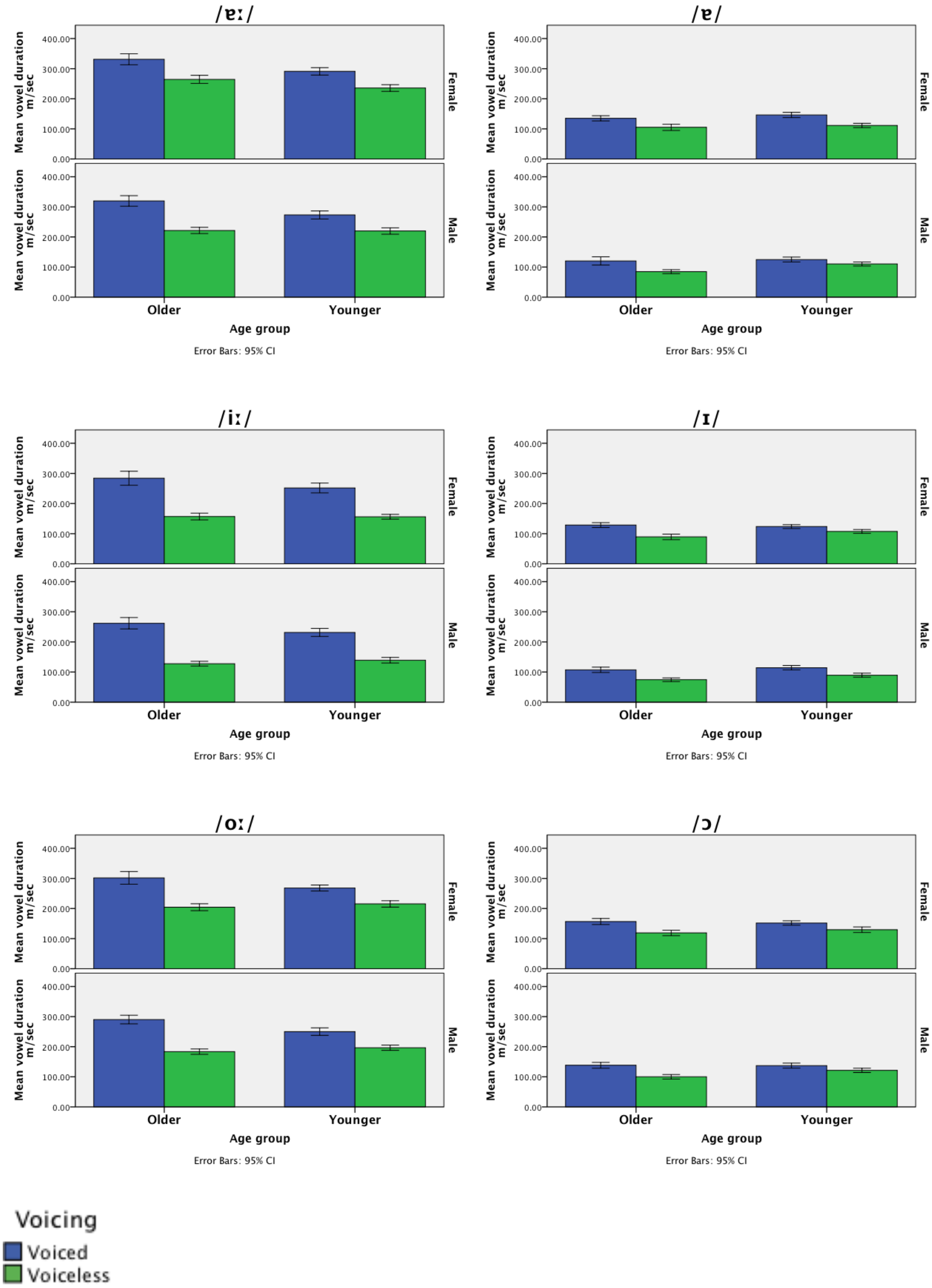

Figure 4.14. Mean vowel duration for each vowel by age group and gender. Error bars represent 95% confidence intervals.

4.3.2 Durational differences

The previous analysis suggests that the older and younger speakers use coda voicing related vowel duration differently. In order to further explore this effect we subtracted the average vowel duration for each vowel type in the voiceless context for each speaker from the average vowel duration for each vowel type in the voiced context for each speaker. The duration difference measures were subjected to a mixed model analysis. Fixed factors were gender, age group, and vowel. We examined both main effects and two- and three-way interactions. The results showed no significant effect for gender, but significant effects for age group ($F(1, 371) = 71.046$, $p < .0001$) and vowel ($F(5, 371) = 81.373$, $p < .0001$), and a significant interaction between age group and vowel ($F(5, 371) = 3.638$, $p = .003$).

As gender was not significant the results were pooled to provide a more robust examination and a new analysis was conducted with age group and vowel as fixed factors. The results showed significant main effects for age group ($F(1, 383) = 76.389$, $p = < .0001$) and vowel ($F(5, 371) = 86.039$, $p = < .0001$), as well as a significant interaction between age group and vowel ($F(5,371) = 3.538$, $p = .0004$). Post-hoc analyses (Bonferroni corrected) showed that /ɐː/ and /oː/ do not differ significantly from one another in the voicing induced vowel length effect but differ significantly from all of the short vowels and /iː/, which shows the largest voicing related durational difference for both younger and older speakers ($p < .0001$). The short vowels do not differ significantly from each other but differ significantly from all of the long vowels ($p < .0001$). These effects are illustrated in Figure 4.15 below. As can be seen, the older speakers have a larger durational difference according to voicing than the younger speakers, and this difference is greatest for long vowels.

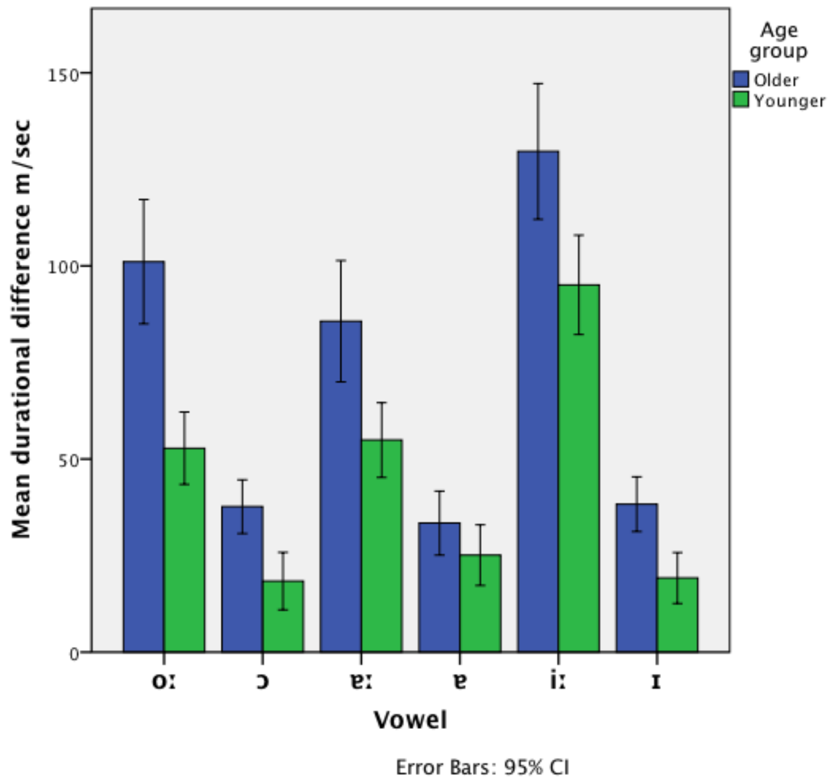

Figure 4.15. Mean durational difference for each vowel according to age group. Error bars represent 95% confidence intervals.

When the short vowels are analysed separately there is a significant effect for age group (F(1,195) = 27.282, p = < .0001), but no significant effect for vowel and no significant interaction. This confirms that the short vowels behave similarly but that younger speakers have a smaller difference in vowel duration between the voiced and voiceless coda contexts. When the long vowels are analysed separately there is a significant effect for age group (F(1,188) = 49.048, p = < .0001) and for vowel (F(1,188) = 23.370, p = < .0001), but no significant interaction. This suggests that among the long vowels younger speakers also have a smaller difference in vowel duration between the voiced and voiceless coda contexts, but that there is a greater durational difference across voicing contexts for/iː/ than for the other vowels. These effects are illustrated for short vowels in Figure 4.16 and for long vowels in Figure 4.17 below.

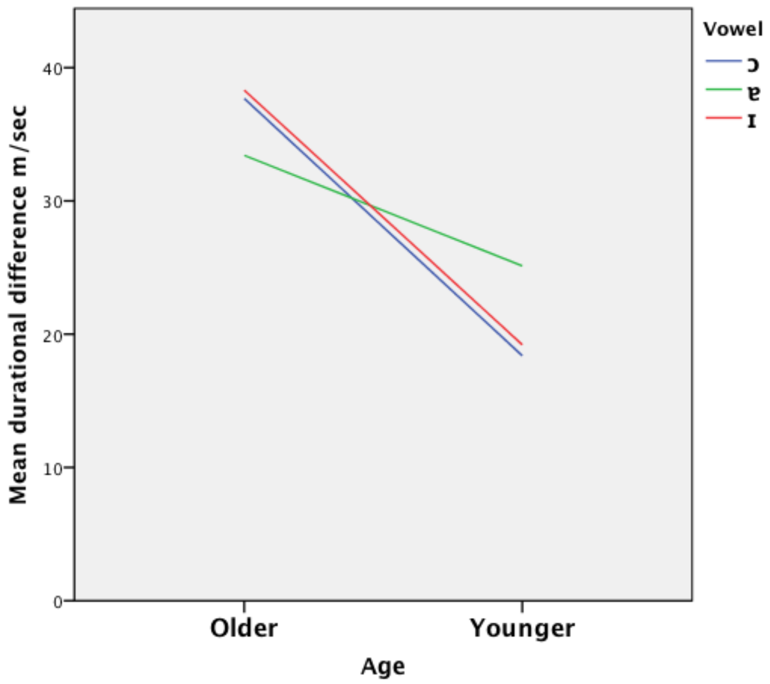

Figure 4.16. Mean durational difference (m/sec) according to coda voicing context for short vowels by age group.

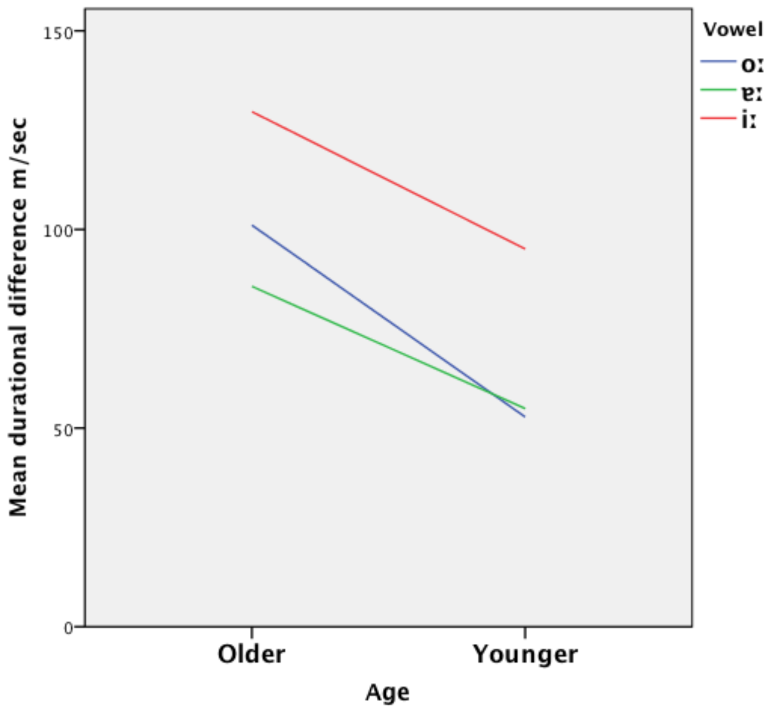

Figure 4.17. Mean durational difference (m/sec) according to coda voicing context for long vowels by age group.

4.3.3 Coda closure duration

Coda closure duration was also examined for rhymes across all of the vowels. Age group, gender, and coda voicing context were included as fixed factors. We also looked for two and three way interactions between these factors. Speaker was included as a random factor. The results showed significant effects for gender (F(1, 1945) = 79.041, p < .0001), age group (F(1,1945) = 9.171, p = .002), voicing (F(1, 1945) = 43.202, p < .0001), and significant interactions between age group and gender (F(1,1945) = 20.862, p < .0001), age group and voicing (F(1, 1945) = 221.187, p < .0001), and gender and voicing (F(1, 1945) = 35.647 p < .0001). These results demonstrate that coda closure duration is greater for voiceless stops as expected, that there is a greater difference in closure duration between the male and female speakers for the younger age group compared to the older age group, that there is a greater difference between the coda voicing contexts for the older speakers, and that females have greater closure durations than males in the voiceless coda context.

An analysis of coda closure duration was then conducted separately for each of the vowel contexts separated by gender. Fixed factors were age group and voicing. Speaker was included as a random factor. Table 4.13 gives the significant main effects and interactions of this analysis. The results showed a significant main effect for voicing for the female speakers in each of the vowel contexts. However, among the male speakers voicing reached significance for rhymes containing /ɐː/, /iː/, and /ɪ/ only. The results showed no significance for age group among the female speakers. There was, however, a significant interaction between age group and voicing in the vowel contexts of /ɐː/, /ɐ/, and /iː/. Post-hoc analyses (Bonferroni corrected) showed significant voicing effects for both the older and younger age groups for /iː/ (p < .0001), and a significant effect only for the younger speakers for /ɐː/ (p < .0001) and /ɐ/ (p = .002). Among the male speakers there was a significant main effect for age group in the vowel contexts of /ɐː/, /iː/, /oː/, and /ɔ/ and a significant interaction between age and voicing for /ɐː/, /iː/, /ɪ/, and /oː/. Post-hoc analyses (Bonferroni corrected) showed a significant voicing effect for the younger age group only for /ɐː/ ($p < .0001$), /iː/ ($p < .0001$), and /oː/ ($p = .007$), and a significant voicing effect for the older age group only for /ɪ/ ($p < .0001$).

Table 4.13. Summary of significant main effects and interactions of the mixed model analysis of coda closure duration for each vowel within gender group.

Variable	Vowel	*df*	*F*	*p =*
Females				
Voicing	ɐː	1, 149	79.891	.000
	ɐ	1, 161	57.294	.000
	iː	1, 131	264.256	.000
	ɪ	1, 160	56.547	.000
	oː	1, 147	123.967	.000
	ɔ	1, 160	46.702	.000
Age group X Voicing	ɐː	1, 140	5.368	.022
	ɐ	1, 158	4.797	.030
	iː	1, 128	5.366	.022
Males				
Voicing	ɐː	1, 175	7.190	.008
	iː	1, 140	19.995	.000
	ɪ	1, 174	9.091	.003
Age group	ɐː	1, 175	8.614	.004
	iː	1, 140	4.145	.044
	oː	1, 172	13.401	.000
	ɔ	1, 179	12.107	.001
Age group X Voicing	ɐː	1, 175	7.259	.008
	iː	1, 140	3.957	.049
	ɪ	1, 174	9.802	.002
	oː	1, 172	5.761	.017

Figure 4.18 shows the mean coda closure durations in each of the vowel contexts for the older and younger age groups separated by gender. As can be seen, for the female speakers coda closure duration is longer in the voiceless compared to the voiced coda

context in each vowel context for each age group; the male speakers, however, did not exhibit this same pattern in all of the vowel contexts. Mean coda closure durations for each vowel context according to age and gender are provided in Appendix B.

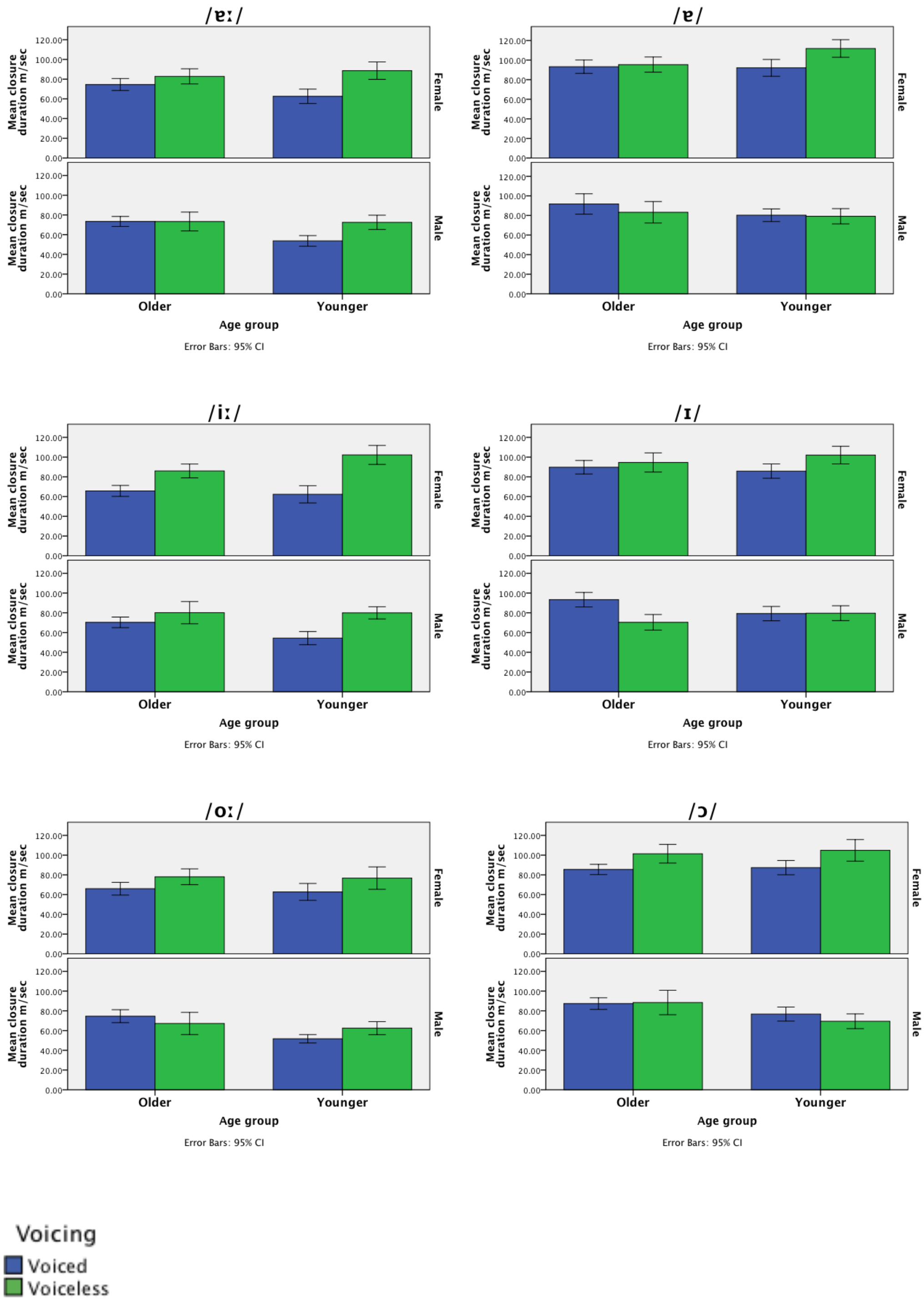

Figure 4.18. Mean coda closure duration in each vowel context by age group and gender. Error bars represent 95% confidence intervals.

4.3.4 C/V ratio

By examining the C/V ratio we were able to analyse the temporal relations between the two components of the syllable rhyme. This allowed us to observe the proportions of the rhyme that the vowel and closure comprised, thereby enabling a comparison across vowels with inherently different lengths. Ratio values close to 1 indicate that the vowel and coda closure occupy a relatively equal proportion of the rhyme; lower ratio values indicate that the vowel occupies a larger proportion of the rhyme than the coda closure. C/V ratios were first analysed across all of the vowels. An initial mixed model analysis to examine the factors age group, gender, coda voicing context and vowel revealed no gender effect so we conducted a further analysis collapsed over gender with the factors age group, coda voicing context, and vowel to examine main effects and interactions between factors. Speaker was included as a random factor. The results showed a significant main effect for age group ($F(1, 1929) = 20.087$, $p < .0001$), with the younger group exhibiting lower C/V ratios indicating the vowel occupies a larger proportion of the rhyme, voicing ($F(1, 1929) = 215.483$, $p < .0001$), with higher C/V ratios occurring in the voiceless context, and vowel ($F(5, 1929) = 208.380$, $p < .0001$), showing that the individual vowels behaved differently. Significant interactions were also found between age group and vowel ($F(1, 1929) = 3.514$, $p = .004$) and coda voicing context and vowel ($F(1, 1929) = 5.292$, $p < .0001$). These interactions show that the difference between age groups is greater for some vowels than others, and that certain vowels behave differently with respect to voicing.

When the data are considered separately by age group there is a significant effect for the older speakers for voicing ($F(1, 941) = 73.609$, $p < .0001$) and vowel ($F(1, 941) = 85.139$, $p < .0001$), but no significant interactions. Post-hoc analyses (Bonferroni corrected) show that each long vowel differs significantly from each short vowel; among the short vowels, /ɪ/ does not differ from /ɐ/; among the long vowels, /iː/ differs from all vowels except /oː/. These results can be seen in Table 4.14 below.

Table 4.14. Significant C/V ratio differences between vowels for older age group across coda voicing contexts. Asterisks represent differences that are significant at *p* < 0.008.

	/oː/	/ɔ/	/ɐː/	/ɐ/	/iː/	/ɪ/
/oː/		*		*		*
/ɔ/	*		*	*	*	*
/ɐː/		*		*	*	*
/ɐ/	*	*	*		*	
/iː/		*	*	*		*
/ɪ/	*	*	*		*	

For the younger speakers there is a significant main effect for coda voicing context ($F(1, 988) = 202.379$, $p < .0001$) and vowel ($F(1, 988) = 159.589$, $p < .0001$), and a significant interaction between vowel and coda voicing context ($F(1, 988) = 6.163$, $p < .0001$). Post-hoc analyses (Bonferroni corrected) show that in the voiced coda context the long vowels differ significantly from all of the short vowels; and /ɔ/ differs significantly from all other vowels. In the voiceless coda context /iː/ differs significantly from all vowels except /ɔ/; /ɪ/ and /ɐ/ do not differ from each other but do differ significantly from all other vowels; and /ɐː/ and /oː/ do not differ significantly from each other, but do differ significantly from all other vowels. These results can be seen in Table 4.15 and 4.16 below. Figure 4.19 below illustrates these results for both age groups. As can be seen, in the voiceless context both /ɐː/ and /oː/ maintain much of their length, whereas /iː/ shows a much higher C/V ratio, which indicates that the vowel occupies less of the rhyme than in the voiced context.

Table 4.15. Significant C/V ratio differences between vowels in voiced coda context for younger age group. Asterisks represent differences that are significant at $p < 0.008$.

	/oː/	/ɔ/	/ɐː/	/ɐ/	/iː/	/ɪ/
/oː/		*		*		*
/ɔ/	*		*	*	*	*
/ɐː/		*		*		*
/ɐ/	*	*	*		*	
/iː/		*		*		*
/ɪ/	*	*	*		*	

Table 4.16. Significant C/V ratio differences between vowels in voiceless coda context for younger age group. Asterisks represent differences that are significant at $p < 0.008$.

	/oː/	/ɔ/	/ɐː/	/ɐ/	/iː/	/ɪ/
/oː/		*		*	*	*
/ɔ/	*		*	*		*
/ɐː/		*		*	*	*
/ɐ/	*	*	*		*	
/iː/	*		*	*		*
/ɪ/	*	*	*		*	

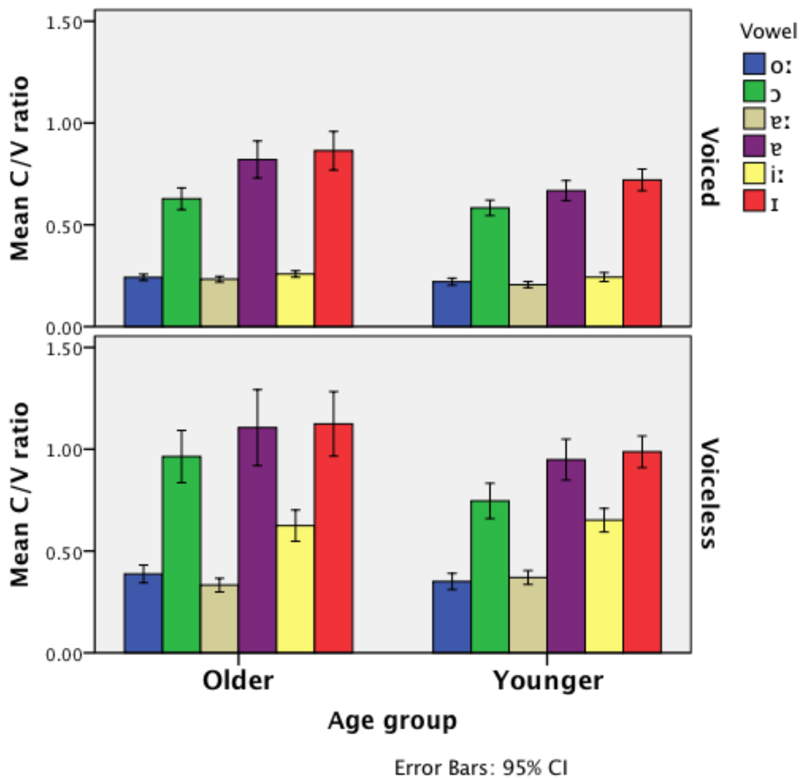

Figure 4.19. Mean C/V ratio values according to coda voicing context, age group and gender for each vowel. Error bars represent 95% confidence intervals.

4.3.5 Glottalisation/vowel ratio

We calculated the ratio of the duration of glottalisation to vowel duration for each token in the voiceless context in order to examine whether the extent of glottalisation differed between the vowels across the age and gender groups. We used a mixed model analysis to examine the factors age group and gender and their interaction for each vowel separately. Speaker was included as a random factor. There were no significant effects for age group. A significant effect for gender was found only for the vowel /ɐː/ ($F(1, 102) = 7.821$, $p = 0.006$) where male speakers glottalised a greater portion of the vowel than the female speakers.

Table 4.17 below shows the mean glottalisation/vowel ratio for each vowel in the voiceless coda context. This is further illustrated in Figure 4.20 below. As can be seen, when mean proportions are considered, glottalisation occupies a greater proportion of the vowel for the short vowels (/ɐ, ɪ, ɔ/) than it does for the long vowels (/ɐː, iː, oː/). For each of the short vowels, the glottalised portion occupies just over a third of the entire vowel. For each of the long vowels, the glottalised portion represents approximately a quarter of the vowel's duration. Although this may seem to indicate that the extent of glottalisation does not change substantially across the different vowels, but rather remains relatively constant across vowels of differing length, an examination of the raw data shows this not to be the case. Figure 4.21 displays the mean duration of the glottalised portion of each vowel in the voiceless context. From this it can be seen that there is substantial variation in the duration of glottalisation among the different vowels. The long vowels do generally exhibit longer glottalised periods than the short vowels, apart from /ɔ/ for which the duration of glottalisation is longer than for /iː/. This is not unexpected as the long vowels have an intrinsically longer duration and hence provide a longer timeframe in which glottalisation can occur. It should be noted, however, that we did not include inherent vowel length as a factor in our analysis of glottalisation/vowel ratio. This should be considered in future analyses.

Table 4.17. Mean values of glottalisation duration/vowel ratio for each vowel in the voiceless coda context.

Vowel	Mean	N	Std. Deviation
ɐː	.2427	106	.11949
ɐ	.3723	108	.10915
iː	.2760	65	.09350
ɪ	.3478	92	.11133
oː	.2577	112	.09840
ɔ	.3664	114	.12591

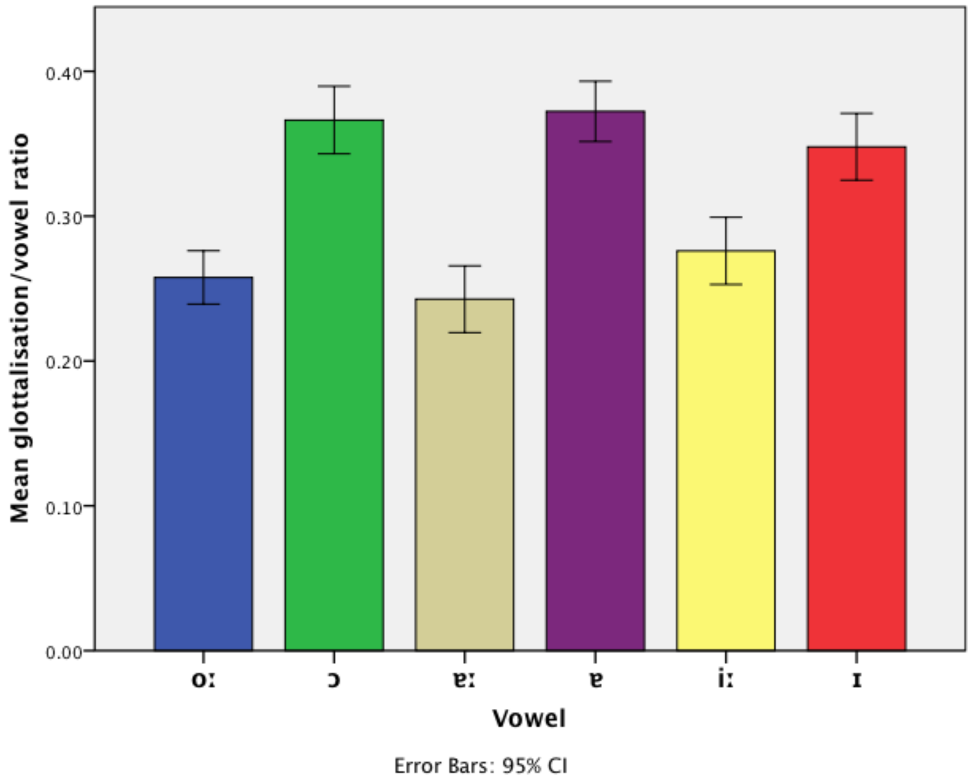

Figure 4.20. Mean glottalisation/vowel ratio for each vowel in voiceless coda context. Error bars represent 95% confidence intervals.

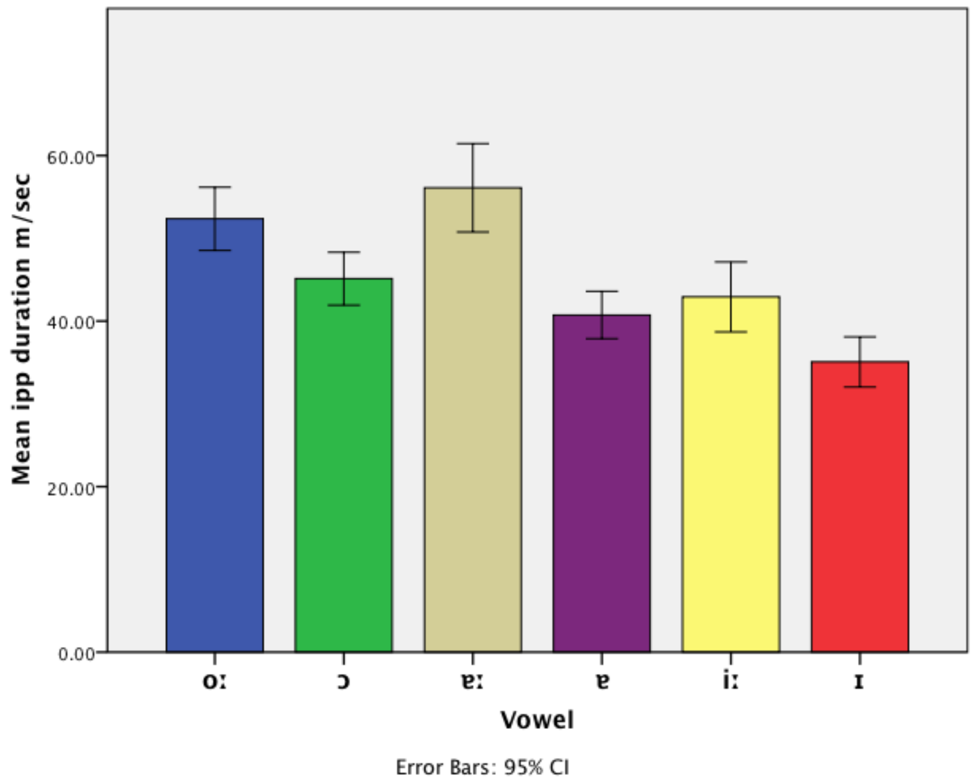

Figure 4.21. Mean duration of glottalisation (m/sec) for each vowel in voiceless coda context. Error bars represent 95% confidence intervals.

4.4 Summary of results

In this chapter we have presented the results of our three different data analyses: descriptive, logistical regression, durational analyses. To summarise, the key findings of this chapter are:

- glottalisation is more likely to occur in voiceless coda contexts
- younger speakers are more likely to employ glottalisation than older speakers
- females use more glottalisation than males
- high vowels are less likely to be glottalised than non-high vowels
- younger speakers exhibit a reduction in the temporal-based cues to voicing compared to older speakers, and this appears to be more prevalent in the male speakers

- /iː/ behaves differently to the other long vowels in that it shortens more in the voiceless coda contexts exhibiting a greater coda voicing induced vowel duration difference than the other long vowels.
- the proportion of a vowel that is glottalised does not differ significantly according to age or gender.

These findings will be expanded upon and interpreted with reference to the literature in the following discussion chapter.

5. Discussion

One of the questions we aimed to provide an answer to in this study was whether glottalisation serves as cue to coda voicelessness in AusE. We hypothesised that glottalisation would be more prevalent before voiceless coda consonants. The significant result for voicing as a predictor of glottalisation as outlined in 4.2 above provides strong evidence that this is in fact the case. Although glottalisation was not found to occur categorically before voiceless coda consonants – a small number of glottalised tokens were found in the voiced coda context – there was a much greater incidence of glottalisation in the voiceless coda context compared to the voiced coda context for all of the vowels examined for speakers in both age groups and of both genders. These results empirically confirm previous anecdotal observations by researchers such as Cox and Palethorpe (2007) and Tollfree (2001), who have noted the tendency for glottalisation to occur before voiceless stops in the variety. These findings also show that glottalisation in AusE functions in a similar manner to glottalisation in many other varieties of English with regard to coda voicing (e.g. Foulkes & Docherty, 2006; Gordeeva & Scobbie, 2013; Pierrehumbert, 1995; Redi & Shattuck-Hufnagel, 2001; Roach, 1973). It would be interesting to extend these findings with a perceptual test, in order to evaluate whether AusE listeners exhibit improved perceptibility of coda voicelessness when it is accompanied by glottalisation, as has been suggested to be the case in AmE (Garellek, 2011a, 2011b; Pierrehumbert, 1995).

Although the overall number of glottalised tokens found in the voiced coda context was quite small, it is nonetheless surprising to discover glottalisation in this context.

As far as we are aware, with the exception of AAVE (Anderson & Nguyen, 2004; Koops & Niedielski, 2009), glottalisation is not reported before voiced coda stops in other varieties of English. One explanation for this result could be that these were examples of phrase final creaky voice. As mentioned in 3.5 above, in this study we did not attempt to differentiate between glottal reinforcement and creaky voice where it appeared on the end of the vowel. On the other hand, the fact that older speakers produced more glottalisation before voiced stops than younger speakers might rather suggest a physiological cause, or boundary tone effect, especially as glottalisation was otherwise far more likely to be employed by the younger speakers. This is an issue that requires further consideration in future work.

We also hypothesised that glottalisation would be more common in the speech of younger AusE speakers. Our apparent time analysis comparing the speech of two age groups has shown that glottalisation occurs more frequently for younger speakers than older speakers, thereby confirming this hypothesis. We interpret this as evidence that glottalisation is a recent change to AusE. As was noted in 2.8 above, descriptions of glottalisation in the variety prior to 1989 are non-existent, and the absence of glottalisation in AusE was actively remarked upon (Trudgill, 1986; Wells, 1982). Taken together with the fact that younger speakers in our study were more than eight times more likely to employ glottalisation than the older speakers, we suggests that this is a change that has quite recently entered the variety with younger speakers more inclined to adopt the change. It is well known that linguistic innovations are more likely to be present in the speech of younger speakers (Chambers, 2009; Eckert, 1988; Labov, 2001). However, it was certainly not the case that glottalisation was completely absent from the speech of the older speakers. On the contrary, the older speakers in our study also exhibited more or less the same patterns for glottalisation as the younger speakers, but made less use of this feature. So while it may appear that glottalisation has appeared relatively recently, the older speakers have also incorporated this feature into their speech production, albeit to a lesser extent than the younger speakers. As such, the fact that both older speakers and younger speakers make use of glottalisation could also suggest that the change predates it first description, that is, that some glottalisation was present in the variety when the older speakers were young.

As mentioned in 2.8 above, one of the limitations of the apparent time method is that it cannot rule out that processes such as age grading or changes to an individual's accent over time are responsible for differences between age groups (Bailey, 2002; Harrington et al., 2000). One method of ensuring the results of an apparent time analysis are valid is to complement the analysis with a real time analysis (Bailey, 2002; Cox & Palethorpe, 2001; Labov, 2001). As such, in our future research we plan to analyse a subset of archival data from the Mitchell and Delbridge (1965) sociolinguistic survey of AusE to complement this analysis, to examine whether glottalisation before voiceless coda stops was present in the speech of young Australians from Sydney in the past using real time data. The speakers in the Mitchell and Delbridge recordings were high school students at the time of recording (1959-1960), which would make them analogous in age to the older group of speakers in the data analysed here. This would enable us to determine whether the reduced incidence of glottalisation in the older speakers in our study is due to an age grading effect, or rather if the older speakers have taken up a recent change to AusE. If there is evidence of glottalisation in young speakers in the archival data, this would suggest that the reduced glottalisation in our older speakers could be due to an age grading effect. That is, it may suggest that young AusE speakers have long employed glottalisation, but they progressively use less glottalisation as they age, and that this process has been taking place for at least three generations (i.e. since the Mitchell and Delbridge survey was carried out). On the other hand, if we find no evidence of glottalisation in the archival data, this will confirm the interpretation offered here that glottalisation is indeed a recent change to AusE.

In this study we examined speakers younger than 35, and speakers older than 56. This raises the question of how much glottalisation would be present in the speech of those speakers in the corpus aged between these two groups. Although this is yet to be empirically tested, one possible hypothesis is that they would demonstrate less glottalisation than the younger speakers but more than the older speakers if glottalisation entered AusE when this generation of speakers was young. On the other hand, it is also possible that the proposed middle aged group would display patterns of glottalisation similar to those shown by the older speakers in this study, which would occur if the point at which glottalisation entered the variety aligns with the first descriptions of glottalisation in AusE at the end of the 1980s (Ingram, 1989). Including an intermediate age group between the older and younger groups in future analyses would therefore be an interesting extension of this study and could help to pinpoint the time frame at which glottalisation entered the variety.

Another question we aimed to answer was whether gender had an effect on the use of glottalisation in AusE, as has been suggested for other varieties of English (e.g. Henton & Bladon, 1988; Mees, 1987, 1990; Redi & Shattuck-Hufnagel, 2001). Based on anecdotal observations, and also the idea that females are often leaders in language change (Labov, 1990), we hypothesised that female speakers would exhibit more glottalisation than male speakers. The results of our analysis indeed showed that overall, females were almost three times more likely to use glottalisation than their male counterparts, and this pattern was visible in both of the age groups: the older females glottalised more than the older males; and the younger females glottalised more than the younger males, confirming anecdotal observations related to gender and glottalisation in AusE. As summarised in 2.6.1, there have been many analyses of cases in which females are more likely to employ glottalisation than males in other varieties of English, such as NZE, CE, and AmE (e.g. Holmes, 1995; Mees, 1987, 1990; Redi and Shattuck-Hufnagel, 2001), though the reverse is also true in yet other varieties, such as RP, MN, and Tyneside English (Henton & Bladon, 1988; Milroy, Milroy, Hartley, & Walshaw, 1994). While the sociolinguistic links between gender and glottalisation may be variety-specific, females are also often identified to be the leaders of linguistic changes (Eckert, 1989; Labov, 1990, 2001). If our interpretation is correct, and glottalisation is a recent change to AusE, it is then hardly surprising that we see the greatest presence of this change in the speech of young, female speakers, as these are the speakers who "are often in the vanguard for linguistic change" (Cameron & Coates, 1989, p. 15). Our results would then seem to suggest that women have been more inclined than men to incorporate the change into their speech. This would also explain why within the older age group it is again the women who exhibit the most glottalisation. Note, however, that the young men in our study still employ more glottalisation than the older women, as young speakers are more likely than older speakers to employ new linguistic features.

Interestingly the results showed that the prevalence of glottalisation did not occur equally among the different vowels. In particular, the vowels /iː/ and /ʉː/ were significantly less likely to be glottalised than all of the other vowels. We hypothesise that this is an effect of vowel height, with non-high vowels more likely to be glottalised than high vowels. Recent work by Żygis and colleagues has shown that low vowels are more frequently glottalised than non-low vowels in both Polish and German (Brunner & Żygis, 2011; Malisz, Żygis and Pompino-Marschall, 2013; Pompino-Marschall & Żygis, 2010). Hejná and Scanlon (2015) have also reported links between increased glottalisation and low vowels in their study of Manchester English (although this effect was not consistent for all vowels). While our results do not replicate the exact same pattern in AusE – rather than specifically low vowels our results suggest that any non-high vowel will exhibit increased glottalisation – our findings do support the notion that glottalisation is sensitive to the feature height, although it seems that the exact interaction between vowel height and glottalisation may manifest differently in different languages. Brunner & Żygis (2011) suggest that the tendency for low vowels to co-occur with glottalisation may be due to vowels being perceived as lower when glottalised. Perhaps, however, the answer is rather physiological. High vowels have an intrinsically higher pitch than low vowels (Lehiste & Peterson, 1961; Ohala & Eukel, 1987), whereas low pitch (low F0) is one of the properties of glottalisation (Esling et al., 2005; Keating & Garellek, 2015; Redi & Shattuck-Hufnagel, 2001). It has been suggested that 'tongue-pull' may be responsible for the higher pitch associated with high vowels, as a higher position of the tongue may increase tension on the vocal folds (Ohala & Eukel, 1987). Perhaps, then, it is simply more difficult to produce glottalisation on vowels in which the tongue is in a high position, and hence which are produced with an intrinsically higher F0.

One interesting anomaly that revealed itself in our analysis is that the short high vowel /ɪ/ does not appear to follow the pattern of less glottalisation on high vowels for many speakers. While overall /ɪ/ was only behind /iː/ and /ʉː/ in prevalence of glottalisation, this was not the case for all speakers. In fact, only the younger males displayed this pattern. Among the younger females more tokens of /ɪ/ were glottalised than either /ɔ/ or /ɐː/. For the older females /ɪ/ was glottalised more frequently than /ɐ/. The older males, on the other hand, produced more tokens of glottalised /ʉː/ than glottalised /ɪ/, making /ɪ/ the second least glottalised vowel for this group. These patterns are problematic for the hypothesis that high vowels are not as frequently glottalised as non-high vowels. It appears that the long/short distinction also plays a role here, and that it is the high long vowels that are less likely to be glottalised. This, however, would not explain the fact that for the male speakers /ɪ/ seems to pattern with the other high vowels in exhibiting less glottalisation than the other vowels. As /ʊ/ was not included in our analysis, it was not possible to compare this vowel to any other short high vowel, but the relationship between vowel height, length and glottalisation does pose an interesting line of enquiry for future research.

Our durational analysis confirmed previous findings that the long vowels of AusE are indeed longer than the short vowels (Bernard, 1967, 1970; Cox, 1996, 2006; Fletcher & McVeigh, 1993; Watson & Harrington, 1999); that vowels are longer preceding voiced coda consonants than they are preceding voiceless coda consonants (Klatt, 1976; Port & Dalby, 1982); and that, generally, longer coda closure periods occur for voiceless coda stops than for voiced coda stops (Cox & Palethorpe, 2011; Yuen et al., 2014). That is, in AusE longer vowels with shorter coda closure periods cue coda voicing; shorter vowels with longer coda closure periods cue coda voicelessness. However, our results also demonstrate that the differences in duration between the voiced and voiceless coda contexts are greater for older speakers than for younger speakers, especially for long vowels. This was shown in our analysis of the durational differences of vowels across voicing contexts. For all of the vowels younger speakers had a smaller difference between the voiced and voiceless contexts. This lends supports to our hypothesis that younger AusE speakers are relying less on vowel duration as a cue to coda voicing than older speakers. If this important cue to voicing is being reduced in the speech of younger speakers, the question that then arises is how these speakers are maintaining the important phonological difference between voiced and voiceless codas.

As mentioned in 2.8 above, Kirby (2013) suggests that in cases in which the precision of a phonological contrast is lost, other redundant cues may be enhanced to preserve that contrast. With this in mind, our results suggest that glottalisation is being enhanced in AusE as a cue to coda voicelessness. This would explain the findings that younger speakers make less use of vowel duration as a cue to coda voicing *but* glottalise more than the older speakers. Crucial support for this hypothesis comes from the complementarity of our glottalisation and durational analyses which show on the one hand that, of all the vowels examined, /iː/ exhibited the greatest vowel duration difference between the two voicing contexts, that is, /iː/ shortens the most preceding voiceless codas as was shown in our analysis of C/V ratio and durational difference measures. On the other hand, /iː/ was also the vowel least likely to be glottalised. Our interpretation of this interaction is that in instances in which vowel duration is exploited as a cue to coda voicing, less glottalisation is necessary. Alternatively, it is possible that glottalisation is physiologically more difficult on high vowels, and therefore the contrast is maintained through duration instead. Conversely, in contexts in which the vowel length cue to coda voicing has been reduced, namely, for all of the vowels apart from /iː/, glottalisation as a cue to voicelessness is enhanced and we suggest this may be a strategy to ensure maintenance of the coda voicing distinction. These results suggest that glottalisation may be in the early stages of phonologisation in the speech of younger AusE speakers. Therefore, in our future research we plan to explore links between glottalisation and the perception of voicelessness, to determine, and better understand, if and how listeners make use of various cues to coda voicing and the weighting of glottalisation relative to other cues in the perception of voicing.

Further support for the interpretation that glottalisation is being enhanced as a cue to voicelessness is the fact that the older males exhibited significant differences in vowel duration between voicing contexts for more vowels than the older females when compared to the younger speakers. That is, the older females behaved more similarly to the younger females than the older males did to the younger males. Recall also that the older females produced more glottalisation than the older males. For example, we found no significant difference for duration of /ɐː/ across voicing contexts between the older females and the younger females. We also found that the older females produced the greatest occurrence of glottalisation on this vowel. That the results of these two separate analyses are so compatible with one another adds support to the suggestion offered above that the older females have been more inclined to incorporate the change than the older males; the older males seem to make the most use of durational differences *and* exhibit the least occurrence of glottalisation. This strengthens the suggestion that the older males are only in the initial stage of the change, whereas the older females appear to have taken on this change at an earlier point.

Our analysis also examined the degree of glottalisation that was produced, in order to explore whether an increase in the extent of glottalisation coincided with a decrease in other durational cues. In order to examine this aspect of phonetic implementation, we measured the duration of the glottalised portion of the vowel. Despite identifying significant durational differences in the rhymes produced by the two age groups, our results showed no differences in the duration of glottalisation for any of the vowels between the younger and older speakers. A significant result was found for the vowel /ɐː/ in the voiceless coda context, for which males produced longer glottalised portions than females, but apart from this there were no gender effects. This may suggest that rather than the proportion of the vowel that is glottalised being important, perhaps a binary distinction between the presence or absence of glottalisation is enough to signal the necessary cue for the voicing status of the following coda to the listener.

Interestingly, we found relatively few examples of unreleased or spirantised coda stops in the data; only 3% of the total number of tokens were unreleased and only 3% were spirantised. Young males were far more likely to produce these non-canonical stops, accounting for the majority of both the unreleased and of the spirantised tokens. This is quite a contrast to the findings of Docherty et al. (2006) in their study of NZE. They also found males to produce more unreleased stops than females (all of the participants in their study were from the same age group, analogous to our younger age group), but they found females produced more spirantised forms than males (Docherty et al., 2006). In both of these categories, the non-canonical stops were produced at much higher rates in their study. While this could indicate a difference between AusE and NZE in terms of stop realisation, it is important to acknowledge that the contexts analysed in our study were in no way analogous to those in Docherty et al. (2006), where the analysis was based on informal interview data. As such, this difference cannot be compared directly without examining AusE speech in natural utterances as opposed to word list data produced in a recording lab.

Also of interest is the fact that young males in our study preferred spirantised stops in the voiceless coda context to the voiced coda context, but produced unreleased stops at similar levels in both coda voicing contexts. This result cannot be compared to the study of Docherty et al. (2006), as their study only investigated voiceless coda stops. However, it might suggest that spirantisation of coda stops may also be tied to coda stop voicing, warranting further investigation in future studies. Garellek (2011a) has noted that glottalisation is common on unreleased stops and suggests this could be a strategy to enhance their perception. Of the small number of unreleased tokens in our dataset, a disproportionately large proportion were glottalised compared to the released tokens. This raises further questions about cue weighting and the strategies speakers use to signal voicing contrast.

There were some notable limitations to this study. As the data were produced as words in isolation, every word that was recorded also served as the end of its own intonational phrase. As such, it was not possible for us to be certain that any glottalisation that was present was solely due to glottal reinforcement rather than being a case of phrase final glottalisation. While establishing a difference between these different sub-categories of glottalisation was not one of the aims of the study, in future work we intend to extend the analysis to utterances in naturalistic speech, rather than isolated words, in order to control for and examine a range of prosodic environments in which glottalisation may be produced.

As the words were presented in a formal elicitation task, it is likely that the recorded data was produced in a relatively formal register, that differs from participants' normal, casual speech. Tollfree (2001) found decreased rates of glottalisation in AusE speakers in formal compared to informal contexts. It is therefore possible that some participants would ordinarily produce different rates of glottalisation if recorded in a more natural context and it remains a possibility that we might find quite different patterns of glottalisation, if more natural speech were analysed.

Another potential problem relates to experiment design, in that the word list participants were recorded reading contained examples of non-words. Garellek (2011b) has suggested that glottalisation may be more likely to occur in low frequency words, which are more confusable than high frequency words. Presumably, this would also apply to non-words. Our word list contained the non-words *horde*, *hort*, and *hod*. Of these, *hort*, which ends in a voiceless coda stop, was one of the words that exhibited the most glottalisation. As such, the possibility exists that this word was so heavily glottalised due to speakers' unfamiliarity with it. On the other hand, the words *heart*, *hut*, and *hot* also exhibited high amounts of glottalisation, and these are high frequency words. In order to counter potential conflation of these issues we plan to focus on real words produced in natural contexts in our future work on glottalisation.

It should also be noted that as glottalisation was the primary focus of this research, we did not attempt to analyse all of the potential cues to coda voicing. Therefore, our analysis did not include an examination of voice bar duration, the presence and amplitude of the coda burst, or of F0 change across the vowel, all of which have been suggested to function as cues to voicing in English (Gruenenfelder & Pisoni, 1980; Lisker, 1978; Song et al., 2012; Wright, 2004). A more comprehensive exploration of cues to coda voicing would therefore also need to include measurement of these potential cues.

Finally, our method for measuring the duration of glottalisation in this study proved to be somewhat subjective, in that it was based on visual evaluation of acoustic data. However, due to the time constraints associated with this project and in light of the fact that the analysis of the duration of glottalised portions of the vowel was only a small part of our overall analysis, the method of visual identification used was sufficient for our purposes in the study and reliability statistics we obtained confirmed this as a measure of validity. Nonetheless, in future studies it is our intention to experiment with some of the other acoustic correlates that have been associated with glottal configuration, such as those outlined by Hanson and Stevens (1995), Hanson et al. (2001), and Keating & Garellek (2015), as well to take advantage of technological advances in the study of voice quality (e.g. Shue, Keating, Vicenik, & Yu, 2011), to identify a more objective method for determining the onset of glottalisation. In addition, in our future work we plan to incorporate electroglottography into our examination of glottalisation. This would allow us to explore issues related to glottal abduction and adduction, to determine if different laryngeal mechanisms are employed for different functions in the production of glottalisation, such as glottal reinforcement and creaky voice.

6. Conclusion.

The aim of this thesis was to provide an empirical examination of glottalisation in AusE, with a specific focus on whether glottalisation functions as a cue to coda voicing and whether glottalisation is a recent change to the variety. While both of these questions have been the subject of speculation in the literature, as far as we are aware these questions have yet to be empirically analysed until now. Our results provide strong evidence that glottalisation is employed by AusE speakers as a cue to voicelessness. Although some glottalisation was identified in the voiced coda context, the number of tokens glottalised in this context was rather meagre compared to those glottalised in the voiceless coda context. These results proved to be consistent across both age groups, both genders, and all vowels. This is compelling evidence that AusE speakers employ glottalisation to cue coda voicelessness, as is common in other dialects of English. It remains to be seen, however, whether AusE listeners also perceive glottalisation as cueing coda voicelessness. This provides an interesting line of enquiry for future studies on the perception of glottalisation by AusE listeners.

Our results further suggest that glottalisation is a recent change to AusE. Glottalisation was significantly more likely in the speech of the younger AusE speakers than it was in the speech of the older AusE speakers, leading to the conclusion that glottalisation has recently entered the variety, although it appears to have been taken up at different levels by both older and younger speakers. This is consistent with the fact that past descriptions of AusE have noted the lack of glottalisation. Future work on archival AusE data will enable us to establish whether glottalisation was historically present in AusE, and thereby either strengthen or refine this hypothesis. At the very least, our results reported here suggest that glottalisation is increasingly being used by younger AusE speakers. At the same time, we have demonstrated that younger AusE speakers use durational cues to coda voicing less than their older counterparts. We propose that this weakening of durational cues to coda voicing in the younger speakers is linked with their increased use of glottalisation as a way to maintain the vital phonological voicing contrast between voiced and voiceless coda consonants. This suggests that glottalisation is being enhanced as a cue to coda voicing, and may be in the process of being phonologised in AusE.

This study has also demonstrated that female AusE speakers are more likely to incorporate glottalisation into their speech than male AusE speakers, a result which was consistent in both age groups, although the younger females exhibited more glottalisation than any of the other groups examined. This could be considered to further support the hypothesis that glottalisation is a recent change to AusE, given that females are often at the forefront of linguistic innovations. In the case of glottalisation in AusE, it seems that it is the younger, female speakers who have most readily incorporated the change into their speech.

Finally, this thesis has raised a number of further questions about glottalisation in AusE in particular, and about glottalisation in general. Are the patterns of glottalisation that have been identified here also present in more naturalistic speech? Why is glottalisation less likely on high vowels? Does vowel length interact with vowel height and glottalisation? What is the relationship between production and perception of glottalisation? Do listeners perceive glottalisation as cueing voicelessness? Is glottalisation a socioindexical feature? When do children learn about glottalisation as a cue to coda voicing? These questions present multiple avenues for the progression of the current study. This work therefore represents a foundation upon which further research can build, and provides a baseline reference for future studies of glottalisation in AusE. In addition, it raises questions about how speakers cue voicing in AusE, as well as how the different cues to voicing are weighted. This thesis therefore also provides a basis for future phonological research related to issues of cue weighting, enhancement, and phonologisation.

7. References

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8. Appendix A

Table 8.1. Presence of glottalisation according to coda voicing context by vowel.

Vowel	Glottalisation present	Voicing		Total
		Voiced	Voiceless	
ɐː	No	153 (88%)	69 (39%)	222 (64%)
	Yes	21 (12%)	106 (61%)	127 (36%)
	Total	174	175	349
ɐ	No	174 (97%)	75 (41%)	249 (69%)
	Yes	6 (3%)	108 (59%)	114 (31%)
	Total	180	183	363
iː	No	117 (94%)	110 (62.5%)	227 (75%)
	Yes	8 (6%)	66 (37.5%)	74 (25%)
	Total	125	176	301
ɪ	No	174 (99%)	87 (49%)	261 (74%)
	Yes	1 (1%)	92 (51%)	93 (26%)
	Total	175	179	354
oː	No	154 (91%)	62 (36%)	216 (63%)
	Yes	15 (9%)	112 (64%)	127 (37%)
	Total	169	174	343
ɔ	No	169 (94%)	66 (36%)	235 (65%)
	Yes	10 (6%)	115 (64%)	125 (35%)
	Total	179	181	360
ʉː	No	168 (95%)	96 (53%)	264 (74%)
	Yes	9 (5%)	84 (47%)	93 (26%)
	Total	177	180	357

Table 8.2. Presence of glottalisation according to coda voicing context and age group by vowel.

Age group	Vowel	Glottalisation present	Voicing: Voiced	Voicing: Voiceless	Total
Older	ɐː	No	69 (84%)	43 (53%)	112 (69%)
		Yes	13 (16%)	38 (47%)	51 (31%)
		Total	82	81	163
	ɐ	No	84 (97%)	57 (66%)	141 (82%)
		Yes	3 (3%)	29 (34%)	32 (18%)
		Total	87	86	173
	iː	No	53 (91%)	61 (78%)	114 (84%)
		Yes	5 (9%)	17 (22%)	22 (16%)
		Total	58	78	136
	ɪ	No	82 (100%)	61 (72%)	143 (86%)
		Yes	0 (0%)	24 (28%)	24 (14%)
		Total	82	85	167
	oː	No	72 (88%)	42 (52.5%)	114 (70%)
		Yes	10 (12%)	38 (47.5)	48 (30%)
		Total	82	80	162
	ɔ	No	78 (92%)	50 (57%)	128 (74%)
		Yes	7 (8%)	38 (43%)	45 (26%)
		Total	85	88	173
	ʉː	No	74 (92.5%)	59 (70%)	133 (81%)
		Yes	6 (7.5%)	25 (30%)	31 (19%)
		Total	80	84	164
Younger	ɐː	No	84 (91%)	26 (28%)	110 (59%)

		Yes	8 (9%)	68 (72%)	76 (41%)
	Total		92	94	186
ɐ		No	90 (97%)	18 (19%)	108 (57%)
		Yes	3 (3%)	79 (81%)	82 (43%)
	Total		93	97	190
iː		No	64 (96%)	49 (50%)	113 (68%)
		Yes	3 (4%)	49 (50%)	52 (32%)
	Total		67	98	165
ɪ		No	92 (99%)	26 (28%)	118 (63%)
		Yes	1 (1%)	68 (72%)	69 (37%)
	Total		93	94	187
oː		No	82 (94%)	20 (21%)	102 (56%)
		Yes	5 (6%)	74 (79%)	79 (44%)
	Total		87	94	181
ɔ		No	91 (97%)	16 (17%)	107 (57%)
		Yes	3 (3%)	77 (83%)	80 (43%)
	Total		94	93	187
ʉː		No	94 (97%)	37 (39%)	131 (68%)
		Yes	3 (3%)	59 (61%)	62 (32%)
	Total		97	96	193

Table 8.3. For glottalised tokens only, the number and percentages according to coda voicing context and age group by vowel.

			Voicing		
Age group			Voiced	Voiceless	Total
Older	Vowel	ɐː	13 (25%)	38 (75%)	51
		ɐ	3 (9%)	29 (91%)	32
		iː	5 (23%)	17 (77%)	22
		ɪ	0 (0%)	24 (100%)	24
		oː	10 (21%)	38 (79%)	48
		ɔ	7 (16%)	38 (84%)	45
		ʉː	6 (19%)	25 (81%)	31
	Total		44 (17%)	209 (83%)	253
Younger	Vowel	ɐː	8 (11%)	68 (89%)	76
		ɐ	3 (4%)	79 (96%)	82
		iː	3 (6%)	49 (94%)	52
		ɪ	1 (1%)	68 (99%)	69
		oː	5 (6%)	74 (94%)	79
		ɔ	3 (4%)	77 (96%)	80
		ʉː	3 (5%)	59 (95%)	62
	Total		26 (5%)	474 (95%)	500

Table 8.4. Presence of glottalisation according to coda voicing context, gender, and age group by vowel.

Gender	Age group	Vowel			Glottalisation present: No	Glottalisation present: Yes	Total
Female	Older	ɐː	Voicing	Voiced	28 (78%)	8 (22%)	36
				Voiceless	13 (39%)	20 (61%)	33
			Total		41 (59%)	28 (41%)	69
		ɐ	Voicing	Voiced	38 (97%)	1 (3%)	39
				Voiceless	25 (64%)	14 (36%)	39
			Total		63 (81%)	15 (19%)	78
		iː	Voicing	Voiced	21 (84%)	4 (16%)	25
				Voiceless	25 (74%)	9 (26%)	34
			Total		46 (78%)	13 (22%)	59
		ɪ	Voicing	Voiced	36 (100%)	0 (0%)	36
				Voiceless	23 (61%)	15 (39%)	38
			Total		59 (80%)	15 (20%)	74
		oː	Voicing	Voiced	29 (81%)	7 (19%)	36
				Voiceless	14 (40%)	21 (60%)	35
			Total		43 (61%)	28 (39%)	71
		ɔ	Voicing	Voiced	38 (97%)	1 (3%)	39
				Voiceless	16 (41%)	23 (59%)	39
			Total		54 (69%)	24 (31%)	78
		ʉː	Voicing	Voiced	35 (92%)	3 (8%)	38

			Voiceless	28 (72%)	11 (28%)	39
		Total		63 (82%)	14 (18%)	77
Younger	ɐː	Voicing	Voiced	36 (86%)	6 (14%)	42
			Voiceless	8 (19%)	34 (81%)	42
		Total		44 (52%)	40 (48%)	84
	ɐ	Voicing	Voiced	39 (93%)	3 (7%)	42
			Voiceless	6 (13%)	39 (87%)	45
		Total		45 (52%)	42 (48%)	87
	iː	Voicing	Voiced	28 (90%)	3 (10%)	31
			Voiceless	16 (36%)	29 (64%)	45
		Total		44 (58%)	32 (42%)	76
	ɪ	Voicing	Voiced	43 (98%)	1 (2%)	44
			Voiceless	8 (17%)	38 (83%)	46
		Total		51 (57%)	39 (43%)	90
	oː	Voicing	Voiced	34 (89%)	4 (11%)	38
			Voiceless	5 (12%)	37 (88%)	42
		Total		39 (49%)	41 (51%)	80
	ɔ	Voicing	Voiced	41 (93%)	3 (7%)	44
			Voiceless	8 (19%)	34 (81%)	42
		Total		49 (57%)	37 (43%)	86
	ʉː	Voicing	Voiced	41 (93%)	3 (7%)	44

				Voiceless	12 (26%)	34 (74%)	46
			Total		53 (59%)	37 (41%)	90
Male	Older	ɐː	Voicing	Voiced	41 (89%)	5 (11%)	46
				Voiceless	30 (62.5%)	18 (37.5%)	48
			Total		71 (76%)	23 (24%)	94
		ɐ	Voicing	Voiced	46 (96%)	2 (4%)	48
				Voiceless	32 (68%)	15 (32%)	47
			Total		78 (82%)	17 (18%)	95
		iː	Voicing	Voiced	32 (97%)	1 (3%)	33
				Voiceless	36 (82%)	8 (18%)	44
			Total		68 (88%)	9 (12%)	77
		ɪ	Voicing	Voiced	46 (100%)	0 (0%)	46
				Voiceless	38 (81%)	9 (19%)	47
			Total		84 (90%)	9 (10%)	93
		oː	Voicing	Voiced	43 (93%)	3 (7%)	46
				Voiceless	28 (62%)	17 (38%)	45
			Total		71 (78%)	20 (22%)	91
		ɔ	Voicing	Voiced	40 (87%)	6 (13%)	46
				Voiceless	34 (69%)	15 (31%)	49
			Total		74 (78%)	21 (22%)	95
		ʉː	Voicing	Voiced	39 (93%)	3 (7%)	42

			Voiceless	31 (69%)	14 (31%)	45
		Total		70 (80%)	17 (20%)	87
Younger	ɐː	Voicing	Voiced	48 (96%)	2 (4%)	50
			Voiceless	18 (35%)	34 (65%)	52
		Total		66 (65%)	36 (35%)	102
	ɐ	Voicing	Voiced	51 (100%)	0 (0%)	51
			Voiceless	12 (23%)	40 (77%)	52
		Total		63 (61%)	40 (39%)	103
	iː	Voicing	Voiced	36 (100%)	0 (0%)	36
			Voiceless	33 (62%)	20 (38%)	53
		Total		69 (78%)	20 (22%)	89
	ɪ	Voicing	Voiced	49 (100%)	0 (0%)	49
			Voiceless	18 (37.5%)	30 (62.5%)	48
		Total		67 (69%)	30 (31%)	97
	oː	Voicing	Voiced	48 (98%)	1 (2%)	49
			Voiceless	15 (29%)	37 (71%)	52
		Total		63 (62%)	38 (38%)	101
	ɔ	Voicing	Voiced	50 (100%)	0 (0%)	50
			Voiceless	8 (16%)	43 (84%)	51
		Total		58 (57%)	43 (43%)	101
	ʉː	Voicing	Voiced	53 (100%)	0 (0%)	53

	Voiceless	25 (50%)	25 (50%)	50
	Total	78 (76%)	25 (24%)	103

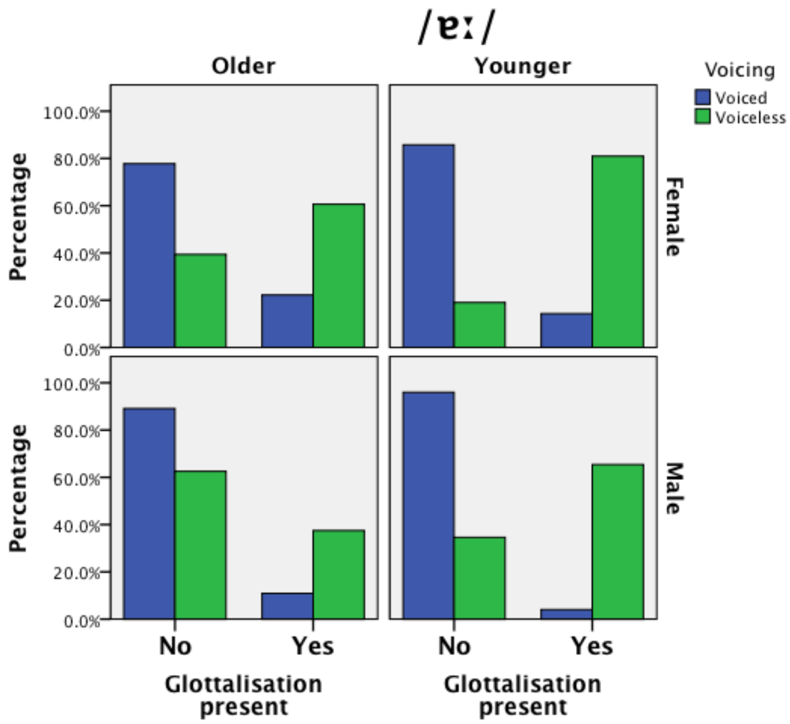

Figure 8.1. Percentages for the presence and absence of glottalisation according to coda voicing context, gender, and age group for the vowel /ɐː/.

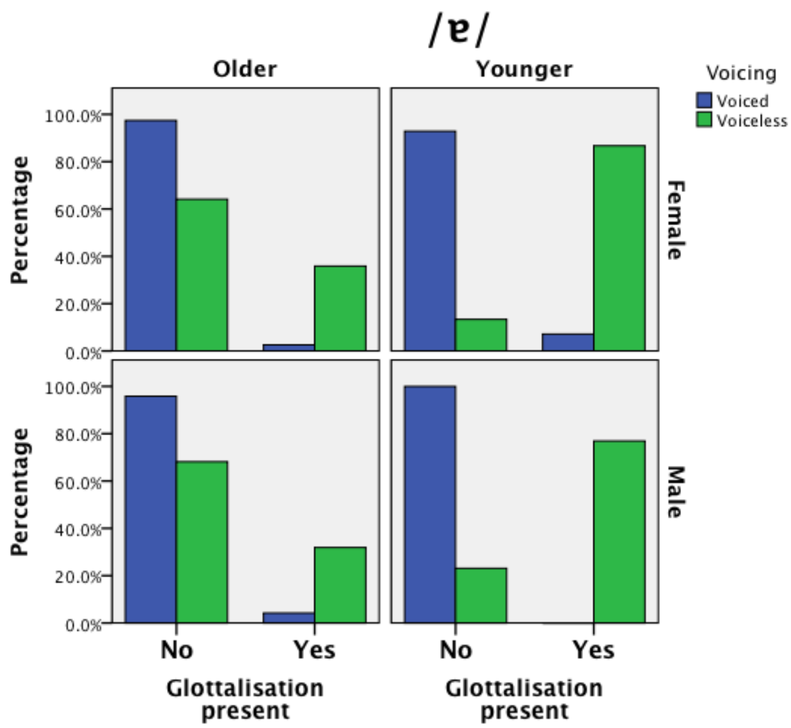

Figure 8.2. Percentages for the presence and absence of glottalisation according to coda voicing context, gender, and age group for the vowel /ɐ/.

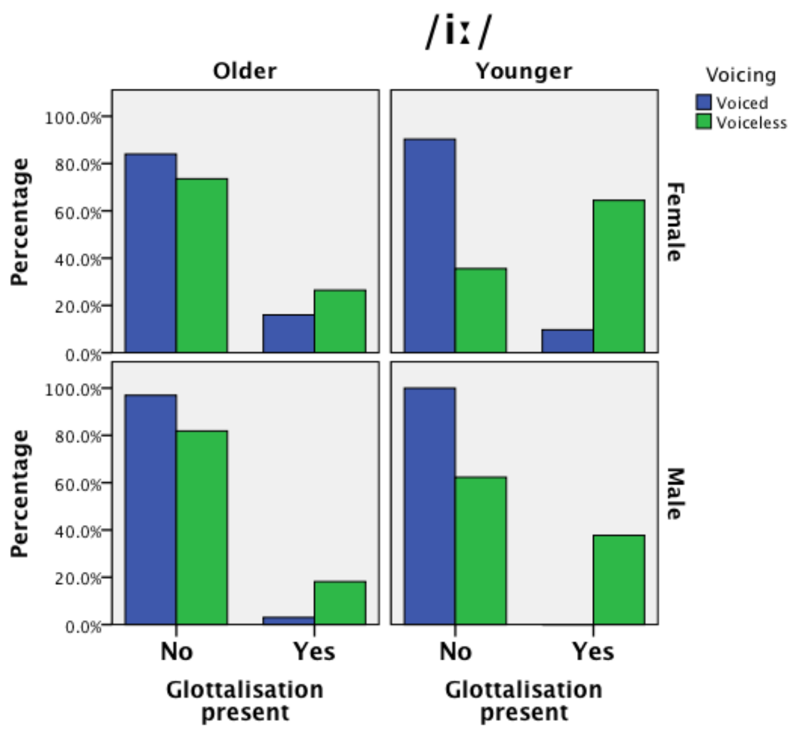

Figure 8.3. Percentages for the presence and absence of glottalisation according to coda voicing context, gender, and age group for the vowel /iː/.

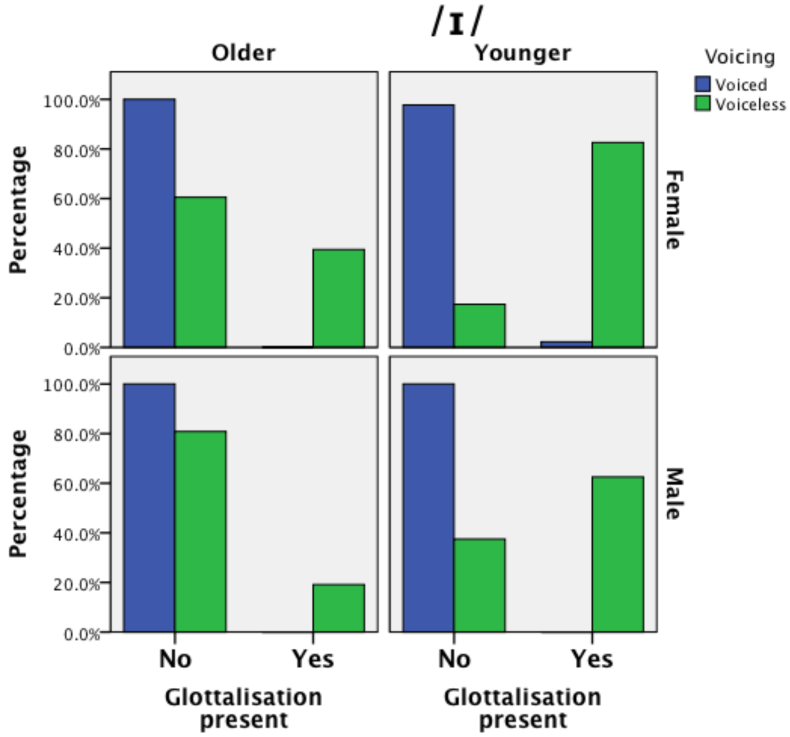

Figure 8.4. Percentages for the presence and absence of glottalisation according to coda voicing context, gender, and age group for the vowel /ɪ/.

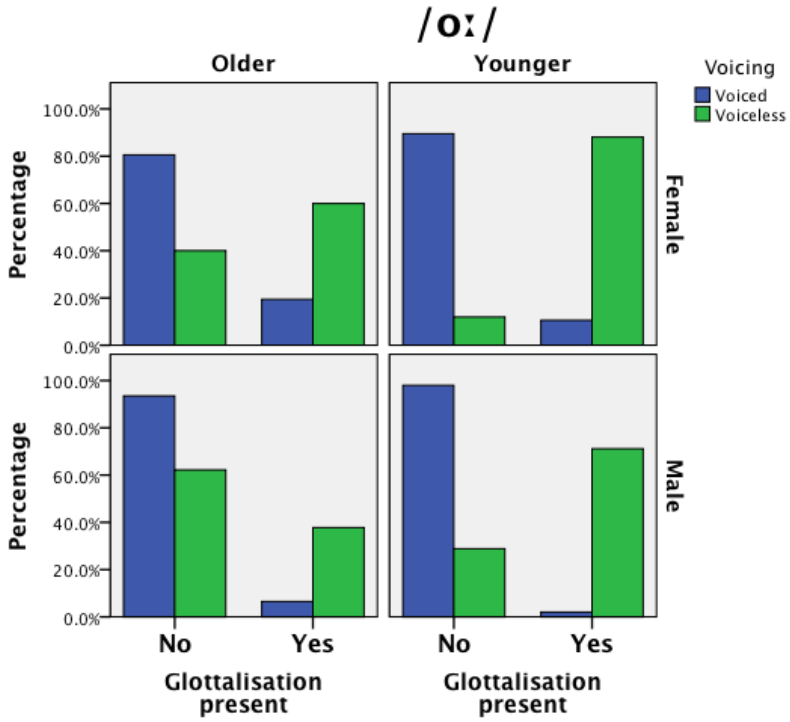

Figure 8.5. Percentages for the presence and absence of glottalisation according to coda voicing context, gender, and age group for the vowel /oː/.

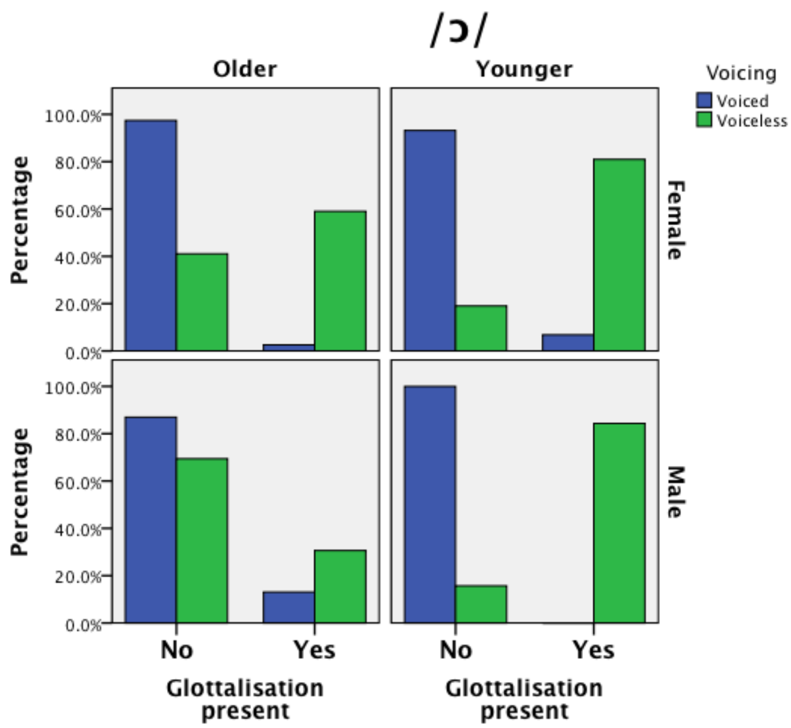

Figure 8.6. Percentages for the presence and absence of glottalisation according to coda voicing context, gender, and age group for the vowel /ɔ/.

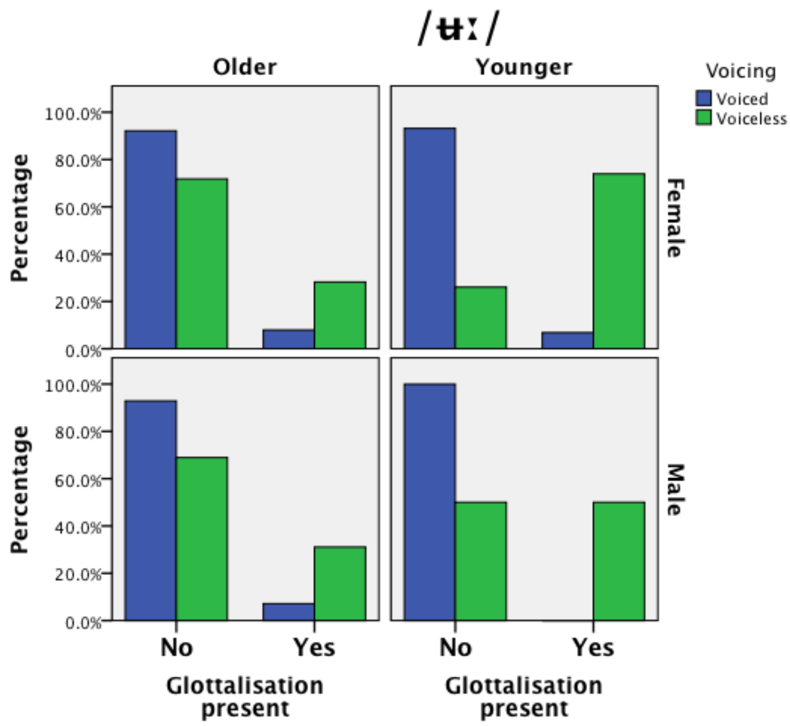

Figure 8.7. Percentages for the presence and absence of glottalisation according to coda voicing context, gender, and age group for the vowel /ʉː/.

Table 8.5. For glottalised tokens only, the number and percentages according to coda voicing context, gender, and age group by vowel.

				Voicing		
Age group	Gender			Voiced	Voiceless	Total
Older	Female	Vowel	ɐː	8 (29%)	20 (71%)	28
			ɐ	1 (7%)	14 (93%)	15
			iː	4 (31%)	9 (69%)	13
			ɪ	0 (0%)	15 (100%)	15
			oː	7 (25%)	21 (75%)	28
			ɔ	1 (4%)	23 (96%)	24
			ʉː	3 (21%)	11 (79%)	14
		Total		24 (18%)	113 (82%)	137
	Male	Vowel	ɐː	5 (22%)	18 (78%)	23
			ɐ	2 (12%)	15 (88%)	17
			iː	1 (11%)	8 (89%)	9
			ɪ	0 (0%)	9 (100%)	9
			oː	3 (15%)	17 (85%)	20
			ɔ	6 (29%)	15 (71%)	21
			ʉː	3 (18%)	14 (82%)	17
		Total		20 (17%)	96 (83%)	116
Younger	Female	Vowel	ɐː	6 (15%)	34 (85%)	40
			ɐ	3 (7%)	39 (93%)	42
			iː	3 (9%)	29 (91%)	32
			ɪ	1 (3%)	38 (97%)	39
			oː	4 (10%)	37 (90%)	41
			ɔ	3 (8%)	34 (92%)	37
			ʉː	3 (8%)	34 (92%)	37

	Total		23 (9%)	245 (91%)	268
Male	Vowel	ɐː	2 (6%)	34 (94%)	36
		ɐ	0 (0%)	40 (100%)	40
		iː	0 (0%)	20 (100%)	20
		ɪ	0 (0%)	30 (100%)	30
		oː	1 (3%)	37 (97%)	38
		ɔ	0 (0%)	43 (100%)	43
		ʉː	0 (0%)	25 (100%)	25
	Total		3 (1%)	229 (99%)	232

9. Appendix B

Table 9.1. Mean vowel durations for older group females

Word	Mean (m/sec)	N	Std. Deviation
hard	331.2608	36	54.24401
heart	264.4621	33	38.01972
heat	156.7853	34	31.76537
heed	283.9405	25	56.57104
hid	128.5107	36	23.79196
hit	89.4215	38	27.75944
hod	156.6850	39	30.81794
horde	301.7186	36	61.98627
hort	204.3015	35	32.84018
hot	118.9040	39	27.96395
hud	135.1184	39	26.52351
hut	105.0927	39	31.65514
Total	184.6967	429	88.77254

Table 9.2. Mean vowel durations for younger group females

Word	Mean (m/sec)	N	Std. Deviation
hard	291.1730	42	39.17252
heart	235.6777	42	35.52310
heat	156.0637	45	25.94208
heed	251.7704	31	44.35415
hid	123.5544	44	21.04361
hit	107.4627	46	21.10768
hod	151.8074	44	23.66539
horde	268.0466	38	29.51645
hort	215.2687	42	34.16205
hot	129.5995	42	29.69375
hud	146.0143	42	27.58286
hut	111.4508	45	23.57825
Total	178.5941	503	69.18404

Table 9.3. Mean vowel durations for older group males

Word	Mean (m/sec)	N	Std. Deviation
hard	319.7286	46	59.20445
heart	221.6021	48	35.60736
heat	127.6754	44	25.52593
heed	261.8211	33	53.34852
hid	107.4152	46	29.72054
hit	74.5924	47	20.54307
hod	138.2174	46	32.54150
horde	290.2402	46	48.02763
hort	183.6110	45	29.62055
hot	100.0862	49	26.20695
hud	120.3321	48	46.76162
hut	84.7898	47	22.22673
Total	166.3963	545	88.70153

Table 9.4. Mean vowel durations for younger group males

Word	Mean (m/sec)	N	Std. Deviation
hard	273.1473	50	47.03559
heart	219.8150	52	38.00190
heat	139.2200	53	33.59440
heed	231.4147	36	39.48353
hid	114.3975	49	25.28816
hit	89.4575	48	22.71707
hod	137.0646	50	28.94682
horde	250.1851	49	43.34046
hort	196.6663	52	31.88037
hot	121.3625	51	25.02937
hud	124.8862	51	28.82353
hut	110.2846	52	23.97447
Total	165.8165	593	68.17015

Table 9.5. Mean coda closure durations for older group females

Word	Mean (m/sec)	N	Std. Deviation
hard	74.5257	36	17.93069
heart	82.7725	27	19.37458
heat	85.9303	34	20.16328
heed	65.7356	25	13.51153
hid	89.7517	36	20.20986
hit	94.5449	37	29.01490
hod	85.4822	39	15.97453
horde	65.9736	36	18.89457
hort	78.0409	35	23.32153
hot	101.4014	39	29.23119
hud	93.2527	39	21.00537
hut	95.3962	39	23.93069
Total	85.2234	422	24.11118

Table 9.6. Mean coda closure durations for younger group females

Word	Mean (m/sec)	N	Std. Deviation
hard	62.5747	41	23.19134
heart	88.6506	40	27.76327
heat	102.1687	42	30.82949
heed	62.2767	31	23.79886
hid	85.7809	44	23.87032
hit	102.0264	43	29.18610
hod	87.3544	44	23.71804
horde	62.7143	37	25.53906
hort	76.7294	42	36.47037
hot	104.8591	40	34.16065
hud	92.0737	41	27.15531
hut	111.8544	43	29.08933
Total	87.4191	488	32.36310

Table 9.7. Mean coda closure durations for older group males

Word	Mean (m/sec)	N	Std. Deviation
hard	73.3656	46	17.11841
heart	73.3208	45	31.95662
heat	80.1408	39	34.72524
heed	70.3005	33	15.07277
hid	93.2789	46	24.62738
hit	70.3650	46	26.47431
hod	87.3316	46	19.84522
horde	74.5671	45	21.86295
hort	67.1941	44	37.13935
hot	88.4355	46	41.73880
hud	91.7357	48	35.79095
hut	83.2650	47	37.28471
Total	79.7766	531	31.06762

Table 9.8. Mean coda closure durations for younger group males

Word	Mean (m/sec)	N	Std. Deviation
hard	53.6705	45	18.00788
heart	72.4785	43	23.61231
heat	79.9549	41	19.56054
heed	54.3448	31	18.03371
hid	79.1682	46	24.34780
hit	79.5994	40	23.60047
hod	76.7067	46	23.89935
horde	51.6601	44	14.02722
hort	62.4297	43	21.42255
hot	69.3986	45	24.74720
hud	80.2438	47	21.97035
hut	79.1609	41	24.62326
Total	70.2077	512	24.11500

10. Appendix C

Dear A/Prof Cox,

RE: 'An acoustic analysis of phonetic variation and change in Australian English ' (Ref: 5201300619)

Thank you for your recent correspondence regarding the amendment request. The amendments have been reviewed and we are pleased to advise you that the request has been approved.

This approval applies to the following amendments:

1. Change in personnel - Mr Josh Penney and Ms Kelly Miles added to the project;

2. Revised Information and Consent form.

Please accept this email as formal notification that the amendments have been approved.

Please do not hesitate to contact us in case of any further queries.

All the best with your research.

Kind regards,
FHS Ethics
****

Faculty of Human Sciences - Ethics
Research Office
Level 3, Research HUB, Building C5C
Macquarie University

Dear A/Prof Cox,

RE: ‘An acoustic analysis of phonetic variation and change in Australian English’ (5201300619)

Thank you for your recent correspondence regarding an amendment request for the above-mentioned project. We apologise for the delay in responding.

The request has been reviewed and we are pleased to inform you that the amendment has been reviewed and approved.

This approval applies to the following amendment:

1. Additional data collection – To obtain data from “The big Australian speech corpus: An audiovisual speech corpus of Australian English”.

Please do not hesitate to contact FHS Ethics if you have any questions or concerns.

All the best with your research.

Kind regards,

FHS Ethics

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FHS Ethics
Faculty of Human Sciences | Level 3, C5C Building
Macquarie University, NSW 2109, Australia